2017 PROCEEDINGS • CROP PRODUCTION CLINICS

University of Nebraska Lincoln

EXTENSION

CROP PRODUCTION CLINICS

PROCEEDINGS 2017

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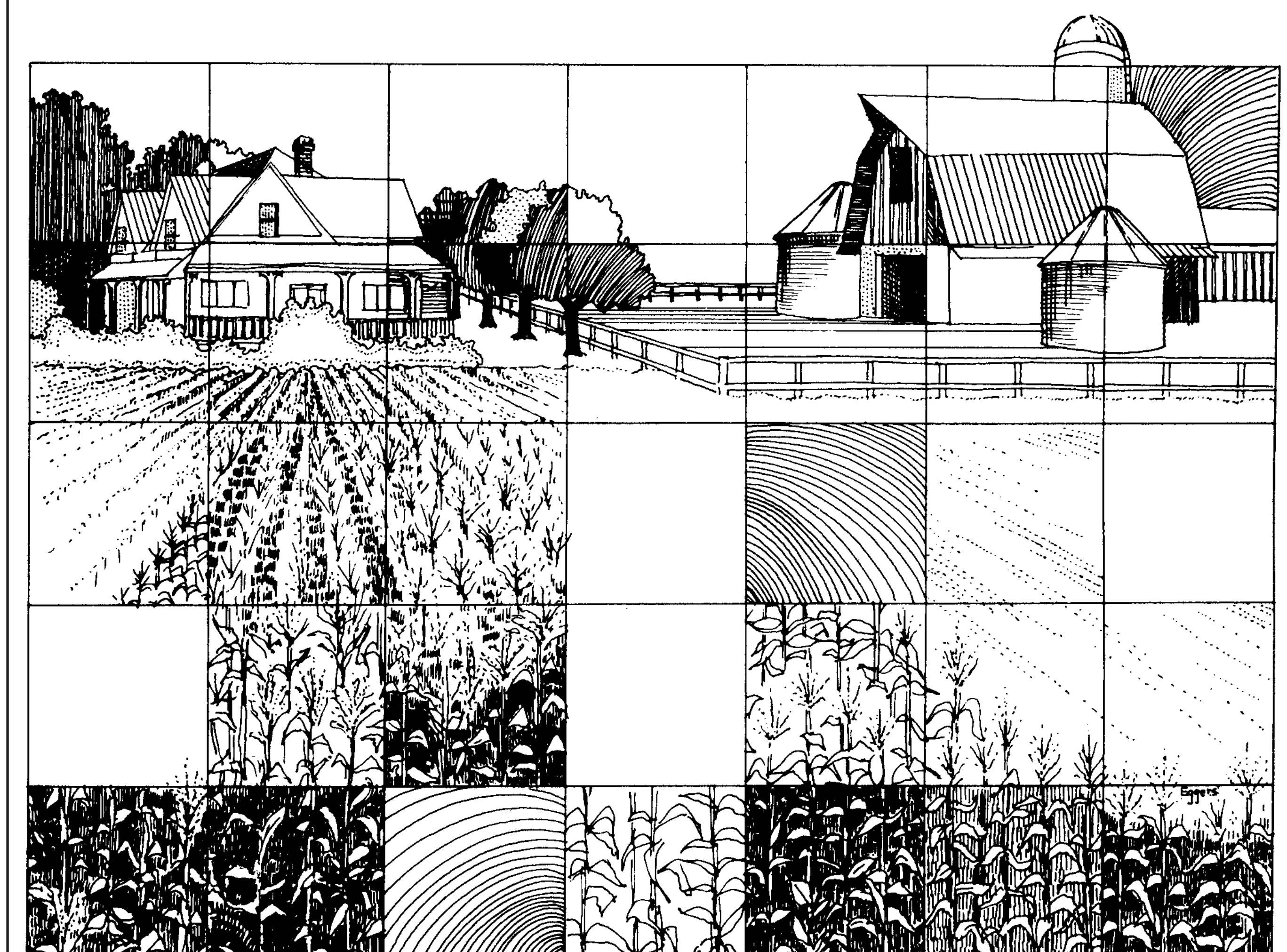

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FOREWORD

The University of Nebraska–Lincoln Extension is pleased to present the 9th Annual Crop Production Clinics to bring you unbiased, research-based information that will help you understand how new technologies can improve the profitability and safety of your operation.

The Crop Production Clinics are the successor to the Crop Protection Clinics (1974 to 2008). In 2009, content was expanded to include Soil Fertility, Irrigation, and Cropping Systems. The Clinics continue to include topics related to Pesticide Safety, Agribusiness Management, Marketing, and Insect, Plant Disease, and Weed Management.

The *2017 Proceedings* contains articles that summarize the information presented at all nine Clinics. It is intended to be both a workbook for you to use during the clinic, and a reference after the clinic.

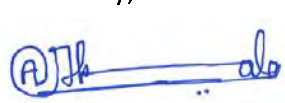
The Clinics are the primary recertification venue for Commercial Pesticide Applicators. Private Pesticide Applicators may also recertify by attending the Clinics. We want this program to meet your information needs. Please share with us how we can make the Clinics and Proceedings more valuable for you, and how what you have learned at the Clinics has benefited your operation. If you have questions about what you have read, please contact the author. Author and presenter contact information is listed before the table of contents.

2017 Crop Production Clinics

January 4, Gering Civic Center, Gering
January 5, Sandhills Convention Center, North Platte
January 6, Holthus Convention Center, York
January 10, Beatrice Country Club, Beatrice
January 11, Adams County Fairgrounds, Hastings
January 12, ARDC, Saunders County Extension Office, Mead
January 17, Atkinson Community Center, Atkinson
January 18, Lifelong Learning Center, Northeast Community College, Norfolk
January 19, Younes Conference Center, Kearney

Have a happy and safe 2017 growing season.

Sincerely,



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EXTENSION

University of Nebraska–Lincoln Extension

2016 Crop Production Clinics

Impact Report

Impact on Nebraska agriculture

<u>1,680</u> total participants; 9 locations

- Over 90% of respondents attended past CPC's
- 22% identify as producers (approx. 370 of total attendees)
- 12% identify as being involved in agriculture sales (approx. 201 of total attendees)
- 18% identify as crop consultants (approx. 310 of total attendees)
- 26% identify as custom applicators (approx. 433 of total attendees)

<u>6.6 million</u> total acres influenced

- 3.4 million acres of corn
- 2.2 million acres of soybeans
- 666,667 acres of wheat
- 220,000 acres of alfalfa
- 133,333acres of sorghum/millet

<u>2.6 million</u> acres of irrigated cropland influenced

92% found the *Crop Production Clinics Proceedings* valuable to their operation

87% felt that the clinic would increase the profitability of their operation

This increase in value was estimated at $3.91 per acre

Total estimated value from the clinic was over $26

What attendees said

"Very informative. Learned new information."

"Knowledgeable speakers with real life answers."

"I have attended this clinic for 15 years and there are always new ideas and new contacts."

"Keeps me in tune with cutting edge information for the coming crop year."

"The reference materials help producsers be more efficient/profitable."

For more information and to download a copy of the *Crop Production Clincs*

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Trends in Nebraska Land Values and Rental Rates 2016-2017

Jim Jansen, Extension Educator

Leading into 2017, Nebraska crop producers face a third year of challenging financial circumstances with lower commodity prices and uncertainty in futures markets. Making informed decisions when purchasing or renting cropland becomes even more important with tighter production margins for producers. This article summarizes key trends in land values and rental rates for cropland in Nebraska and insight for 2017 leases.

Trends in Nebraska Land Values and Rental Rates

The Nebraska all land average peaked in 2014 and declined approximately 6 percent over the last two years. The two major land classes relevant to row crop or small grain production for Nebraska include dryland cropland without irrigation potential and center pivot irrigated cropland. Dryland cropland without irrigation potential either has regulations present in the area restricting the drilling of new irrigation wells or the geology of the ground which limits further development.

The Nebraska Farm Real Estate Survey tracks the changes in the dryland and center pivot irrigated cropland values and rental rates. Each year the Department of Agricultural Economics at the University of Nebraska–Lincoln surveys agricultural appraisers, professional farm and ranch managers, and agricultural bankers in the state to determine the major trends in the land markets.

These land industry professionals have a keen perspective on the annual movement in agricultural land values and rental rates given their professions. Based upon their survey responses, preliminary estimates are provided during the second week of March each year with the final completed report published the second week of June. Summaries on land values and rental rates are displayed according to the eight major agricultural districts.

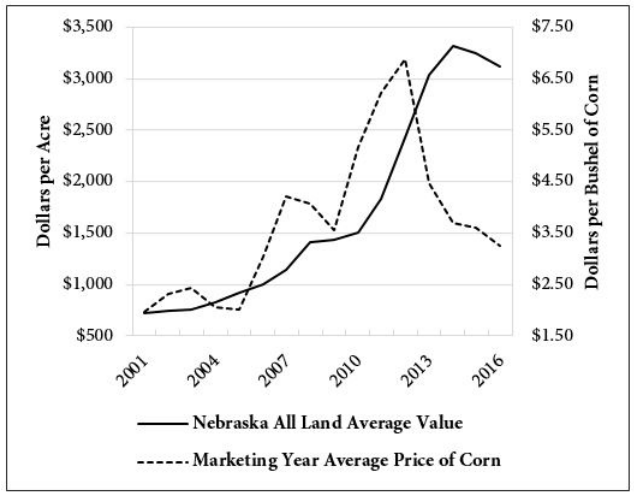
Cropland Values for 2016

Trends in Nebraska All Land Average Value

The Nebraska all land average price of $3,315 per acre reached in 2014 set the highest nominal (non-inflation adjusted) value during the 38 year history of the UNL Nebraska Farm Real Estate Market Surveys (Figure 1). Since the peak two years ago, the state-wide weighted average farmland value has fallen about 6 percent or $200 per acre to $3,115.

Record setting marketing year average price for corn of $6.89 per bushel set in 2012 declined approximately 53 percent to $3.25 per bushel (preliminary estimate) in 2016. The fall in corn and related commodity prices have led to a tighter production margin for farmers. Survey members indicated that a multi-year period of lower commodity prices might lead to further declines in the average value of land in the state.

Figure 1. Historical Nebraska All Land Average Value per Acre and Marketing Year Average Price of Corn, Selected Years 2001-2016[ab]



Source: [a] Nebraska Farm Real Estate Survey, 2001-2016.
[b] World Agricultural Supply and Demand Estimates (WASDE), Office of the Chief Economist, USDA, 2001-2016. Preliminary marketing year average price estimates for corn in 2016.

The ability of new owners to purchase and finance land at low long-term interest rates remain a positive factor in maintaining current land prices from falling any further according to survey members. Historically, periods in Nebraska agricultural real estate when the cost of financing new purchases increases the value of agricultural property tends to act inversely.

Trends in Dryland Cropland Values

Dryland cropland in Nebraska had a weighted average value of $3,470 per acre in 2016. Compared to 2015, this value slightly increased by approximately 2 percent. Across the 8 agricultural districts of Nebraska the average dryland cropland value recorded changes ranging from a decline of 4 percent in the Southwest District to an increase of 7 percent in the South District.

Between 2011 and 2014 cropland values in Nebraska rose steadily with the increase in commodity prices. As the cropland values rose, the rental rates of these assets also increased rapidly. Survey responses for 2015 showed the first decline in dryland cropland values correlating with lower commodity prices. Recent observation from survey participants on cropland values in Nebraska suggest that this class has not substantially changed for 2016.

Table 1. Average Reported Value per Acre of Dryland Cropland in Nebraska, February 1, 2016[a]

Agricultural District	Dryland Cropland[b] Quality Grade Value Ranges		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	965	745	555
North	2,220	1,650	1,565
Northeast	7,010	5,760	4,140
Central	3,940	3,235	2,490
East	7,635	6,360	4,820
Southwest	2,395	1,955	1,480
South	4,400	3,575	2,405
Southeast	5,910	4,845	3,305

Source: [a] Nebraska Farm Real Estate Survey, 2016.
[b] Dryland cropland without irrigation potential.

Differences in the quality of dryland cropland are displayed in Table 1. Averages displayed in this Table include the high third in quality (high), all land classes (average), and low third in quality (low). These quality ranges reflect the productivity and yielding potential of the ground. The lowest dollar per acre average was reported in the Northwest District of $555 per acre and highest per acre dollar value of $7,635 per acre in the East District.

The relatively low level of movements in dryland cropland values indicates that this land class may be poised for moderate declines or growth in 2017. Returns for grain and oilseeds coupled with long term interest rates remain two key driving forces influencing future movements in the value of dryland cropland.

Trends in Center Pivot Irrigated Cropland Values

Center pivot irrigated cropland in Nebraska had a weighted average value of $6,940 per acre in 2016. Center pivot irrigated cropland has historically been the highest valued land class reflecting the higher productivity of the ground. Rates of decline were higher for this land class compared to dryland cropland. On average across the state, center pivot irrigated cropland declined about 2 to 12 percent.

The highest rate of decline in center pivot irrigated cropland was noted in the South District at 12 percent while the lowest decrease occurred in the East District at 2 percent. Differences in the quality grades for center pivot irrigated cropland relates to the quality of the parcel of ground and the consistency of the water supply.

In recent years survey participants indicated with marginal dryland cropland being developed into center pivot irrigated cropland the availability and consistency of the well water supply had a major influence on the value of the ground. As a result, the value of center pivot irrigated cropland may vary widely across a district due to these factors and various regulations.

Table 2. Average Reported Value per Acre of Center Pivot Irrigated Cropland in Nebraska, February 1, 2016[a]

Agricultural District	Center Pivot Irrigated Cropland[b] Quality Grade Value Ranges		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	4,415	3,290	3,100
North	5,620	4,350	3,935
Northeast	9,240	7,880	7,015
Central	8,200	7,530	6,255
East	10,410	9,410	8,035
Southwest	6,890	5,330	4,840
South	8,355	7,240	5,710
Southeast	9,865	9,185	7,400

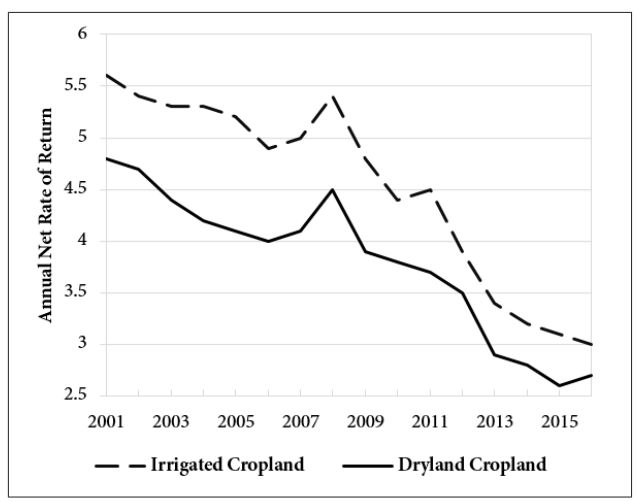
Source: [a] Nebraska Farm Real Estate Survey, 2016.
[b] Value of pivot not included in per acre value.

Producers across Nebraska place a higher premium on center pivot irrigated cropland compared to dryland cropland as shown in Table 2. High grade center pivot irrigated cropland in the East District noted land values of well over $10,000 per acre. A low of $3,100 per acre for the low grade center pivot cropland was noted in the Northwest Districts.

Considerations for Cropland Values in 2017

Landowners evaluating the value of their cropland need to consider the net income earning potential of their asset. Another way to evaluate values takes into account that land is an investment and typically every investment needs to have a return.

Figure 2. Historical Estimated Annual Net Rates of Return by Land Type in Nebraska, Selected Years 2001-2016[a]



Source: [a] Nebraska Farm Real Estate Survey, 2001-2016.

Simply put, return on an investment takes into account the income earning potential of an asset over future years. With the current return on land as an investment taking into account the income earning expectation of lower crop prices into the future and input costs remaining relatively unchanged to slightly lower, the resulting return on the asset may be lower for 2017. Figure 2 shows the historical estimated annual net rate of return for irrigated and dryland cropland in Nebraska.

As a non-operator land owner negotiating a rental rate with a tenant, finding an economical viable rental rate may be a challenge. Ownership expense for agricultural land will likely remain high with current property tax policies.

Cropland Rental Rates for 2016

Trends in Dryland Cropland Rental Rates

Rental rates for the 2016 production were on average 5 to 10 percent lower from 2015 dryland cropland rental rates. Survey participants noted current commodity prices, property taxes, and farm input costs as the most negative factors leading to the lower rental rates paid by cropland tenants. Entering into 2017, cropland tenants face very similar dynamics in terms of returns on cropland acres.

Table 3. Reported Cash Rental Rates for Dryland Cropland in Nebraska: 2016 Averages[a]

Agricultural District	Dryland Cropland Quality Grade Rental Rate Ranges		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	45	32	23
North	70	60	43
Northeast	290	225	180
Central	125	96	75
East	250	200	160
Southwest	57	42	29
South	110	80	64
Southeast	225	165	125

Source: [a] Nebraska Farm Real Estate Survey, 2016.

Rental rates for dryland cropland across Nebraska ranged from High of $290 per acre in the Northeast District to a low of $23 per acre in the Northwest District. The highest rates of decline were noted in the Northwest, North, and Southwest Districts where dryland cropland yields typically have more yield variability than compared to the eastern third of the state.

Trends in Center Pivot Irrigated Cropland Rental Rates

Center pivot irrigated cropland historically has the highest rental rate paid on a per acre basis for agricultural ground in Nebraska. Out of the four major land classes followed by the survey, higher and less variable crop yields on center pivot irrigated cropland have led to the rates paid by tenants. The rate of decline for this land class followed a trend similar to dryland cropland. On average, center pivot irrigated cropland for 2016 declined about 5 to 10 percent across the state compared to the prior year.

Table 4. Reported Cash Rental Rates for Center Pivot Irrigated Cropland in Nebraska: 2016 Averages[a]

Agricultural District	Center Pivot Irrigated Cropland[b] Quality Grade Rental Rate Ranges		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	250	170	145
North	260	220	195
Northeast	405	345	275
Central	290	240	205
East	375	320	270
Southwest	255	225	210
South	280	240	195
Southeast	355	290	255

Source: [a] Nebraska Farm Real Estate Survey, 2016.
[b] Cash rents on center pivot irrigated cropland assumes landowners own the total irrigation system.

A high of $405 per acre was reported in the Northeast District with a low of $145 per acre in the Northwest District. Higher rates of decline for this land class were noted in the west compared to the eastern part of Nebraska. For 2016 crop producers reported on average good yields across the state, but still expect foreseeably lower commodity prices to market these commodities.

Further Readings

Nebraska Farm Real Estate Market Highlight Reports

For more information and to access the entire Nebraska Farm Real Estate Market Highlights Reports visit the University of Nebraska-Lincoln Farm Real Estate website at: http://agecon.unl.edu/realestate

USDA–NASS Farm-Level Cash Rental Rate Survey Maps

For more information and to access the USDA-NASS Farm-Level Cash Rental Rate Maps and Data visit the USDA-NASS Northern Plains Regional Field Office for Nebraska website at: https://www.nass.usda.gov/Statistics_by_State/Nebraska/Publications/County_Estimates/

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Landlord and Tenant Negotiations
Lease considerations for 2017

Allan Vyhnalek, Extension Educator

Introduction

As I write this report in late 2016, we are experiencing our 3rd year of relatively lower corn and soybean prices. For many tenants, the cash reserve of the operation has been diminished to the point that it is time to really get serious at lowering input costs for 2017. One large expense line for the crop budget is the cash rent paid by tenants.

Landlords have gotten used to the 2008-2013 rental rate income. They are also faced with increased land taxes. Because of these opposite forces, tenants want rent to go down and landlords want rent to stay steady or go up to reflect the increased cost of taxes, negotiating the 2017 rent will be tricky at best.

Both landlords and tenants need to think about their key rental rate questions heading into next year. For the tenant the key question is: "Am I willing to walk away, or give up renting land if the landlord won't drop the rent?" The key question for the landlord is: "Do I want top cash rent, or do I want to keep tenant I have?" Top rent and keeping the same tenant may or may not work out. Thinking about that relationship is the first factor to work on for determining 2017 rental rates.

Sell the Landlord on Your Good Stewardship

One suggestion for tenants as we head into negotiating cash rents for 2017 is to list the positives that you have brought to that land asset. In many cases, tenants go beyond the requirements for cash leases and provide service which improves the asset. Things like: maintaining water ways, maintaining tile drains, noxious weed control on non-crop acres, volunteer tree control on non-crop acres, fence maintenance, farm path or road maintenance, are just a few of the examples.

The tenant needs to feature these positive contributions to that land asset. In many cases, the landlord should be paying for that work to be done, but in many cases, the tenant never turns in a bill. Tenants need to bring up the positive land stewardship and management they bring to that land resource and have the landlord recognize these contributions.

Successful Elements of Communication

Good cropland leases are based on trust between the two parties. Without trust between the landlord and tenant, a sound written contract does not carry the same weight involving mutual respect between the two parties. If trust between the tenant and landlord does not exist or cannot be repaired, the lease should be terminated and a different tenant would be recruited. Poor communication serves as one of the main reason for a lack of trust.

Neither the landlord nor tenant should feel like the other party has more power in the leasing negotiation.

Sometimes, landlords feel that the tenant withholds information about their ground, thus making it difficult for them to set an appropriate rental rate. Landlords may want to get specific information on the productivity of the ground including crop yields or soil tests. If the landlord wants production information, it is appropriate to ask for that with a clause written in the lease. Through proper communication this should be the type of information that a tenant would share with the landlord. Still, if this type of information is not readily shared between the two parties then a provision could be put in as a contingency of the lease.

For landlords, the communication also needs to include any expectations for practices used or that you want used on your land. This means you need to communicate about specific weed control expectations, or no-till, or organic production (as examples) if you have strong feelings about those practices. These expectations can also be outlined in a written lease provision.

Just as common, the tenant feels that the landlord has all the power in the lease negotiation. The feeling is if the tenant does not give the landlord exactly what he or she wants for lease terms, the lease will be terminated. In some neighborhoods of Nebraska, the demand for farms to lease far exceeds supply. Losing a land lease contract is a common fear among many tenants.

For the tenant, specific communication needs need to be addressed. Tenants need to keep landlords up to date with things like current prices, cost of equipment, repairs, seed, fertilizer, insecticides, herbicides, etc. – with the main goal of keeping the landlord informed on true cost per bushel for production relative to current prices heading into 2017.

In a contract there should not be any winner or loser. Both parties need to communicate their needs, realistic crop budgeting, and realistic yield goals when determining how to set an economically viable rental rate.

Production Expenses and Depreciating Investments Paid for By Tenants on Cropland

The cash lease for irrigated cropland assumes that the landlord owns all of the irrigation equipment. In many cases over the past few years, the tenant provides some of the equipment such as the power unit to lift irrigation water. The ownership cost of providing this equipment should be discounted from the cash rent.

In most leases the landlord may provide amendments to the soil such as lime. In some cases, lime has become a tenant expense. In this scenario, the depreciable part of the lime expense should be paid back to the leaseholder if the tenant is vacating the lease prior to the length of the useful life of the lime.

Removal or Additions of Soils Nutrients and Implications on Lease Agreements

The cost of adding phosphorus can also be quite expensive. In most places in Nebraska, a large amount of phosphorus will last more than one year. When this expense is born, the tenants should have a lease clause that pays them their undepreciated share of the fertilizer expense if they are not farming that land during the period that the added phosphorus is readily available to the plants.

In another scenario related to landlord regarding this matter, if the tenant 'mines' phosphorous and depletes the phosphorous in the soil, an appropriate compensation should be made to the landlord based on soil test benchmarks that outline a minimum phosphorous level.

Corn stalks either for grazing or harvesting for forage may also be a point of concern. Unless held out of the lease, the stalks belong to the tenant and the residue can be used as the tenant desires, including subleasing them to another person. An appropriate clause can be included in the lease, if the landlord wants to maintain the rights to the stalks, or prevent the tenant from subleasing the stalks.

Disaster Payments for Crop or Price Losses

Under a straight cash lease, the tenant assumes all financial risk in the growing and marketing of the crop. By taking on production and marketing risk, the tenant gets the consequences of that contractual obligation either being good or bad. Risk management programs available to crop producers are available to those who bear the element of risk and only make indemnity or assistance payment to those parties.

Two major risk management programs available to crop producers in Nebraska include:

- Federal Farm Programs including the Agricultural Risk Coverage (ARC) or Price Loss Coverage (PLC) Program. Parties eligible to receive federal assistance through this program must bear production and financial risk.
- Crop Insurance including Revenue Protection (RP) or Yield Protection (YP) Insurance. To be eligible to purchase a policy the party must also have production and financial risk in a growing crop. Indemnities made under this program are paid to those who paid the premium (party that bear the production risk).

Landlords must remember that assistance or indemnity payments made to tenants are provided due to actual crop production or revenue falling below a guaranteed level for the party that assumed the risk. The purpose of these payments are to help the individual cover variable and fixed expenses associated with the cropping enterprise including the rental payment to the landlord.

If a landlord is interested in participating in these risk management programs he or she must be willing to take on production risk in the lease arrangement. This would mean moving away from a cash lease to an arrangement such as a crop share.

Other Resources:

For more information about the 2015-2016 Farm Real Estate Report, or for cash lease provisions review the articles: "Nebraska Farm Real Estate Market Highlights 2015-2016", "Farmland Leasing Checklist", or "Frequently Asked Questions – Farmland leases", at http://agecon.unl.edu/realestate

For example written lease agreements visit the web site http://aglease101.org

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CornSoyWater: online real-time monitor for soil water balance and irrigation aid for corn and soybean fields

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James Han, Postdoc
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Conventional irrigation decision making relies heavily on experience and requires frequent visit to each field. The process is time consuming and labor demanding, while the results are not quantitative and prone to error.

The state-of-the-science of crop modeling powered by IT technology can help make smarter irrigation decisions with less effort. **CornSoyWater** (Fig. 1, www.cornsoywater.unl.edu) is an online app that predicts, in real time with 10 day forecast, if a particular corn or soybean field needs irrigation now. The recommendation is based on predictions of (1) the amount of crop-available water in the soil, (2) crop stage and stage-based irrigation threshold, and (3) the possibility of crop water stress. Users receive those predictions, in numerical values, from their computers or mobile devices without the need of driving to the fields and scratching their heads to guess. In addition, the program can help irrigators schedule their work more efficiently by showing the fields that need attention.

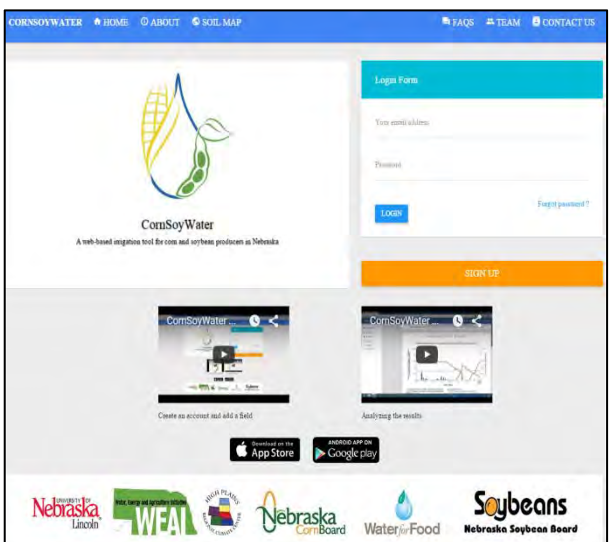

Fig. 1 Login page of the CornSoyWater program at www.cornsoywater.unl.edu

1, What does it takes to use CornSoyWater?

1. A user must open an account at www.cornsoywater.unl.edu by clicking on the yellow SIGN UP button. It is free.
2. Registering a field is simple:
   a. Choose between Corn or Soybean field.
   b. Mark field location directly on the Google map.
   c. Specify the following:
      i. Crop maturity
      ii. Planting date
      iii. Plant population
      iv. Maximum soil rooting depth
      v. % of soil surface coverage by residues
      vi. Soil moisture condition at planting

You will need to do this only once in a season.

2, How do predictions for a field look like?

Upon logging into your account, all your fields, corn and soybean, will be shown on the Google map with either green or red colors: green indicates no need for irrigation while red indicates need for irrigation (Fig. 2). To see detailed predictions for a field, clicking the symbol for that field will lead to a screen as Fig. 3.

Fig. 2. Upon login of CornSoyWater, the map shows all registered fields with green color to indicate fields without need for irrigation and red to indicate fields that may need irrigation.

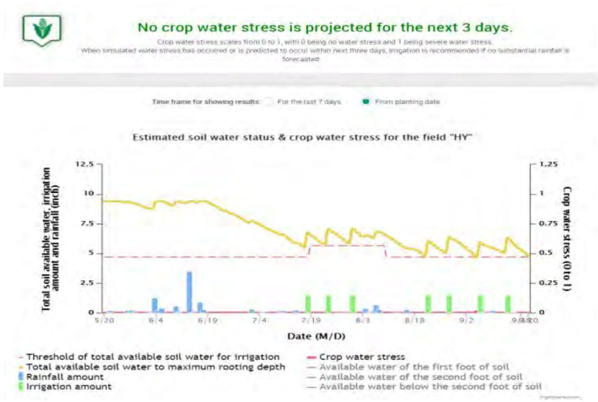

Fig. 3. Predicted total available water in root zone (yellow line), threshold for irrigation (dotted red line), rainfall (blue bars), and user input irrigation events green bars). X-axis is calendar date, left Y-axis is for water amount, and right Y-axis is for water stress (the red line that has been 0 for this field)

Whenever soil available soil water amount falls below the threshold for irrigation, or the crop is under water stress, the program will recommend irrigation if no significant rain is expected for the next three days. The message is displayed at the top of the screen (Fig 3). In addition, the program also shows the up-to- date summary of:

- Amount of available water in soil root zone
- Available water in soil root zone at planting
- Total rainfall since planting
- Total irrigation amount
- Total crop water use (i.e., actual ET)
- Total water losses (non-ET losses)

3, How does CornSoyWater work in the background?

CornSoyWater uses crop simulation models (Hybrid-Maize model corn and SoySim for soybean) to predict crop growth, development, crop water use, and soil water balance. Based on the location of the field, the program automatically determines (1) the weather station that is closest to the field in the weather station network, and (2) the soil texture for the field. Each time the user logs in and selects a field, the program will make the prediction as in Fig 3 using the up-to-date weather data for that field and other crop and soil information the user has provided at field registration. When the user has irrigated a field, the irrigation date and amount must be entered in the program so that prediction next time will reflect that.

Summary

The **CornSoyWater** provides recommendation on irrigation, in real time mode, based on quantitative prediction of (1) amount of available water in soil root zone along with stage-related threshold for irrigation, and (2) possible crop water stress. It also provides summary about up-to-date water inputs (rain and irrigation), crop water uses and losses, and overall water balance. Users get those up-to-date predictions without going to the fields.

CornSoyWater is current being evaluated using data from irrigators' field and research plots. Irrigators and crop consultants are encouraged to try it out and send their comments and feedbacks to the developers. Potentially, the software can be implanted into irrigation control modules for automated irrigation control, variable rate irrigation, and other irrigation decision supports packages.

References

Setiyono, T, Cassman, KG., Specht, J, Dobermann, A, Weiss, A, Yang, H., Conley, SP., Robinson, Andrew P., Pedersen, P., and De Bruin, JL. 2010. Simulation of soybean growth and yield in near-optimal growth conditions. Field Crops Research. 119, 161-174.

Yang, HS., Dobermann, A., Lindquist, JL., Walters, DT., Arkebauer, T J., and Cassman, KG. 2004. Hybrid-maize - a maize simulation model that combines two crop modeling approaches. Field Crops Research. 87, 131-154.

Cover Crops – An Update

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INTRODUCTION

Several of us have presented overviews of cover crops in Nebraska cropping systems the last couple of years at the Crop Production Clinics. This year we will present a quick overview of several on-going University of Nebraska research projects that focus on agronomic aspects of cover crops mostly in corn and soybean systems. This report summarizes the status and early findings of some of those projects.

1) IMPACT OF COVER CROPS ON PRODUCTIVITY OF WHEAT-CORN-FALLOW ROTATION IN SEMI-ARID NEBRASKA

Researcher: Rodrigo Werle

Department of Agronomy and Horticulture & West Central Research and Extension Center

Background

Wheat-corn-fallow (WCF) rotation is commonly adopted across rainfed areas of western Nebraska and much of the semiarid Great Plains. No-tillage and proper crop residue management have been key to the success of WCF rotation. Proper wheat stubble management at harvest plays an important role on the water availability for the subsequent corn crop, especially during drier years. Well-managed wheat stubble can increase snow retention during the winter, reduce soil water evaporation during the fallow period, increase water infiltration, reduce water and wind erosion, and suppress weeds. Cover crops are becoming popular across Nebraska and growers in the western part of the state are questioning whether and how should they be incorporated into their cropping systems. Cover crops have the potential to reduce soil erosion and compaction, increase water holding capacity and soil organic matter, and suppress pests. One of the major concerns regarding the inclusion of cover crops in the WCF rotation in rainfed areas, including western Nebraska, is the amount of water used by these “non-cash” species and potential yield reduction of the subsequent corn crop.

The objective of the study is to determine if different cover crop mixtures planted at different times after wheat harvest and terminated at different times before corn in a WCF rotation impact water availability, soil fertility, weed suppression, and subsequent corn productivity.

Study Description

The first year of the study was established in 2016 after winter wheat harvest at two locations in Western Nebraska, North Platte and Grant. Different cover crop mixtures (cold-sensitive and cold-hardy) were planted at different times after wheat harvest (6, 9, and 12 weeks) and will be terminated at different times before corn planting (cold-sensitive species will be winter killed and the winter-hardy mixture will be killed either one month before or at corn planting with herbicides). Cover crop and weed biomass, and soil water content will be assessed multiple times throughout the study. Soil samples will be collected at corn planting and analyzed for organic matter and N, P, and K content. Corn yield across treatments will be compared at the end of the study. The study will be repeated in the 2017/2018 season. The results of this research will allow UNL specialists and educators to further develop their recommendations for cover crop management in rainfed cropping systems in western Nebraska.

Fig. 1. Top to Bottom - Planted on 08/17/2016, 09/07/2016 , and 09/26/2016

Figure 1. Cover crop mixture (brassica + legume + grass) planted at three different times after winter wheat harvest in North Platte in 2016 (wheat was harvested on July 7, 2016). Pictures taken on 10/30/2016.

Applied Question

Can we optimize cover crop selection, planting, and termination timing in order to take full advantage of the benefits associated with cover crops and yet not reduce corn productivity?

Thus far we have learned that in order to obtain the maximum cover crop growth in the fall, cover crops should be planted shortly after winter wheat harvest (Figure 1). Delaying planting reduces biomass accumulated in the fall. The impact of cover crop growth in the fall on subsequent corn productivity is still unknown. These measurements will be taken in 2017; the study will be repeated in the 2017-2018 growing season.

2) IMPLEMENTATION OF COVER CROPS IN CORN AND SOYBEAN SYSTEMS IN NEBRASKA

Researchers: Katja Koehler-Cole, Roger Elmore, Humberto Blanco, Charles Francis, Charles Shapiro, Tim Shaver, Matt Stockton, Richard Ferguson, Suat Irmak, Derek Heeren

Department of Agronomy and Horticulture and Department of Biological Engineering

Funded by the *Nebraska Corn Board* & the *Nebraska Soybean Board*

Background

Cover crops in corn and soybean systems can reduce soil erosion, mitigate nutrient loss, improve soil physical soil properties, and increase yields. High biomass production is key for cover crops to fulfill these functions, but may not be attainable due to the short window of opportunity for winter cover crops in Nebraska corn and soybean systems. Cover crops may negatively impact subsequent crop yields if they leave soil water deficits or immobilize nitrogen upon their decomposition.

With this study we want to determine the feasibility and impact of winter cover cropping on soil quality, soil water, and crop yields in corn-soybean systems across Nebraska. Our objectives are to quantify cover crop emergence, fall and spring biomass production, soil water changes, soil chemical and physical property changes, and crop yields.

Study description

Experiments were carried out at four research farms, two that were irrigated (SCAL – Clay Center, and WRCEC, Brule) and two that were rainfed (ARDC, Mead, and HAL, Concord). Five types of cover crops were grown: cereal rye (alone), forage radish (alone), a mix of hairy vetch and winter pea, a mix of cereal rye, forage radish, hairy vetch and winter pea, and a mix of these four along with red clover, black oats, and forage collards. Cover crops were planted either early (broadcast into corn or soybeans when corn was at the half-milk stage, R5.5) or late (drilled after corn or soybean harvest). All cover crops were terminated with glyphosate two weeks before planting of corn or soybeans. Variables measured included cover crop emergence, fall and spring biomass production, soil nutrients (NPK and organic C), bulk density, aggregation, water infiltration, soil water, and crop yields.

Applied question(s)

1. *Which cover crops produce the most spring biomass?* Cereal rye was the highest producer, yielding up to 1,800 lb/A in the first and up to 4,800 lb/A in the second year at the HAL station. Forage radishes winterkilled and the legume mix yielded less than 500 lb/A at all site-years. Mixes were intermediate in productivity, but most of their dry matter was rye.
2. *Which planting date resulted in the most spring biomass?* The early planting date had significantly higher biomass.
3. *What were the impacts on crop yields?* Corn yields were 10 bu/acre lower and soybean yields were 4 bu/acre lower after early-planted cover crops at HAL in 2015. No impacts on corn or soybean yields at the other locations.

3) FINDING THE BALANCE BETWEEN CORN YIELD AND COVER CROP BIOMASS

Researchers: Angela Bastidas, Chris Proctor and Roger W. Elmore

Department of Agronomy and Horticulture

Background

Cover crops can provide either ecosystem services or forage benefits but understanding how they fit in cropping systems is still limited. In the US Midwest, fall-seeded cover crops are limited by the relatively short growing season remaining after the primary crop is harvested. Increasing biomass is critical for cover crop effectiveness. There is the possibility of lengthening the cover crop growing season by modifying corn management and thus enhancing cover crop productivity.

Study description

The study was established in the 2015 and 2016 growing seasons under both rain-fed (Havelock Farm, Lincoln, Lancaster County) and irrigated (South Central Agricultural Laboratory-SCAL, Clay Center, Clay County) conditions in Nebraska. Our objective was to assess the effects of planting date (early and late), plant population (low, average and high) and corn maturity (80 to 115 days relative maturity, RM) on corn yield to allow different dates for cover crop establishment after corn harvest. At each location, two blocks were established; one for measuring corn yield and one for planting a cover crop (rye [*Secale cereale* L.]) at different planting dates according to estimated harvest maturities of the different RM hybrids; fall and spring rye cover crop biomass were collected.

Applied questions

How is corn yield affected by changes in management?

Corn yield was affected by planting date and RM under both irrigated and rain-fed conditions; corn yield was also affected by plant population and RM across years under irrigated conditions. Shorter-season hybrids (95 and 105 RM) compared to the regionally used (111 RM or higher) may allow earlier corn harvest and cover crop planting without negatively impacting corn yield ultimately increasing cover crop biomass production (Fig 2 and 3).

How is the cover crop impacted by planting date?

The corn harvest maturity was spread out a month with the different management treatments, allowing 4 cover crop planting dates. Cover crop biomass production was affected by these different planting dates for both fall and spring measurements, with highest production for the earliest planting date in both the fall and the spring (Figure 4).

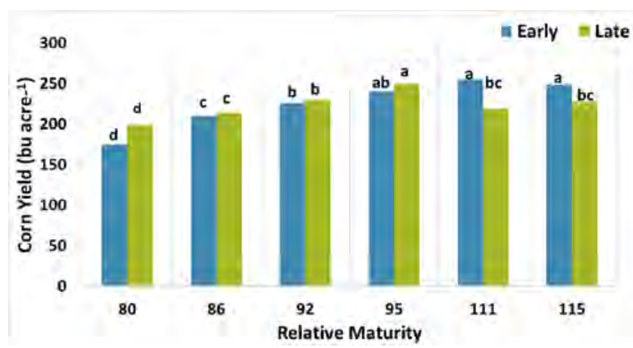

Fig. 2. Corn yield as affected by planting date and relative maturity at SCAL (irrigated) across years. Bars with the same letter(s) are not different (Significant at P ≤ 0.05).

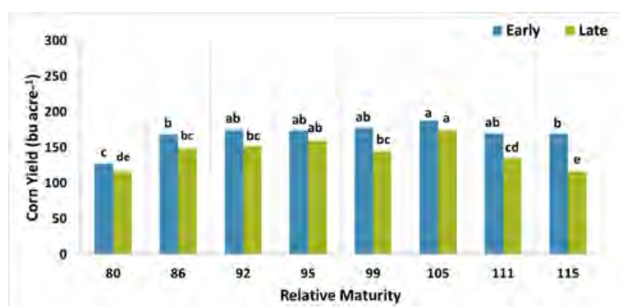

Fig. 3. Corn yield as affected by planting date and relative maturity at Havelock (rain-fed) in 2016. Bars with the same letter(s) are not different (Significant at P ≤ 0.05).

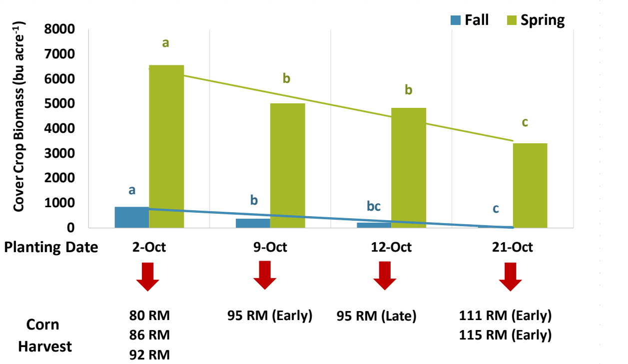

Fig. 4. Fall and Spring biomass production as affected by the planting date at SCAL (irrigated). Bars with the same letter(s) within same sampling are not different (Significant at P ≤ 0.05). Sampling dates: 12/08/2015 and 04/14/2016.

4) INTERSEEDING COVER CROPS INTO CORN

Researchers: Angela Bastidas and Roger W. Elmore

Department of Agronomy and Horticulture

Background

In the US Midwest, cover crop use has been limited by the relatively short growing season remaining after the primary crop is harvested. When wheat, seed corn, corn for silage, or sweet corn is grown in a rotation, planting cover crops after harvest could provide a longer season potential for cover crop growth. But where grain corn and soybean are the predominant cash crops, their relatively long growing seasons leave a short window for the cover crop establishment and biomass production. Increasing biomass is critical for cover crop effectiveness; planting time, weather conditions, length of the growing season and cover crop specie(s) are the most important factors to consider. The objective of this study was to determine of interseeding cover crops into corn – later harvested for grain – would be a way to establish productive cover crops.

Study description

The study was established in the 2015 and 2016 growing seasons under both rain-fed (Havelock Farm, Lincoln, Lancaster County) and irrigated (South Central Agricultural Laboratory-SCAL, Clay Center, Clay County) conditions in Nebraska. The treatments consisted of five different cover crop planting dates into corn (hand broadcast) and 3 single-species cover crops (rye [*Secale cereale* L.], radish [*Raphanus sativus* L.], hairy vetch [*Vicia villosa* Roth]) and a 3-species mixture, representing the most commonly used in the region. Growth, development, leaf chlorophyll, plant height, stem diameter and yield were measured for corn; summer, fall and spring biomass -the following spring- were collected for cover crops; soil temperature and soil water content were monitored. Plant population, plant height and yield were examined for the subsequent rotation (soybean).

Applied question(s)

Is corn affected by interseeding cover crops?

All corn measurements were affected when cover crops were planted at the same time as the corn but we found no detrimental effects on corn when cover crops were planted at or after corn canopy closure (V8 corn stage). Rye seeded at corn planting negatively affected corn the most followed by the mixture and radish (Fig. 5).

How are the cover crops impacted by planting date?

Maximum cover crop biomass was produced during summer followed by spring while fall biomass was greatly reduced; cover crops planted at R6 corn stage (at corn physiological maturity) produced higher spring biomass than cover crop planted at V8, R5 or after corn harvest (Figure 6). Rye and the mixture produced the greatest biomass during both summer and spring; radish only produced measurable biomass during the summer since it did not overwinter.

How is the subsequent crop in the rotation (soybean) affected?

The first year of the soybean rotation was just harvested - Fall 2016. Initial data suggest differences in soybean plant population due previous cover crop treatments.

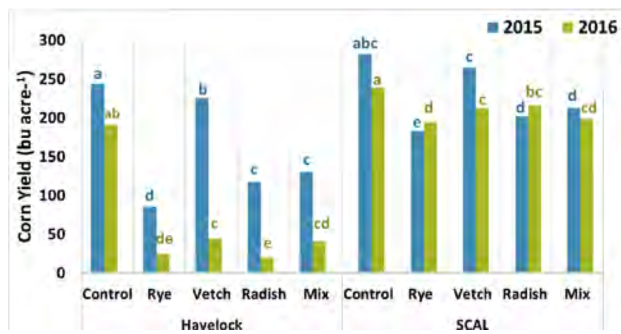

Fig. 5. Corn yield as affected by the cover crop when both are planted at the same time (V0 Treatment). Bars with the same letter(s) within same year and location are not different (Significant at P ≤ 0.05).

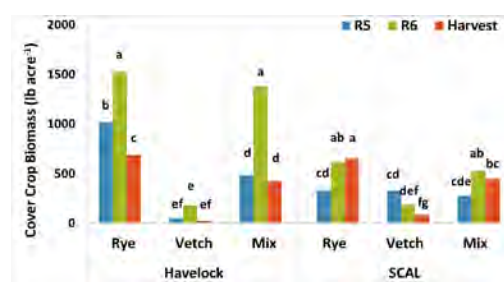

Fig. 6. Spring biomass production as affected by the cover crop specie(s) and planting date. Bars with the same letter(s) within same location are not different (Significant at P ≤ 0.05). Sampling dates: 4/12/2016 at Havelock and 04/14/2016 at SCAL.

5) EVALUATION OF GRAZABLE COVER CROPS AND ANNUAL FORAGES IN WESTERN NEBRASKA SEMI-ARID DRYLAND

Researchers: Mitchell Stephenson, Karla Jenkins, and Cody Creech

Panhandle Research and Extension Center

Background

Producers are interested in potential benefits of crop/livestock production systems and what impact that integration may have on their soil and the economics of their operations. Thus, producer interest in better understanding diversified agriculture systems is driving this research project focused on grazing of annual forages and cover crops.

The primary yield limiting factor in semi-arid western Nebraska is precipitation and available soil water. Previous research demonstrated that cover crops use this valuable resource and leaves little soil moisture for the following crop resulting in yield reductions. Therefore, in order for a cover crop to fit into the system, some type of revenue generating activity must occur. Due to the abundance of cattle in Nebraska, it makes sense to move away from the traditional cover crop that is planted solely for the benefit of the soil and toward annual forages that can be grazed by cattle.

The objective of the study is to determine if growing an annual forage and grazing it is more economical than fallow, growing a cash crop, or a traditional cover crop. In order to fully capture this, yield data will be collected on these sites. A secondary objective is to determine what changes occur to the soil during the course of this study.

Study Description

The first year of the study will be established in 2017 on a 30 acre field near Sidney, NE that was planted to field peas in 2016. This field will be divided into three paddocks for grazing. Each paddock will be planted using a forage pea and oat seed mix. Within each paddock, there will be areas that are not planted and maintained as fallow or that are not grazed at all like a traditional forage crop. Forage production, quality, and daily gain on the cattle will all be monitored. After the grazing period, the forage will be terminated and winter wheat will be planted in the fall. Yield will be collected from the winter wheat in 2018. Soil water and nutrients will be monitored throughout the period. The study will be repeated the following year. At the end of the study, an economic analysis will be performed to determine what system provided the best returns.

A second component of this study will look at multiple cover crop and forage mixtures on a smaller scale without the grazing. Forage biomass, quality, and water use will all be measured. Following termination, a grain crop will be planted to determine if any differences exist in the yield of the grain crop. These results will be used to expand the findings of the grazing study as well as the economic analysis.

Applied Question

Can grazing forage mixtures provide similar soil benefits as growing a traditional cover crop while being more economically feasible for western Nebraska producers?

We know that cover crops, in a traditional sense, do not work well in rain-fed areas of western NE. The hope is that this research will identify an alternative method to traditional cover crops that also captures some of the similar benefits.

TAKE HOME MESSAGES

Here are a few take-home messages based on what we know to date:

- Regardless of cover crop choice, early cover crop planting dates are critical for increasing biomass production
- Early cover crop planting dates offer more cover crop choices while later planting dates reduce cover crop choices
- Cover crop planting dates after mid-October greatly reduce fall growth of cereal rye
- Cereal rye spring growth is reduced with later fall planting dates
- Cover crops can sometimes negatively impact primary crop yields
- Early-season corn hybrids allow earlier cover crop planting, however, grain yields may be reduced.
- Cover crops fit better following harvest of: winter wheat, seed corn, silage, and sweet corn relative to following either corn or soybean for grain.

Alternative Crops for western Nebraska

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The total cropland in the Panhandle District is 3,440,000 acres. Forty percent (~1,376,000 acres) under irrigation and 60% (almost 2 million acres) does not have irrigation water. Crops grown on these acres are referred to as dryland or rain-fed crops. The predominant dryland areas are in the southern Panhandle counties; however, significant acres are also in Box Butte, and Sheridan counties. Given the semi-arid climate, most dryland crops are grown using practices that conserve soil moisture, including limiting the amount of tillage or using fallow periods. During the fallow period, no crops are grown for an entire year to allow soil moisture to recharge.

Over 45% of Nebraska's winter wheat, approximately 660,000 acres (267,095 ha), is grown in the Panhandle. Typically, dryland crops are grown using a two- to four-year rotation that includes a fallow period during one year. Winter wheat is the main crop under dryland production system. Nearly half of the acres is with wheat-fallow rotation is nearly half of the dryland acres and the remaining is under three or four years rotation using various common alternative crops such as proso millet, pea (often called also as field/yellow pea), sunflower, corn, and annual forages. Other minor alternative crops with very limited acres include grain sorghum (milo), safflower, and amaranth. Few other potential alternative crops that can be produced under limited irrigation or even dryland conditions during years with timely precipitation are winter canola and fenugreek. Although complete replacement of fallow may not be possible under current climate, reducing fallow period is important for sustainable crop production under dryland in the region. Diversifying crops in farm can enhance economic viability of producers, sustain future food production, and provide new market alternatives. Therefore, alternative crops that are suitable for dryland and limited irrigation production are important for sustainable farming in the region. This article include recent progress with developing proso millet, pea, fenugreek, sunflower, and winter canola.

Proso Millet:
Proso millet, a warm-season grass that typically produces seed from 60 to 100 days after planting. It is normally planted in June and harvested in September-October. It is the only millet grown as a grain crop in the U.S., and it's used primarily as birdseed but recently it is increasingly being used in various specialty (e.g. multi-grain, gluten-free) cereals, noodles and bakery products. It is very good for human health. Not only is proso millet gluten-free, but it also has an extremely low glycemic index, so it is good for people who have chronic metabolic health disorders. Plus, proso millet is high in iron, calcium, magnesium and other vitamins and minerals. Although there are several different types of millet, including foxtail, Japanese and pearl millet, proso millet is best-suited to western Nebraska's semi-arid climate. Western Nebraska's growing conditions are perfect for proso millet, a crop that requires little water and other inputs and can improve yields of the main dryland crop, winter wheat when used as rotational crop. Thus, proso millet leaves minimal carbon foot print to the environment. Add in its short growing season and its many health benefits, and it's easy to see why the region's farmers are incorporating proso millet into dryland crop production system. As a result, the state is home to one-third to one-fourth of the nation's proso millet acreage, according to the National Agricultural Statistics Service. Western Nebraska growers typically harvest between 100,000 and 150,000 acres of proso millet annually, which produce 1.2 million to nearly 4.5 million bushels and contribute approximately $12 million to the state's economy each year. Proso production suffers from significant yield loss (quantity and quality) due to lodging, seed shattering and non-uniform maturity of grains, which hinders direct combine. Proso millet production in the region is solely dependent on six varieties with narrow genetic base, which make existing cultivars vulnerable to unforeseen production risks. Research of genetic improvement of proso millet through plant breeding, germplasm utilization, developing & utilizing modern genomic tools in variety development is extremely limited. Although proso millet is critically important for the western-central United States agriculture there is little Federal and no foundation or industry research funds available for proso millet. The UNL's Panhandle Research and Extension Center (PHREC) is the only proso millet breeding center in the country.

The long-term goal of this project is to develop regionally adapted high yielding proso millet varieties suitable for bird feed, human food and other industrial uses through plant breeding and genetic research. The short-term objectives are to: (1) make crosses and generate new breeding populations to identify new cultivar, (2) characterize proso millet germplasm for desirable agronomic traits and important seed components needed in improved varieties, and (3) develop genetic linkage map and DNA markers for marker-assisted selection of the desirable traits.

We have developed the FIRST waxy proso millet cultivar, 'Plateau' with comparable yield and other characteristics of commonly grown cultivars (Table 1). As part of breeding program, we make crosses every years and develop breeding population for testing in the field. We have identified several new advanced breeding lines, which have variety release potential in near future (Table 2). Although proso millet cultivars were mainly developed for conventional dryland production, the same varieties also yield well irrigated and organic production system with some differences (Table 3).

Table 1. Averages for grain yield (n=20), grain volume weight (n=17), seed size (n=14), heading (n=16), plant height (n=12), and lodging (n=10) from dryland proso millet cultivars trials in Nebraska (Sidney), Colorado (Akron) and Wyoming (Lingle) from 2002 to 2013.

Cultivar	**Grain Yield ($kg\ ha^{-1}$) (n=20)**	**Grain Volume Weight ($kg\ m^{-3}$) (n=17)**	**1000 grain weight (g) (n=14)**	**Heading (days after planting) (n=16)**	**Plant Height (cm) (n=12)**	**Lodging[¥] (%) (n=4)**
Sunrise	2016	728	5.96	51	78	20
Huntsman	2003	735	5.79	49	80	10
Horizon	1988	729	6.03	51	76	5
Plateau	1953	698	5.53	46	75	10
Earlybird	1953	721	5.97	47	76	10
Sunup	1905	720	5.62	54	81	5
Dawn	1604	714	5.60	50	77	5
PI436626[*]	1020	530	5.21	62	80	10
Average[€]	1805	697	5.71	51	78	9
LSD[¥]	193	18	NS	10	5	0.9

n = Number of trials across the site years, which was used to calculate the trait

[*]Tested only in four trials.

[€]Average of all the values for the trait for the entries that were in the trials

[¥]Least Significant Difference (p=0.05) was calculated from the analysis of variance from the entries common to the trials across years

Table 2. 2015 proso millet variety trial under dryland no-till at the High Plains Ag. Lab in Cheyenne Co. Yield and test weight (bushel weight) were reported at 12% grain moisture since grain moisture significantly varied among the plots. Names in **bold** are check varieties.

Variety	Entry '15	Yield Rank	Yield (lbs/acre)	Bushel weight (lbs/bu)	Plant Height (inches)	Heading (days after Jan.1)	Pedigree
Dawn	1	1	1595	51	28	220	**Check**
PMx11.26-32	22	2	1552	50	32	221	Sunup (3-1)/Horizon
PMx11.35-52	18	3	1532	51	33	222	Huntsman (5-1)/Horizon(4-1)
5098	17	4	1498	49	27	222	
Horizon	6	5	1497	51	35	220	**Check**
Huntsman	4	6	1495	48	34	221	**Check**
5008	15	7	1480	49	32	221	
PMx11.16-30	25	8	1429	48	30	221	Sunrise/PI346937
Minco	8	9	1415	49	34	221	**Check**
PMx11.27-79	24	10	1398	49	29	222	Huntsman (4-2)/174-7-13
PMx11.25-70	30	11	1385	50	28	222	Huntsman (1-1)/Plateau
177-9-13	11	12	1382	48	33	221	
5016	12	13	1373	50	35	221	
PMx11.31-101	21	14	1366	51	35	222	177-9-13 (1-1)/Horizon
PMx11.36-3	26	15	1359	46	31	220	**Check**
Plateau	7	16	1358	47	31	220	**Check**
Earlybird	3	17	1341	47	33	223	**Check**
PMx11.24-40	23	18	1339	47	31	222	Huntsman (1-2)/182-4-24
5106wx	14	19	1328	49	37	222	
524	16	20	1324	48	33	220	
PMx11.23-52	27	21	1305	46	34	221	177-8 (3-1)/ Rise
PMx11.28-52	19	22	1301	46	33	222	Huntsman (1-3)/Dawn
Sunrise	5	23	1293	48	33	222	**Check**
PMx11.32-85	20	24	1290	49	32	221	Huntsman (1-1)/ Sunup
Sunup	2	25	1280	48	26	221	**Check**
5100	13	26	1269	45	36	221	
Snowbird	9	27	1263	46	32	222	**Check**
PMx11.39-27	28	28	1263	47	38	221	177-9-13 (1-3)/182-4-24
FarmerEntry	10	29	1263	47	35	221	Landrace from Austria
PMx11.34-7	29	30	1208	46	33	220	Huntsman (1-2)/Earlybird
Mean			**1372**	**48**	**32**	**221**	
LSD at 5%			**288**	**4**	7	**2**	

Table 3. Grain yields of proso millet varieties under dryland, organic and irrigation.

3- years average grain yield (lb/acre)

Variety	Released	Dryland	Organic	Irrigated
Horizon	2002	2603	2257	2932
Sunrise	1995	2678	2376	2323
Huntsman	1994	2475	2326	2323
Earlybird	1994	2237	2140	2567
Sunup	1989	2556	1970	2163
Dawn	1976	1983	1697	2269
Plateau	2014	2508	2117	2738

Germplasm evaluation: A total of 78 genotypes from 24 different countries were evaluated in the field during 2015 at the High Plains Ag. Lab (Sidney) and Scottsbluff. Nine morpho-agronomic traits, which were evaluated were heading date, plant height, peduncle length, internode number, lodging, panicle length, grain shattering, 100 grain weight, and grains per panicle. Phenotypic data for all these traits were taken on randomly selected plants in the middle of row. Except for heading date, all the traits were recorded at the time of physiological maturity and after harvest.

Mapping genes and QTLs: No genetic linkage map and QTL mapping for proso millet are available. Objectives of the present study were to (1) construct a genetic linkage map and (2) map and identify DNA markers linked of QTLs for morpho-agronomic traits. A total of 93 recombinant inbred lines derived from a single F_1 ('Huntsman' x 'Minsum') were genotyped with GBS-SNP markers and phenotyped for nine morpho-agronomic traits in the field during 2013 and 2014 at Scottsbluff and Sidney, NE. IciMapping v.4.0.6.0 was used for genetic linkage map construction and QTL mapping. The RILs were significantly different for many traits and several traits showed genotype x environment interactions. A total of 833 GBS-SNP markers formed 18 major and 84 minor linkage groups, whereas 519 markers remained ungrouped. A total of 117 GBS-SNP markers on the 18 major linkage groups spanning a genome length of 2137 cM of proso millet with an average distance of 18 cM between markers (Figure 1). The length and number of markers in each of the 18 major linkage groups ranged from 54.6 cM to 236 cM and four to 12, respectively. A total of 17 QTLs for seven morpho-agronomic traits were detected on 14 linkage groups, which explained 13.2 to 34.7% phenotypic variance (Table 4). The genes (QTLs) for these morpho-agronomic traits were identified and mapped on proso millet chromosomes (Fig.1). The DNA markers flanking the QTLs were identified, which would be useful in marker-assisted selection of these traits. This is the first genetic linkage map and QTL mapping in proso millet, which would be useful for further genetic analysis and map-based cloning the genes.

Table 4. Summary of QTLs identified by composite interval mapping for seven morpho-agronomic traits in 93 recombinant inbred lines of 'Huntsman X Minsum' which were evaluated at Scottsbluff (SB) and Sidney (SY) location in 2013 and 2014.

Trait	QTL name¶	LG	Location & Year$	Flanking markers	Interval # (cM)	LOD	PVE¥ (%)	Additive effect
Plant height	***QPh.unac-lg44***	44	SB13	TP111068 - TP16292	20.18	2.92	13.65	0.883
Peduncle length	***QPdl.unac-lg80***	80	SY13	TP8566 - TP15649	20.18	2.87	13.27	0.191
	QPdl.unac-lg45	45	AVG	TP100630-TP102086	23.53	3.37	23.92	0.180
Lodging	*QLh.unac-lg5*	5	SB13	TP32911 - TP53747	17.72	2.65	34.77	695.16
	QLh.unac-lg6	6	SY14	TP18431 - TP55268	21.41	3.20	14.66	-568.02
	QLh.unac-lg15	15	AVG	TP14533 - TP11547	20.96	3.03	14.22	-295.29
	QLh.unac-lg41	41	AVG	TP64024 - TP111750	22.91	2.55	16.78	320.80
Panicle length	***QPl.unac-lg44***	44	SB13	TP111068 - TP16292	20.18	3.61	16.60	0.219
	QPl.unac-lg92	92	SY13	TP72722 - TP101136	23.20	2.62	15.79	0.116
Grain shattering	***QGs.unac-lg5***	5	SY14	TP6831 - TP69094	19.06	3.98	21.57	3.846
	QGs.unac-lg6	6	SY14	TP83720 - TP115604	18.68	3.11	14.22	3.046
	QGs.unac-lg13	13	SB14	TP63964 - TP23581	21.18	3.59	14.99	2.933
	QGs.unac-lg91	91	SB14	TP3611 - TP28849	24.89	3.65	17.15	3.094
100 grain weight	***QGw.unac-lg40***	40	AVG	TP102597 - TP27724	24.24	3.43	22.47	-0.015
Grains per panicle	***QGpp.unac-lg1***	1	AVG	TP102734 - TP73504	39.03	2.97	14.21	-20.45
	QGpp.unac-lg4	4	SY14	TP115888 - TP78877	21.89	2.89	21.49	65.287
	QGpp.unac-lg39	39	SY13	TP113467 - TP58737	20.93	2.80	18.53	-31.72

¶QTLs indicated in bold were detected by both (SMA and CIM) methods.

$: AVG= QTL detected on average mean data of all four environments

#: Distance in centimorgan between flanking markers; ¥: Phenotypic variance explained

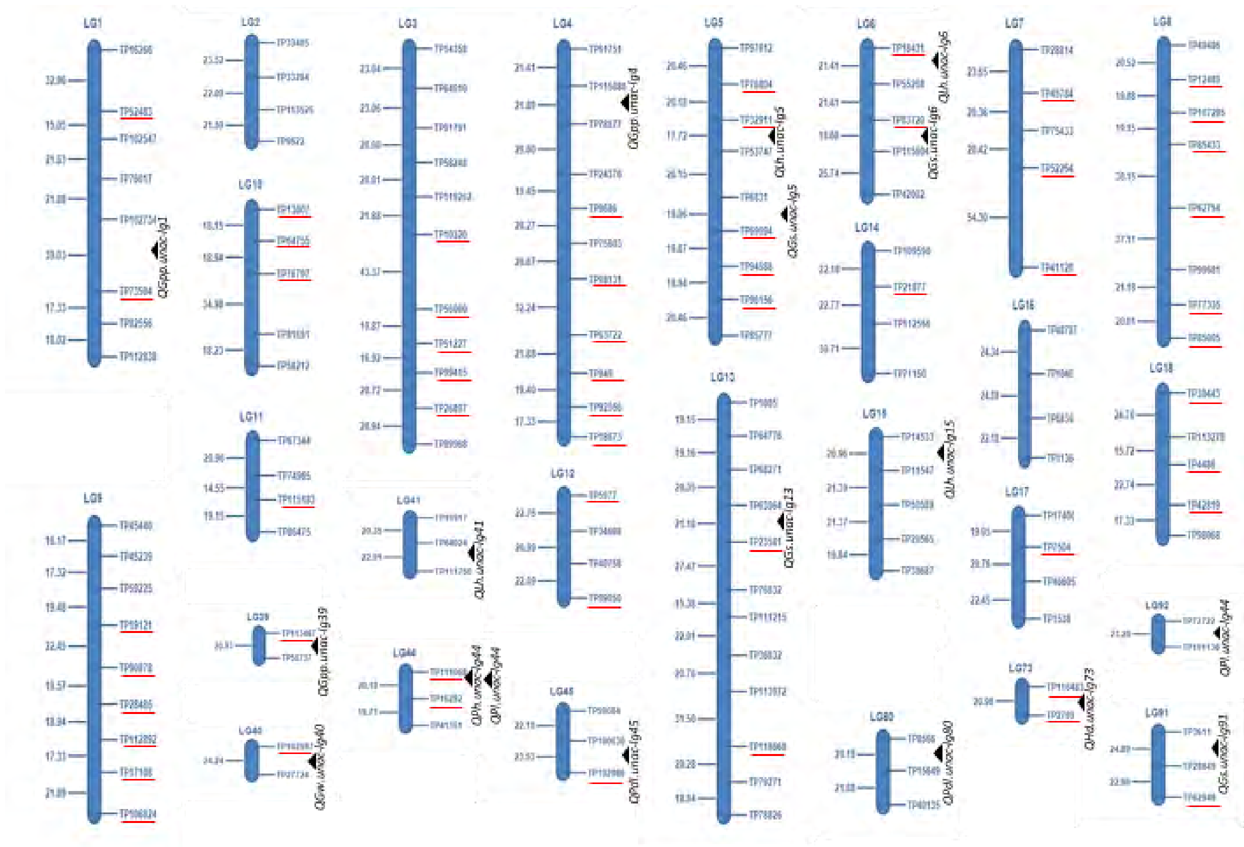

Fig.1 Genetic linkage map of proso millet with QTLs identified using 93 recombinant inbred lines of 'Huntsman X Minsum' which were evaluated at Scottsbluff (SB) and Sidney (SY) location in 2013 and 2014. GBS-SNP marker names and QTL names are on right hand side and genetic distances (cM) between the markers are on left hand side. QTL location between marker interval is indicated by arrow. The segregation distorted markers were underlined with red lines.

Pea

Pea has known as adapted alternative crop for rotating with winter wheat in western Nebraska. However, no significant pea production happened because of lack of market until recently. There has been new interest for pea production due to new international export market in for human food. Pea is an annual, cool-season grain legume, or "pulse crop". According to the USDA, three types of pea are identified as specialty crops and these are 'dry edible pea', 'garden pea', and 'English/edible pod'. This project will focus on 'dry edible pea'. We will refer this 'dry edible pea' as 'pea' throughout this proposal. Pea is marketed as a dry, shelled product for human consumption and as livestock feed depending on the marketing grade. Pea has high levels of protein (~25%) and the amino acids, lysine and tryptophan, which are relatively low in cereal grains. Therefore, pea is commonly used throughout the world with cereal-based diets.

Pea serves as an excellent rotation crop in predominantly cereal-based cropping systems. Commercial pea production started in Nebraska (primarily western part of the state) in 2013. In its first year approximately 25,000 acres were planted to pea and it doubled in 2014. The production continued to expand and reached approximately 65,000 acres by 2015. Environmental benefits of pea are associated with its biological nitrogen fixation. Pea eliminates need for N fertilizer supplementation, and leaves an average of 10-24 lb. N/ac to the subsequent crop, which reduces input cost (N fertilizer) and substantially reduced GHG emissions.

Pea is an excellent source of highly digestible proteins, which offers a variety of opportunities to market it in livestock, pet industry and for human consumption. They may also be used by the cattle industry as a corn replacement in finishing diets and/or protein supplement for grazing. Most of pea (70-80%) are exported to overseas markets for human consumption. Pea protein is becoming extremely valuable source of non-GMO plant based protein for the US food (human & pet) industry because of its blunt nature and balanced amino acids. Pea with higher protein gets premium price. Identification of high seed protein pea varieties and production practices will make Nebraska pea industry competitive and profitable, which will ultimately promote commercial pea production in the state. The

objective is to identify commercial pea cultivars which are high yielding and adapted to western Nebraska.

We have started pea variety testing since 2013 and I am summarized the result here (Table 5 and 6). Eight varieties have seed yield potential of 27 bu/acre to 33 bu/acre based on last three years of testing at the HPAL in Cheyenne Co. only. The varieties are Agassiz, Salamanca, Spider, DS Admiral, Bridger, Nette, SW Midas, and Jetset. Therefore, this result is applicable for southern Panhandle. Tame result may not be expected at other locations where climate (especially temp. and rainfall) could be significantly different from southern Panhandle. Pea varieties seed yield and other related characteristics varied significantly across years and locations throughout western Nebraska.

Table 5. 2016 Pea Variety Evaluation in western Nebraska: (Cheyenne Co., Perkins Co., Lincoln Co.)

Brand	Variety	Yield rank	Yield (bu/a)	1000 seeds weight (g)	Seed Protein (%)	Flowering start (DAP)	Flowering end (DAP)	Flowering period (days)
Great Northern	Bridger	1	32	205	25	61	74	13
Pulse USA	Durwood	2	32	210	25	63	74	11
Pulse USA	Mystique	3	31	213	25	63	75	12
Meridian	Jetset	4	31	212	25	62	74	12
Pulse USA	Nette 2010	5	30	201	24	60	74	13
Meridian	AAC Carver	6	29	216	24	65	76	11
Great Northern	Navarro	7	28	235	25	60	74	14
Legume Logic	Hyline	8	28	214	25	63	74	12
Pulse USA	DS-Admiral	9	28	215	25	62	74	12
Great Northern	Salamanca	10	27	220	25	63	74	11
Meridian	CDC Saffron	11	27	208	25	64	75	11
Pulse USA	SW Midas	12	26	188	24	64	76	12
Great Northern	Spider	13	26	209	26	64	76	12
Pulse USA	Korando	14	25	229	26	61	74	13
Meridian	AC Earlystar	15	25	195	24	62	74	13
Pulse USA	Abarth	16	24	229	24	62	74	12
Av. of all entries			**28**	**212**	**25**	**62**	**74**	**12**
LSD at 5%			**9**	**11**	**1**	**2**	**2**	**2**

Table 6. Pea Variety Testing Across Years (2014-'16) at the HPAL in Cheyenne Co (Rainfed)

Brand	Variety	Yield rank	Yield (bu/a)	Bushel weight (lbs/bu)	1000 seed weight (g)	Protein (%)	Flowering (days after planting)
Great Northern Ag.	Bridger	1	34	60	241	24	62
Great Northern Ag.	Spider	2	32	59	254	25	64
Great Northern Ag.	Salamanca	3	31	58	249	25	63
Pulse USA	Mystique	4	30	59	250	24	63
Meridian Seeds	AC Earlystar	5	29	59	230	23	63
Pulse USA	Hyline	6	28	60	246	24	63
Meridian Seeds	Jetset	7	28	59	244	24	63
Pulse USA	SW Midas	8	27	58	226	23	64
Pulse USA	Nette 2010	9	27	60	235	24	61
Great Northern Ag.	Navarro	10	26	60	235	24	61
Pulse USA	DS Admiral	11	26	59	241	24	63
Pulse USA	Abarth	12	25	59	258	23	62
Av. of all entries			**28**	**59**	**242**	**24**	**63**
LSD at 5%			**7**	**1**	**23**	**1**	**2**

Fenugreek

Fenugreek, an annual legume, is known for its medicinal properties for multiple metabolic diseases, e.g., type 2 diabetes, hypercholesterol, cancer. Currtly, the US medicinal and nutraceutical industry imports all fenugreek seed. For better quality control and profit margin, the US nutraceutical industry would prefer domestically produced fenugreek, which is not available anywhere in the USA. The only US study on fenugreek cultivar development and production were by this program in the western Nebraska. We identified several fenugreek lines with high level of medicinal compounds and high seed yield potential. We have developed fenugreek production parameters (optimal planting and harvesting dates, irrigation level) using the two The only two publicly available Canadian non-medicinal cultivars are 'Tristar' and 'Amber', which were developed for forage production in Canada. Our research clearly showed that fenugreek is well-adapted to western Nebraska where diseases and insects were not issues for the past. Therefore, western Nebraska can be an ideal location for fenugreek production under both conventional and organic system. Organic fenugreek production may be difficult due to poor weed weed management options. Therefore, it is necessary to develop best fenugreek cultivar for both organic and conventional production system. With the best cultivar and production combination identified, pilot production can commence on growers' field. In near future, Nebraska would be the leader in the American nutraceutical and medicinal industries for this high-value medicinal crop. The objectives are to (1) evalute fenugreek germplasm for major medicinal compunds and agronomic parameter, (2) develop cultivar with high seed yield and adapted to western Nebraksa, and (2) develop important agronomic production parameters

Germplasm evaluation: Summary results of the PI lines tested in 2013 is presented in Table 7. All the 155 PI lines flowered between 37 to 45 days after planting (Figure 2A). Approximately 48% (75 lines), 43% (67 lines) and 8% lines (13 lines) flowered 37, 42 and 47 days after planting, respectively. Plant height ranged from 30 cm to 69 cm (Fig.2B). Majority of the lines (62%) ranged within 41 cm to 55 cm. Seed size also varied significantly from 5g (PI269992, Pakistan) to 24g (PI212922, India) per 1000 seeds (Fig.2C).

Variety evaluation: We have developed several high seed yielding fenugreek lines which are adapted to western Nebraska and few of these have cultivar release potential for commercial production in western Nebraska under irrigation (Table 8).

Fenugreek seems to be adapted in western Nebraska and could be a new highly valuable medicinal crop. Several high yielding lines were developed and had higher seed yield compared to 'Tristar' and 'Amber', two publicly available fenugreek varieties in North America. All these high seed yielding varieties were originally from India, Iran and Pakistan. This is not surprised since fenugreek was originated in that region of Asia.

Table 7. Country of origin of 155 PI lines and their trait values based on field trials under irrigation in 2013 at Scottsbluff, Nebraska.

Country	**Number of lines**	**Flowering (DAP)***	**Plant height (cm)**	**1000 seed weight (g)**	**Diosgenin %**	**Galactomannan %**
Afghanistan	12	**37 - 47**	38 - 61	11 - 18	1.55 - 2.94	11 - 19.7
Angola	1	42	43	10	1.57	16.60
Armenia	1	42	56	17	1.45	11.83
Australia	2	**37**	44, 56	15	3.00	14.76, 15.96
Bulgaria	5	**37** - 42	**30** - 66	15 - 18	2.37 - 3.36	16.86 - 18.21
Egypt	6	**37 - 47**	**30** - 64	11 - 18	1.15 - 2.82	10.66 - 19.55
Ethiopia	13	**37 - 47**	33 - 51	11 - 22	**0.53** - 3.23	11.75 - **31.30**
Greece	1	**37**	48	21	1.29	14.93
India	27	**37** - 42	36 - 64	8 - **24**	0.63 - 3.27	**7.41** - 20.11
Iran	27	**37 - 47**	36 - 58	9 - 21	0.76 - **4.46**	13.03 - 19.47
Italy	1	42	51	21	1.26	13.69
Jordon	2	**37**	46, 48	10, 21	1.77, 2.17	14.96, 15.50
Morocco	6	**37** - 42	**30** - 53	7 - 19	0.81 - 3.16	14.03 - 17.22
Nepal	4	**37** - 42	36 - 64	10 - 19	1.50 - 2.68	14.38 - 16.51
Pakistan	22	**37 - 47**	**30 - 69**	**5** - 22	0.71 - 3.12	8.83 - 18.04
Spain	4	42 - **47**	33 - 48	10 - 17	1.12 - 2.30	12.78 -17.16
Syria	2	**37**	38, 51	18, 22	1.81, 2.10	15, 15.63
Turkey	17	**37 - 47**	36 - 58	10 - 21	0.60 - 3.22	10.35 - 19.45
Yemen	1	**37**	46	19	2.40	15.87
Unknown	1	**37**	41	17	1.74	15.34
Total/Av.	155	40	47	15	1.97	15.69
Data ranges	1-27	37-47	30-69	5-24	0.53 – 4.46	7.45 – 31.30
Lowest value		37	30	5	0.53	7.45
	Line	Majority		PI 269992	PI 194022	PI 180351
	Country	Multiple	Several	Pakistan	Ethiopia	India
Highest value		47	69	24	4.46	31.30
	Line	Several	PI532861 & PI426970	PI212922	PI226679	PI195691
	Country	Multiple	Pakistan	India	Iran	Ethiopia

*Days after planting; Lowest and highest values are in **bold**

Table 8. Two or three years average seed yield of 13 fenugreek varieties tested at the HPAL and Scottsbluff under irrigation during 2013 to 2015.

Variety	Country	09 Ori. Entry	Years tested	No. of Yrs tested	Yld. Rank	Av.Yield (lbs/a)
PI302449	India	160	14-'15	2	1	1782
PI141725	Iran	54	13-'15	3	2	1552
PI141728	Iran	51	13-'15	3	3	1495
PI141724	Iran	55	13-'15	3	4	1460
PI426970	Pakistan	118	14-'15	2	5	1442
PI543073	Pakistan	113	14-'15	2	6	1425
Tristar	**Canada**	**V-2**	**13-'15**	**3**	**7**	**1354**
PI183911	Unknown	24	14-'15	2	8	1349
PI138954	Iran	59	13-'15	3	9	1330
PI567879	Turkey	133	14-'15	2	10	1310
Amber	**Canada**	**V-1**	**13-'15**	**3**	**11**	**1188**
PI181814	Syria	21	14-'15	2	12	1152
PI557489	Turkey	112	14-'15	2	13	1115

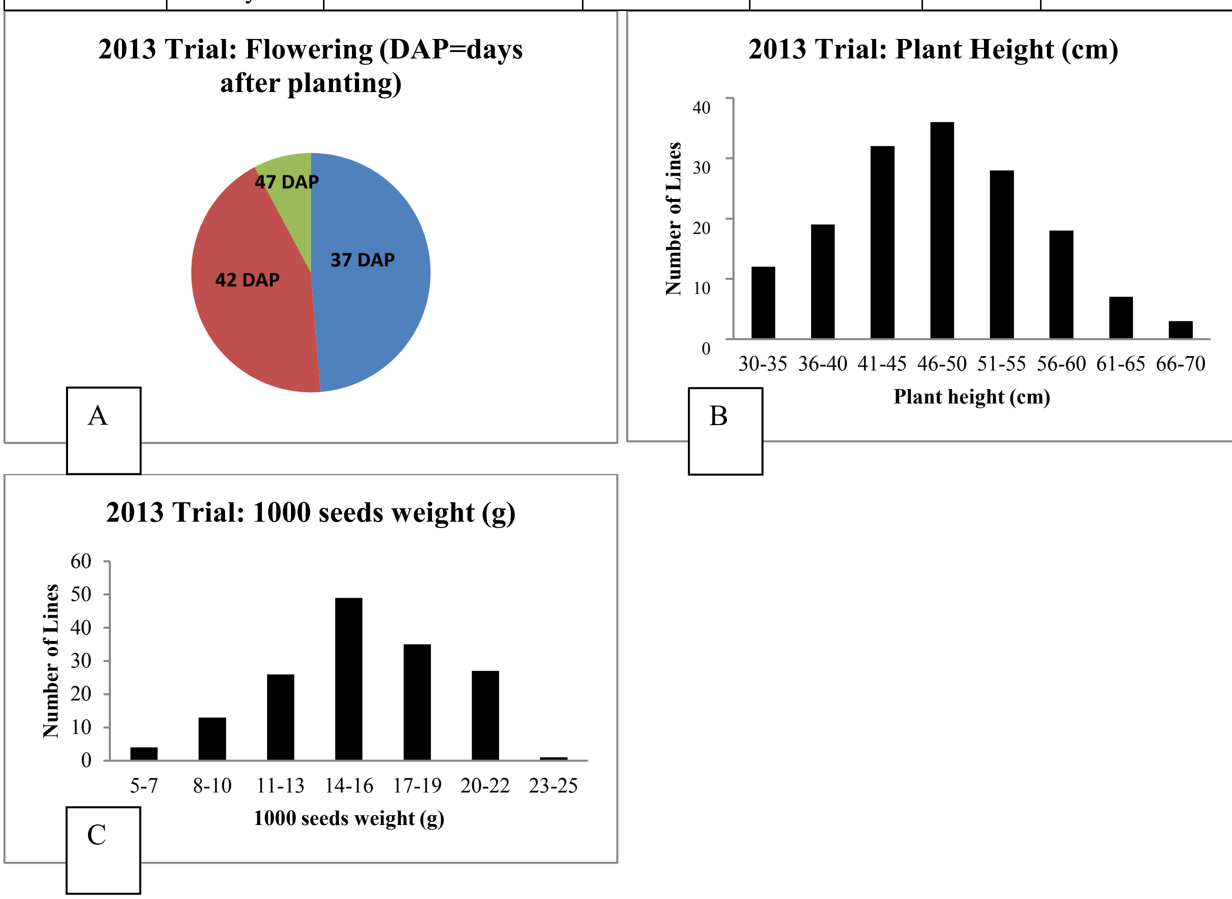

Figure 2: Frequency distribution of flowering time (A) and plant height (B), seed weight (C) of 155 PI lines tested at Scottsbluff, NE under irrigation in 2013.

Winter Canola

Winter canola could be an important alternative crop in western Nebraska if regionally adapted high yielding cultivars and suitable production practices are developed. The cultivars adapted in states south of Nebraska such as Kansas, Oklahoma are not suitable for western Nebraska because of unique winter (very cold, no snow cover, high wind chill). Therefore, winter hardiness is very important for regional adaptation. Establishing a uniform stand of small-seeded crops such as canola has proven to be problematic under dryland conditions in the semi-arid climate of western Nebraska. The **objectives** of the study in Nebraska are to evaluate: (1) cultivars and advanced breeding lines for yield, oil content and regionally important agronomic traits, (2) evaluate early generation breeding populations for winter survival/hardiness in western Nebraska, and (3) To evaluate the impacts of a fallow period, tillage, and seeding equipment on canola establishment in western Nebraska.

Winter canola could be an important alternative crop both under dryland and irrigated condition in the region because this is broadleaf and fall planted, the only fall planted crop after wheat in the region. Few high seed yielding cultivars with good winter survival have been developed. However, consistency of winter survival is limited. Another critical factor for successful production of winter canola in the region is establishing this crop under dryland condition when soil often is dry. Since last couple of years, we have been trying to develop the best method for its fall establishment and winter survival but with limited success. More future research is necessary before winter canola can be successfully used for commercial production in the region. Below, I summarize 2016 winter canola variety testing result in Table 9.

Table 9. Results for the 2016 National Winter Canola Variety Trial

Name	**50% bloom**	**Maturity**	**Plant height**	**Lodging**	**Shatter**	**Test weight**	**Yield**	**Yield**
	(d)	**(d)**	**(in)**	**(%)**	**(%)**	**(lb/bu)**	**(bu/a)**	**(% of Mean)**
KS4506	118.3	177.0	59.3	0.0	56.7	38.9	16.7	101.4
KSR07363	117.3	175.0	57.0	10.0	60.0	37.4	13.9	84.4
KSUR1211	119.7	177.0	62.0	0.0	60.0	39.5	16.3	98.7
Riley	117.3	178.0	60.0	8.3	63.3	39.1	17.6	106.6
Sumner	109.0	175.0	56.0	0.0	56.7	38.6	12.2	74.0
Wichita	120.7	177.0	59.0	0.0	46.7	39.4	14.1	85.3
DKW41-10	109.0	178.0	56.3	0.0	56.7	37.7	13.5	82.1
DKW44-10	119.7	177.0	59.0	0.0	56.7	37.8	15.3	92.9
DKW45-25	116.0	175.0	60.7	0.0	56.7	38.0	14.7	89.3
DKW46-15	119.3	175.0	60.0	0.0	70.0	36.8	12.5	75.7
DKW47-15	120.7	178.0	59.7	0.0	53.3	37.7	14.9	90.5
HyCLASS115W	116.0	177.0	61.0	0.0	70.0	38.3	15.0	90.9
HyCLASS125W	117.0	178.0	58.7	0.0	70.0	38.1	17.7	107.1
HyCLASS220W	118.3	178.0	59.7	0.0	63.3	38.6	15.6	94.7
HyCLASS225W	119.3	176.0	60.0	0.0	70.0	39.0	13.6	82.4
Claremore	123.3	177.0	59.3	0.0	50.0	39.1	18.4	111.4
Star 915W	119.3	181.3	59.3	0.0	53.3	38.1	18.2	110.3
Kadore	122.7	180.0	57.7	13.3	56.7	39.5	19.9	120.3
Quartz	122.0	182.3	58.7	0.0	36.7	39.1	21.7	131.4
15.UI.WC.1	122.7	180.0	63.3	0.0	60.0	39.0	19.9	120.3
15.UI.WC.05633	122.0	180.0	60.3	8.3	30.0	37.6	19.8	120.1
Virginia	115.3	179.0	58.0	0.0	43.3	38.2	17.0	102.8
VSX-3	119.7	179.0	55.0	0.0	53.3	38.7	17.7	107.0
VSX-4	118.3	181.0	57.0	0.0	53.3	37.8	19.9	120.6
Mean	**118.5**	**177.9**	**59.0**	**---**	**56.1**	**38.4**	**16.5**	
LSD (0.05)	**4.8**	**3.0**	**NS**	**---**	**19.1**	**NS**	**4.5**	

Help Us Identify Yield-Limiting Factors in NE Soy Fields

Patricio Grassini - Cropping Systems Specialist | Juan Ignacio Rattalino Edreira - Post-Doctoral Research Associate | Jenny Rees - Extension Educator | Amy Timmerman - Extension Educator | Michael Rethwisch - Extension Educator | Randy Pryor - Extension Educator | Gary Lesoing - Extension Educator | Ron Seymour - Extension Educator | Todd Whitney - Extension Educator | Strahinja Stepanovic - Extension Educator | Chuck Burr - Crops and Water Extension Educator | Daran Rudnick - Extension Irrigation Engineer | Tyler Williams - Extension Educator | Keith Glewen - Extension Educator | Nathan Mueller - Extension Educator | Aaron Nygren - Extension Educator | Allan Vyhnalek - Extension Educator | Keith Jarvi - Extension Educator | John Wilson - Extension Educator | Wayne Ohnesorg - Extension Educator

The United States is the largest soybean producer in the world, accounting for 35% of total production. The North Central Region accounts for 80% of US soybean production. We have started a three-year project, funded by the Nebraska Soybean Board and the North Central Soybean Research Program (NCSRP), to identify the key factors that preclude soybean producers from obtaining top yields that should be possible on their individual farms.

Last winter, we collected data from fields planted with soybean in 2014 and 2015 from 10 states in the North-Central region (IL, IN, IA, KS, MI, MN, OH, NE, ND, and WI). Producers completed surveys to provide information on 3,500 fields. All data submissions are kept strictly confidential.

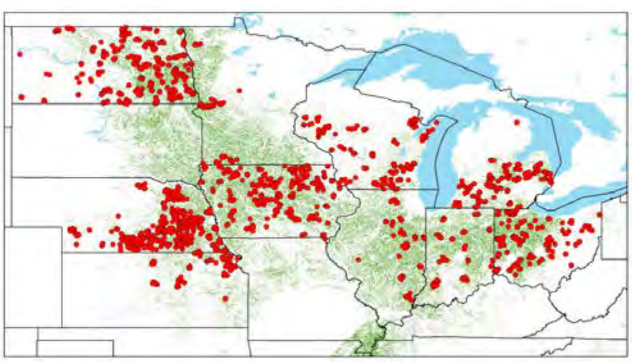

FIGURE #1. Location of the irrigated and dryland soybean fields that were surveyed during 2014 and 2015 (red circles). Surveyed fields portrayed well the range of yield management practices across major soybean production regions of the US North-Central region.

A report summarizing yield and management practices in producer soybean fields in NE and the rest of the North-Central region is available online at: http://cropwatch.unl.edu/2016-soybean-survey. Some interesting findings are:

- Average dryland and irrigated yields in NE were 56 bu/ac and 67 bu/ac respectively, both above average yield in the North-Central region (54 bu/ac).
- Only a small proportion of producers (2%) attained soybean yields near or above 80 bu/ac.
- Half of the soybean area in the North-Central region is no-till. Adoption of no-till in NE is greater in dryland (77% of fields) than in irrigated fields (51% of fields).
- Only 25% of soybean fields in the North-Central region are planted during the first week of May or earlier. This figure rises to 45% in NE.
- Seeding rates used by producers (140-200k/acre) are well above economically optimal soybean seeding rates (the latter is around 120k seeds/acre in NE).
- Most producers in the region grow soybean at a 15-inch row spacing, except for NE and eastern IA producers, where 30-inch spacing still prevails.
- Across the entire North-Central region, 8%, 19% and 24% of soybean fields are treated with foliar fungicide only, insecticide only, and both fungicide and insecticide, respectively. These figures are lower in NE at 6%, 3% and 17%, respectively.

Here's How You Can Become Part of This Soybean Study.

This winter, we are asking NE crop producers to provide us with yield and other agronomic data specific to four fields planted with soybean in **2016 (see survey on the next page)**. Both dryland and irrigated fields are acceptable. With these data, we can conduct an in-depth analysis of what on-farm factors might be limiting soybean yield in your fields. We will appreciate if you complete this survey ***before April 1, 2017*** and mail it to:

Dr. Patricio Grassini
Department of Agronomy and Horticulture
387 Plant Sciences Hall, UNL
Lincoln, NE 68583-0915

You can also e-mail the survey: pgrassini2@unl.edu We look forward to receiving your data. In this project, our objective is to work for you. Our goal is to use the data you supply to help you get higher soybean yields in your fields.

PRODUCER NAME (optional): **MAILING ADDRESS (optional):**

Please provide information for four dryland or irrigated SOYBEAN fields on your farm in 2016. If you have questions, contact Professor Patricio Grassini (Phone: 402-472-5554 / e-mail: pgrassini2@unl.edu). Note that all provided info will be kept confidential! An EXAMPLE is shown in red.

	EXAMPLE:	2016 Soybean	2016 Soybean	2016 Soybean	2016 Soybean
Specify field location by Section: Township: Range. →	NE ¼ 25 : 20N : 26W	___ : ___ : ___	___ : ___ : ___	___ : ___ : ___	___ : ___ : ___
Please sketch-in the boundaries of your field location within the Section →	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4
OR GPS coordinates of field centroid: OR County & field location relative to Rd Intersection:	41.678, -100.257 Saunders Co, SW of Rd 11 & N				
Dryland? OR Pivot, Gravity? Indicate field size (acres)	Pivot (130 ac)				
Does this field have drainage? (no, old clay tile, new systematic tile, surface drainage, other)	No				
Total Inches of Irrigation Applied to crop?	4.5 inches				
SOYBEAN YIELD (bushels/acre) for this FIELD:	60				
Lowest|Highest Yield (bu/ac) of your soy fields that year *Use Irrigated fields yield range if this crop was Irrigated: *Use Dryland fields yield range if this crop was Dryland:	Low: 50 | High: 71	Low: | High:	Low: | High:	Low: | High:	Low: | High:
Planting Date in this FIELD (Month/Day/Year):	5/15/2016				
Variety Name (Brand & Number):	Pioneer P93M11				
Seeding Rate (seeds/ac):	125,000				
Row spacing (inches):	30				
Seed Treated (Yes/No)? What Brand Name Product(s)?	Yes (Cruiser-Max)				
Prior Crop in this FIELD? Residue harvested or grazed?	Corn - Grazed				
Tillage after prior crop? No-Till (NT); Ridge (RT); Strip (ST); Disk (D); Chisel (C); Vertical (V) – Indicate timing (month-year)	ST (March-2016)				
Any (non-starter) fertilizer after prior crop? Specify rate (pounds NUTRIENT/ac) and timing (month-year)	P_2O_5: 70 | K_2O: 30 Other: S (11 lbs) Time: March-2016	P_2O_5: | K_2O: Other: Time:	P_2O_5: | K_2O: Other: Time:	P_2O_5: | K_2O: Other: Time:	P_2O_5: | K_2O: Other: Time:
Any STARTER fertilizer (Yes/No)? If Yes, specify nutrients	Yes (N, P, Zn)				
Any Lime (L) or Manure (M)? If yes, specify timing (mm-yy)	M (Nov-2015)				
PRE- or POST-emergence herbicide program or BOTH?	Both				
Any in-season foliar fungicide (F) / insecticide (I)?	F and I				
Soy Cyst Nematodes (Yes/No/I don't know)?	No				
Iron Deficiency Chlorosis (Yes/No)?	No				
Any significant yield loss due to Insects, Diseases, Weeds, Frost, Hail, Flood, Lodging? Specify problem	Weed infestation Hail (July-2016)				

Climate Information and Decision-Making

Tyler Williams, Extension Educator, University of Nebraska – Lincoln
Martha Shulski, State Climatologist and Director, Nebraska State Climate Office, University of Nebraska – Lincoln
Al Dutcher, Extension Ag Climatologist, Nebraska State Climate Office, University of Nebraska – Lincoln
Tamra Jackson-Ziems, Extension Plant Pathologist, University of Nebraska – Lincoln

Introduction

It is not a secret to those involved in agriculture that the climate and weather of the Great Plains can be challenging, rewarding, and often, quite surprising. Nebraska's average annual [1]temperature and precipitation ranges from 45°F and 15-inches in the west to 55°F and 36-inches in the southeast; however, there are a wide range of extremes contributing to those averages. [2]Since 1895, temperatures have reached 118°F three times and -47°F two times.

The Nebraska climate determines the crops we grow, but the weather in any given year often controls how successful they are. The University of Nebraska – Lincoln continues to develop research and education to help agricultural producers prepare for and become resilient to climate variation and extreme weather events.

Nebraska State Climate Office

Nebraska has been fortunate to have a State Climatologist position at the University of Nebraska – Lincoln since the 1970s. Beginning in January of 2016, the University centralized state resources with the formation of the Nebraska State Climate Office (NSCO). The mission of the NSCO is to provide science-based climate services at the local and state level. Our focus is within three main areas – weather and climate monitoring, climate services, and stakeholder engagement. In addition to State Climatologist, the NSCO is composed of three other full time positions – an Extension Agricultural Climatologist, a Weather Network Administrator, and a Network Manager.

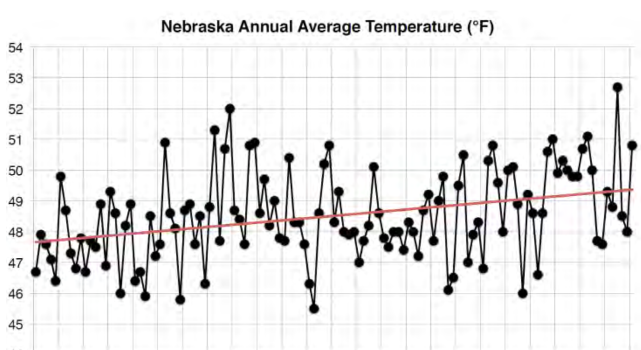

Figure 1. Nebraska annual average temperature (°F) from 1895 to 2015.

The website for the Nebraska State Climate Office is now live and users can find a variety of resources on the site (https://nsco.unl.edu/). Climate normals and frost/freeze statistics are a common type of data request and these are compiled for all available stations in each of Nebraska's eight climate divisions. Historical trends in temperature and precipitation are available on a statewide basis as well as by location. Not surprisingly, year to year variability is high for Nebraska. However, some common themes are present. Overall, temperatures have generally increased (**Figure 1**) – mostly during the cold season and for minimum temperatures. Precipitation shows a slight wetting on an annual average basis. The strongest seasonal trends are an overall wetting during the spring.

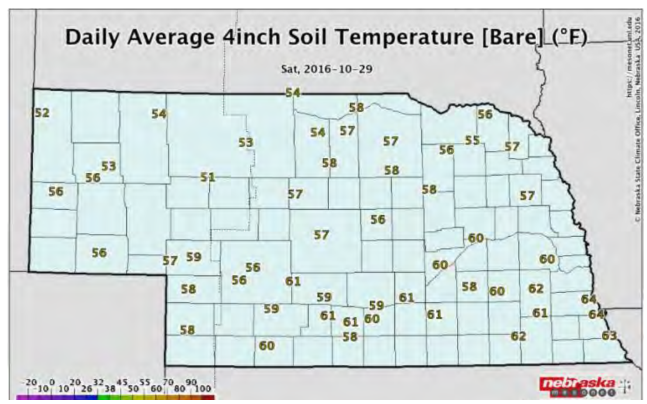

Figure 2. Example soil temperature map from the Nebraska Mesonet, a network of automated weather stations from the Nebraska State Climate Office.

Other resources available through the NSCO website include a state monthly climate summary. This feature is posted within the first week of the new month and recaps temperature, precipitation, and drought conditions, highlights extreme events, discusses agricultural impacts, and provides a climate outlook for the coming month and season. Links to select web resources are available as well, including drought, hydrology, weather forecasts, climate outlooks, and climate change resources.

The long-time monitoring program with the NSCO is the statewide automated weather network, the Nebraska Mesonet (https://mesonet.unl.edu/). At present, there are 67 stations representing 46 Nebraska counties. Users can find the latest hourly observations, which include air temperature, relative humidity, precipitation, wind speed and direction, solar radiation, and soil temperature at 4 inches under bare ground (**Figure 2**). Also available is soil moisture at four discreet depths under grass cover.

There are several calculated metrics available, based on Mesonet data. These include: evapotranspiration (ET) and growing degree days (in season); heat and wind chill index; as well as a cattle comfort index. Furthermore, to give a higher resolution picture of rainfall than what the Mesonet offers, RADAR-estimated precipitation is available on a daily, weekly, and monthly basis. New products and tools will continue to be added. Visit our websites and follow us on Facebook (/NEclimate and /NEMesonet) and Twitter (@mshulski3) for the latest news and information.

AgriTools

AgriTools is a free mobile app for iPhone, iPod, and iPad devices utilizing climate and weather data from the National Weather Service, Nebraska State Climate Office, and High Plains Regional Climate Center in combination with resources from Nebraska Extension. The app is designed for agricultural producers in Nebraska to utilize location-specific ag climate and weather information and easy access to UNL mobile resources and apps. The app will use your GPS location on your device to get weather and climate data for your location. You can select and store other locations, which may be useful for operations or fields separated by a long distance.

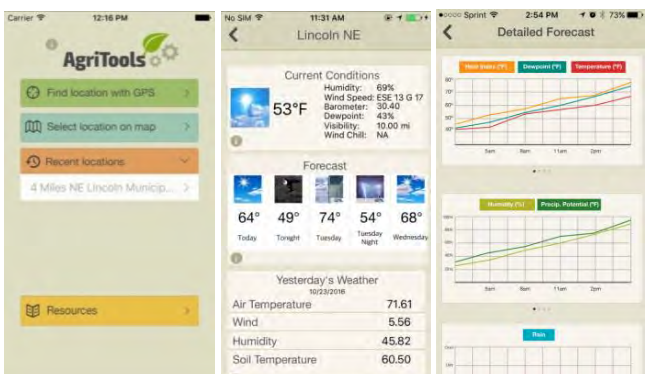

Figure 2. Screenshots from the AgriTools mobile app from Nebraska Extension. The app is available for free on your iPad, iPhone, or iPod thru the iTunes store.

Once your location of interest is determined, detailed forecast information is provided from the National Weather Service. The newest feature on the app is the Forecast Graph. The Forecast Graph provides hourly forecast data in 12 hour segments out to 120 hours. This is especially useful when planning agricultural practices, such as spraying herbicides or applying fertilizer. It is important to remember forecasts are predictions with an inherent amount of error, so use forecasts accordingly.

Another feature of the app is to provide recent weather information, such as yesterday's air temperature, wind gusts, soil temperature, solar radiation, GDD daily and seasonal totals, crop water use, rainfall maps, etc. This allows you to monitor and utilize past data, in combination with forecast data, to make more informed agricultural decisions.

The Resources tab in AgriTools allows you to have easy access to relevant UNL mobile friendly webpages and apps. No more searching the app store or zooming in and out on a website to find more information. With only a couple clicks, you can easily and quickly find information that is pertinent to you.

Role of Weather on Corn Disease Development

Weather conditions are among several very important factors that influence disease development. Weather can play a role in both the timing of disease development and on its ultimate severity. The optimal conditions that favor disease development depend upon the pathogen that causes the disease. Moisture (including relative humidity) and temperature are the two most important weather factors that impact pathogens and disease development. Familiarizing yourself with the weather conditions favorable for diseases in your area can help you anticipate when, and if, they will develop and sometimes, when a management strategy (such as a foliar fungicide application) can be helpful. Here are links to two new Nebraska Extension publications that are part of the Corn Disease Profiles series that summarizes some of the diseases that can be a problem during and following wet or dry growing conditions.

Corn Disease Profiles:
Diseases of Corn Favored by Wet Conditions
http://extensionpublications.unl.edu/assets/pdf/ec1909.pdf

Diseases of Corn Favored by Dry Conditions (EC 1910)
http://extensionpublications.unl.edu/assets/pdf/ec1910.pdf

References

[1] Bathke, et al. 2014. *Understanding and Assessing Climate Change: Implications for Nebraska.* http://snr.unl.edu/download/research/projects/climateimpacts/2014ClimateChange.pdf

[2] *State Climate Extremes Committee-Records*. NOAA National Centers for Environmental Information. https://www.ncdc.noaa.gov/extremes/scec/records

Corn Ear Formation Issues – 2016

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Eastern Nebraska Research and Extension Center
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Jenny Rees, Extension Educator, York County, University of Nebraska-Lincoln

This article is an update from a CropWatch report published on August 19th, 2016 entitled, "Corn ear formation issues likely correlated with the loss of the primary ear node" (Elmore et al. 2016).

Corn yields in many parts of Nebraska were very good this year, however, in other places, yields were quite variable even within fields. We received and documented widespread reports from many individuals experiencing ear formation issues. These reports ranged from Gothenburg to Saunders County and south to Kansas with numerous reports in Clay and Thayer counties. However, it did not just affect Nebraska; well -substantiated reports of the issue range from the Texas Panhandle to eastern Colorado and then east through Nebraska and Iowa to Illinois. This widespread of a problem points to a weather factor most likely interacting with hybrids of specific genetics. We first reported these issues in UNL Extension's *CropWatch* on 19 August 2016

Here are types of symptoms commonly observed (Fig. 1):

1) Normal secondary ears
2) Tipping back
3) Short husks – Normal ear length
4) Dumbbell shaped ears
5) Multiple ears per node

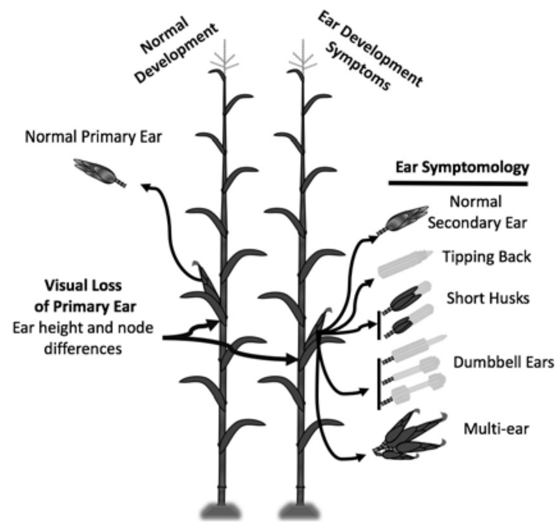


Figure 1. Illustration showing a normal plant on the left and a plant with ear development symptoms on the right. Note that the various ear development symptoms usually do not occur on the same plant.

'Normal' secondary ears can occur with a good-sized primary ear when early season conditions are excellent for specific hybrids. They also occur on field borders and in fields with low seeding rates. Tipping back often occurs when plants experience stress after pollination – usually moisture or heat stress. Some hybrids naturally tip back in production situations – check with your seed agronomist.

Short husks – normal ear length

Symptoms: Shortened husk leaves with normal ear protruding beyond the husks. Indeed ears of some hybrids often protrude a bit beyond the husk leaves – some suggest this aids in dry-down. However, the symptoms we're discussing here are more severe. In these situations, ears outgrow husks by 1/3 to ½ (Aldrich et al. 1986). Based on our observations this year, the primary ear was aborted in most if not all situations. Thus, these ears are predominantly secondary ears.

Incidence: Common in some fields with some hybrids.

Developmental timing: Likely resulting from stress prior to tasseling, VT, but before the blister stage, R3. Aldrich et al., 1986, observed this where, "…extreme [drought] prevailed during the time of ear set with abundant rainfall and good growing conditions thereafter." These symptoms tell us something about corn ear development: husk leaf elongation must proceed ear elongation, and was subjected to stress at a critical time. In these cases, when the stress was alleviated, the ear grew at a normal rate and to a normal length.

Potential stress agent and interacting factors: Bob Nielsen, corn agronomist at Purdue University, states, "…The development of stunted husk leaves and exposed ears seems to be related to a combination of severe stress before or during pollination that is then relieved in the initial weeks following pollination. The most common combination of conditions that results in this oddity is severe heat and drought stress that is then relieved by cooler temperatures and rainfall (Nielsen, 2012)." In our situation we think high June temperatures, followed by a cool spell in very early July which was followed by more high temperatures and the high winds associated with the July 7 storm not only affected primary ear formation/abortion, but also suppressed husk elongation rates. The problem with this hypothesis is that these extreme winds affected Nebraska and parts of Iowa but did not likely affect other states where the symptoms are reported to have occurred.

Potential consequences: Kernels exposed to bird/insect feeding and other damage. This could result in fungal infection, ear molds, and potentially discounted grain price.

Dumbbell shaped ears

Symptoms: Kernels may form at the tip or the butt or the ear, or at both locations but not the entire length of the ear. Based on our observations the primary ear was aborted in most if not all situations. Thus, these ears are predominantly secondary ears.

Incidence: Common in some fields with some hybrids.

Developmental timing: Ohio State Univ. (2015) suggests this is triggered during ear formation (see reference below). Our observations when coupled with work at Iowa State (See Abendroth et. al. 2011) fine tune that general timing to the period of time from V12 to perhaps V15, just prior to tasseling (VT).

Potential stress agent and interacting factors: According to Ohio State (2015), **"**This problem is associated with chilling injury during ear formation and more evident in certain sweet corn genetic backgrounds. Low temperatures disrupt normal kernel development resulting in anomalous ear growth." (From Ohio State Univ. 2015). We agree that low temperatures mentioned in the last section may have contributed; however, we wonder if that the high winds of July 7, 2016 which followed good growing conditions were an overriding factor as well as the loss of the primary ear. As mentioned above, the problem with this hypothesis is that these extreme winds affected Nebraska and parts of Iowa but did not likely affect other states where the symptoms are reported to have occurred.

Potential consequences: Reduced yield per plant and depending on extent, over the entire field.

Multiple ears per node

Symptoms: Multiple ears per node

Based on our observations the primary ear was aborted in most if not all situations. Thus, these ears are predominantly secondary ears.

Incidence: Varied depending on location and hybrid.

Developmental timing: Vegetative, pre-tassel development stages.

Potential stress agent and interacting factors: In almost all cases where we've seen this, the primary ear never developed (See Elmore and Abendroth, 2006). Our hypothesis is that when the primary ear is aborted or fails to develop, apical dominance is lost and that loss triggered the secondary node to develop. We know that the ear shank is a 'mini stalk' and when apical dominance is lost or weakened, ears can develop on shank nodes… thus multiple ears per node.

Potential Stress Agent and Interacting Factors: In almost all cases where we've seen this, the primary ear never developed. (Elmore & Abendroth, 2006). Our hypothesis is that when the primary ear was aborted or failed to develop, apical dominance was lost and that loss triggered development of the secondary node. As Bob Nielsen (Purdue) stated in an email, "We know from past experiences with this phenomenon that some hybrids seem particularly prone to "releasing" the normal hormonal suppression of the axillary meristems on the ear shank when the primary is damaged or fails to successfully pollinate." We know that the ear shank is a "mini stalk" and when apical dominance is lost or weakened, ears can develop on shank nodes… thus, multiple ears per node.

The question is why? Temperature extremes earlier in the season could be responsible as suggested above. Certainly stress like the wind we had could disrupt the primary ear. But, in 2006, there were clear hybrid differences and no clear stress agent or event so it's likely a hybrid-specific stress response. The earlier cool spell followed by good growing conditions coupled with the strong winds on July 7 could have damaged the primary ear. But as before, did this happen in all the other states affected too?

Potential consequences: Reduced yield per plant and depending on extent, over the entire field.

What we've done and intend to do:

1. Whole plant samples were collected from affected and unaffected fields across central and eastern Nebraska. In addition, information is currently being compiled from weather data and management practices from each site to isolate the primary factors that led to ear development issues.
2. We are currently evaluating individual plants for the presence of primary and secondary ears, ear development type, ear height, plant location, stalk and shank internode lengths, plant orientation, cob diameters, stalk fractures, root growth, and yield.
3. Keep you up to date on our findings.

Preliminary Overriding conclusions

1. The main observation that seems to cut across all these symptoms is the loss of the primary ear node.
2. The issues all appear to be hybrid specific. The hybrids affected reportedly are often offensive, race-horse hybrids.
3. The widespread nature of the symptoms suggest a weather related stress event interacting with genetics.

References:

Abendroth et al. 2011. Corn growth and development. Iowa State Univ. Extension. https://store.extension.iastate.edu/product/Corn-Growth-and-Development

Aldrich, S.R., W.O. Scott, and R.G. Hoeft. 1986. Modern corn production. A&L Publications, Champaign, IL.

Elmore, R. and L. Abendroth. 2006. Multiple ears per node: Iowa 2006 situation & hypothesis. http://crops.extension.iastate.edu/corn/production/management/mid/multiple.html

Elmore, R., J. Rees, J. McMechan, T. Jackson-Ziems, and T. Hoegemeyer. 2016. Corn ear formation issues likely correlated with the loss of the primary ear node. Univ. Of Nebraska Extension. CropWatch. 19 August, 2016. http://cropwatch.unl.edu/2016/corn-ear-formation-issues-likely-correlated-loss-primary-ear-node

Ohio State University. 2015. Troubleshooting abnormal ears. http://u.osu.edu/mastercorn/bar-bell-and-bear-claw/

Nielsen, R. L. 2006. A problem with bouquets. Purdue Extension.https://www.agry.purdue.edu/ext/corn/news/articles.06/Bouquets-0912.html

Nielsen, R.L. 2012. Short Husks and Exposed Ears, R.L. (Bob) Nielsen, Purdue University, https://www.agry.purdue.edu/ext/corn/news/timeless/EarHusks.html

Nebraska Extension On-Farm Research Network

Laura Thompson, UNL Extension Educator
Keith Glewen, UNL Extension Educator

The Nebraska On-Farm Research Network is a statewide program where growers and industry representatives take an active role in the research. On-farm research can provide a great avenue to accelerate learning about topics that impact farm productivity and profitability. Research done on farms can be directly applicable to a farming operation. The Nebraska On-Farm Research Network has been working with farmers, consultants, and industry since 1989.

Results of 2016 studies will be shared at 4 locations in February 2017. Thanks to support from the Nebraska Corn Board, Nebraska Soybean Board, and Nebraska Corn Growers Association, there is no cost to attend. Lunch is included; please pre-register at least 2 days in advance for meal planning purposes by email, onfarm@unl.edu or phone, 402-624-8000. Plan to join us!

February 20, 2017 - Agricultural Research and Development Center, near Mead – 9 A.M. to 4:30 P.M.

February 21, 2017 - Lifelong Learning Center, Northeast Community College, Norfolk – 9 A.M. to 4:30 P.M.

February 23, 2017 - West Central Research and Extension Center, North Platte – 12 noon to 4:30 P.M.

February 27, 2017 - Hall County Ext. Office, College Park Campus, Grand Island – 9 A.M. to 4:30 P.M.

Alliance - **new location this year - date and location TBD. Call the Box Butte Extension Office for details at 308-762-5616**

10 Steps for On-Farm Research Success

Many agriculture producers routinely do some form of on-farm testing in their fields. These tests often consist of side-by-side plots, or split-planter variety trials, or include a non-treated check strip. But, in order to provide **meaningful information** from which to make future **decisions with confidence**, proper consideration at all phases of planning and execution of the trial are important. This article outlines 10 steps to achieve success in on-farm research trials.

1) Ask the Right Question

What do you want to find out? It may seem obvious, but taking time to state your question clearly will help you stay on the right track. Don't make your question overly complex; try to focus on one practice that you want to compare with your standard practice. Your question might be: "Does applying a fungicide on corn at V5 increase yield?" or, "What is the economic optimum seeding rate for soybeans?" When choosing your question consider practices that are of importance to the long term sustainability and profitability of your farming operation.

2) Determine What Data You Need To Collect

Can your question can be answered with data you can readily collect? If your question is "Does applying a foliar fungicide on corn at V5 increase yield?" you will need to be able to accurately measure yield with a weigh wagon or a well-calibrated yield monitor. Are there other measurements you could take that would help you better understand your results? Maybe you would be interested in knowing if the fungicide application increased stalk health. This will require additional measurements and observations prior to harvest, like a stalk "pinch test" or "push test". You may also be interested in documenting any differences in amount of disease at a particular time during the growing season. Consider the research question, "Does starter fertilizer result in increased yield?" In this case pre-season soil samples would be beneficial to establish the base fertility for the field. This information will be valuable when trying to make sense of your results.

3) Consider Field History and Variation

Productivity of a field can vary significantly due to soil type, slope, previous crop and fertilizer history, etc. For example, one portion of the field may have more clay and lower elevation, which in a wet year results in reduced yields and drowned out areas (Figure 1). Many producers like to split fields in half; however this soil-type variability, if not accounted for, can influence the results of your study. Steps 4 and 5 address how to account for this variability.

Figure 1: Field productivity variability shown by yield data. Soils with higher clay contents on the west-(left) side of the field had reduced yield.

4) Replicate

Let's go back to our original question "Does applying a fungicide on corn at V5 increase yield?" To answer this question, we could compare 2 practices: 1. An untreated check strip and 2. A fungicide-treated strip. Sets of these two treatment strips should be **replicated** or repeated multiple times throughout the field, usually a minimum of 5 times. Replication provides more data across a field, improving your confidence in the yield results. However, replication alone does not minimize field variability – it simply helps account for it. Consider the field in Figure 1. If your fungicide treatment is always placed on the east (right) side, and the field is more productive as you move west to east, the results will favor the treatment on the east - (the fungicide treatment). If the fungicide treated area produces higher yields, you will not know if the yield increase is due to soil conditions or if the fungicide truly resulted in a yield increase. This issue is addressed in step 5, randomization.

5) Randomize

Randomization is used to assign the placement of each treatment within a block to eliminate preference for one treatment over another. The assignment is made randomly, such as by flipping a coin. Figure 2 depicts a properly laid out experiment featuring our two treatments. This diagram has both replication and randomization.

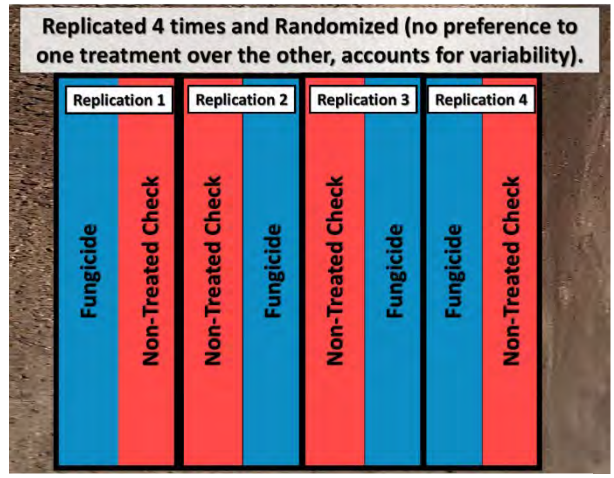


Figure 2: A randomized, replicated plot layout for testing two treatments – in this case a fungicide and non-treated check (your standard practice).

The diagram in Figure 3 shows the same principles for a scenario looking at 3 or 4 treatments, in this case soybean seeding rates.

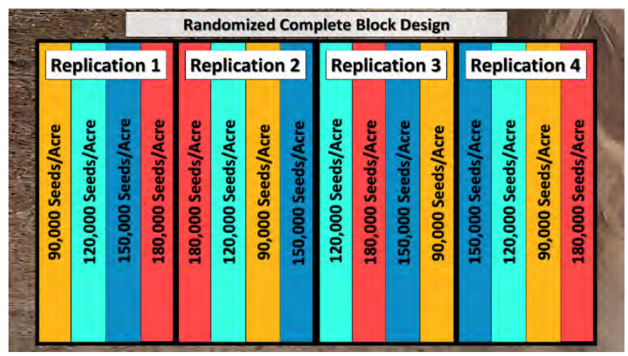


Figure 3: A randomized, replicated plot layout for testing four soybean seeding rates.

6) Collect Data

Data collection is a key element of on-farm research. You are probably already collecting a lot of the information you need, however additional data collection may be beneficial. The following list of information often useful for understanding on-farm research data:

- Background information: previous crop, planting and harvest date, varieties/hybrids used, seeding rate, plant populations at harvest, chemical applications, soil types, and rainfall/irrigation.
- Treatment strip locations: flag or log strip boundaries with GPS or document with as-applied data.
- Observations: additional data may be collected such as stand counts (Figure 5), stalk strength, soil samples, tissue samples, disease/insect/weed pressure, storm damage and more.

- Photos: take pictures to help document and remember what you saw. Cell phones often have good cameras which make this easy to do and GPS location of the photo can also be logged.
- Aerial imagery: This can be obtained in a variety of ways, from satellite to manned or unmanned aircraft.
- Yield: Review your research design prior to harvesting. Yield data can be recorded using a calibrated yield monitor or weigh wagon.

  There are a number of apps that will allow you to collect and organize records, take pictures, and store GPS locations of your observations.

7) Analyze Results

After gathering harvest data, it's time to analyze the results. If the trial was set up using replication and randomization as we suggest, statistical tools can be used to determine if differences between the treatments. Using statistics to analyze the data will allow you to have confidence in your results and help you determine if you would get similar results in another field or year. We at the Nebraska Extension On-Farm Research Network are available to conduct statistical analyses of your results.

8) Use Precision Ag Tools

A number of precision ag tools can make conducting on-farm research very simple. Inputs can be distributed across the field at different rates and as-applied data can be tracked. At harvest, yield for each strip can be recorded using a yield monitor. It is important to make sure that the yield monitor is accurately calibrated to provide accurate yield estimates. Detailed information on yield monitor calibration is available from Nebraska Extension. Yield monitor data should also be cleaned or filtered to remove errors that occur during data collection. Free USDA software such as Yield Editor is available to help accomplish this.

If yield is recorded using a yield monitor, it is possible to perform additional spatial analysis which can provide valuable information. For example, using computer software you could analyze how optimal seeding rate may vary by soil type within the field. Extension Educators and Specialists working with the Nebraska On-Farm Research Network can also aid in conducting these analyses.

9) Draw Conclusions

Once data has been analyzed, you can draw conclusions and use the results to inform future production practices. With only one year and one location of data, caution should still be used. Your results will be more reliable if you have data from multiple years or locations – for example, convince a neighbor or a client to do the same comparisons! When making management decisions, consider the economic impact of the research results. Perhaps the fungicide treatment increased yield, but the treatment did not pay for itself.

10) Share and Learn From Others

A great way to increase confidence in your results is to pool your data with others who have conducted similar on-farm research. The Nebraska On-Farm Research Network provides an opportunity for you to add your data to a larger pool of research and discuss results with others at an annual results update meeting. You can also read about what others tested and learned by viewing Nebraska On-Farm Research results online at: http://cropwatch.unl.edu/farmresearch/resultshome.

When properly executed, on-farm research experiments will allow you to **generate your own science-based information** that is **highly relevant** to a farming operation.

Additional Resources

The Nebraska On-Farm Research Network has produced a number of excellent resources that will aid farmers and industry representatives in designing and carrying out research studies.

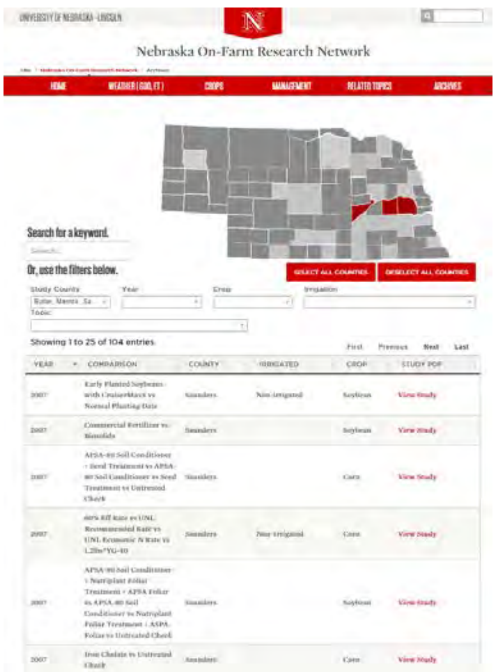
Grower's Guide to On-Farm Research

This interactive guide will provide instructions on basic concepts such as randomization and replication that will help you get reliable results from your on-farm research. Common pitfalls to avoid and resources for further information are included. If you are going to do experimenting on your farm, make it worth your time! Plan and design a correct experiment.

http://go.unl.edu/growersguide

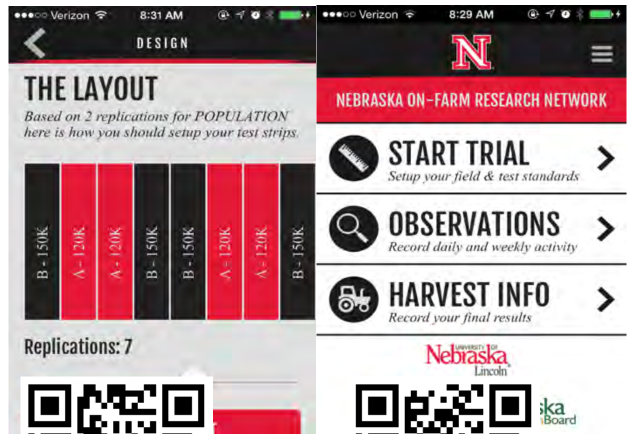
On-Farm Research Results Finder

Make informed management decisions by browsing research conducted with the Nebraska On-Farm Research Network. A database of 800+ studies conducted over 26 years is now available on the Nebraska On-Farm Research website. This tool allows users to filter study results by county, year, crop, irrigation status, and topic. Visit www.cropwatch.unl.edu/farmresearch to learn more!



Nebraska On-Farm Research App

The app released in April 2015 enables users to create treatment strips and develop a plot layout. Once the study layout is created, the user can input observations such as stand counts, insect, weed, and disease pressure, irrigation totals, and more. At the conclusion of the season, yield data can be calculated and recorded. All recorded information can be emailed to yourself and the Nebraska On-Farm Research Network.



Android:
http://go.unl.edu/onfarmappandroid

Apple:
http://go.unl.edu/onfarmappiphone

Nebraska Extension's On Farm Research Network exists to help in planning, conducting, analyzing, and sharing valuable on-farm research data. For more resources or to get started with the on-farm research network, visit: http://cropwatch.unl.edu/farmresearch/ , follow us on twitter @OnFarmResearch, or email: OnFarm@unl.edu.

Crop Insect Resistance Issues in Nebraska

Robert Wright, Julie Peterson, Thomas Hunt, Jeff Bradshaw & Justin McMechan
Extension Entomology Specialists

Several recent studies have highlighted the status of insect resistance to insecticides and Bt toxins in crop production systems in Nebraska. This article will provide an overview of recent results.

Corn rootworms

Bt corn hybrids

Western corn rootworm larvae have exhibited resistance to several of the four Bt toxins currently available in Bt corn hybrids. Recent research published by Wangila et al. (2015) documents several populations in Nebraska with reduced susceptibility to Cry3Bb1 and mCry3A Bt toxins based on laboratory whole-plant bioassays. Similar studies in Iowa have documented reduced susceptibility to these two toxins as well as Cry34/35Ab1 (Gassmann et al. 2016).

Nebraska Extension Entomologists recommend use of crop rotation on farms periodically to reduce densities of rootworms. Lower densities of rootworms will reduce the impact of possible reduced susceptibility to Bt toxins currently available in Bt rootworm corn hybrids. Seed corn companies have made available Bt hybrids with two Bt proteins active against rootworms. These pyramided hybrids are desirable from a corn rootworm efficacy perspective as well as a resistance management perspective.

Bifenthrin

In parts of southwest Nebraska and southwest Kansas insecticides containing the pyrethroid, bifenthrin, (e.g. Capture LFR, Brigade 2EC and others) as the active ingredient have been frequently used for many years on corn, as a planting time application for corn rootworm larvae, and as a foliar application for control of corn rootworm adults, western bean cutworm and spider mites. A recent study by UNL and KSU Entomologists (Pereira et al. 2016) documented reduced susceptibility of adult western corn rootworms in southwest Nebraska and southwest Kansas, compared to populations of adults from eastern Nebraska and states to the east.

Avoiding repeated use of the same insecticide active ingredient in a field during the growing season, or over multiple growing seasons is a good insecticide resistance strategy. Rotation among insecticide modes of action is also beneficial to minimize the development of pest resistance. See NebGuide G2066, or www.irac-online.org for more information on which insecticides belong to different mode of action classes.

Western bean cutworm

Bt corn hybrids

Field reports from the western Great Plains over the past several years have indicated reduced efficacy against western bean cutworm larvae in Bt corn hybrids expressing the Cry1F Bt protein (e.g. Herculex I, SmartStax, and others). Without controlled laboratory studies it is not possible to know if these observations are because of increased western bean cutworm densities the last few years, reduced susceptibility to Cry1F, or both. Recent laboratory studies by DuPont Pioneer scientists indicate that LC_{50} (dose required to kill 50% of test population) levels for Cry1F were increased 5.2X when comparing populations collected during 2013-2014 to those from 2003-2004 (Ostrem et al. 2016).

Bifenthrin

Similar to the situation described above for the western corn rootworm, there are concerns of possible changes in susceptibility to bifenthrin in western bean cutworm larvae in areas of Nebraska where bifenthrin has been frequently used in the past. Research has begun at UNL to evaluate this possibility.

References cited

Ostrem, J. S., Z. Pan, J. L. Flexner, E. Owens, R. Binning and L. S. Higgins. 2016. Monitoring susceptibility of western bean cutworm (Lepidoptera: Noctuidae) field populations to *Bacillus thuringiensis* Cry 1F protein. J. Econ. Entomology 109(2): 847-853.

Pereira, A. E., H. Wang, S. N. Zukoff, L. J. Meinke, B. W. French, and B. Siegfried. 2015. Evidence of field evolved resistance to bifenthrin in western corn rootworm (*Diabrotica virgifera virgifera* LeConte) populations in Western Nebraska and Kansas. PLoS ONE10(11):e0142299.

Wangila, D. S., A. J. Gassmann, J. L. Petzold-Maxwell, B. W. French and L. J. Meinke. 2015. Susceptibility of Nebraska western corn rootworm (Coleoptera:Chrysomelidae) populations to Bt corn events. J. Econ. Entomol. 108(2): 742-751.

Wright, Robert J. 2016. Insecticide Mode of Action Classification for Nebraska Field Crops, NebGuide G2066, Nebraska Extension, http://extensionpubs.unl.edu/publication/9000016367675/insecticide-mode-of-action-classification-for-nebraska-field-crops/

Gassmann, A. J., Shrestha, R. B., Jakka, S. R. K., Dunbar, M. W., Clifton, E. H, Paolino, A. R., Ingber, D. A., French, B. W., Masloski, K. E., Dounda, J. W., St Clair, C. R. 2016. Evidence of Resistance to Cry34/35Ab1 Corn by Western Corn Rootworm (Coleoptera: Chrysomelidae): Root Injury in the Field and Larval Survival in Plant-Based Bioassays. J. Econ. Entomology 109(4): 1872-1880.

Susceptibility of Nebraska Western Corn Rootworm (Coleoptera: Chrysomelidae) Populations to Bt Corn Events

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J. Econ. Entomol. 108(2): 742–751 (2015); DOI: 10.1093/jee/tou063

ABSTRACT Transgenic plants have been widely adopted by growers to manage the western corn rootworm, *Diabrotica virgifera virgifera* LeConte, in field corn. Because of reduced efficacy in some Nebraska fields after repeated use of Cry3Bb1-expressing hybrids, single plant bioassays were conducted in 2012 and 2013 to characterize the susceptibility of western corn rootworm populations to the rootworm-active proteins Cry3Bb1, mCry3A, and Cry34/35Ab1. Results demonstrate that there are heritable differences in susceptibility of Nebraska western corn rootworm populations to rootworm-active Bt traits. Proportional survival and corrected survival data coupled with field histories collectively support the conclusion that a level of field resistance to Cry3Bb1 has evolved in some Nebraska populations in response to selection pressure and that cross-resistance exists between Cry3Bb1 and mCry3A. There was no apparent cross-resistance between Cry34/35Ab1 and either Cry3Bb1 or mCry3A. The potential implications of these results on current and future corn rootworm management strategies are discussed.

KEY WORDS genetically modified crop, evolution, resistance management, *Bacillus thuringiensis*, *Diabrotica virgifera virgifera*

Introduction

Corn rootworms (*Diabrotica* spp.) are economically important pests of field corn in the U.S. Corn Belt. The economic impact of this pest complex to U.S. farmers has been estimated at US$1 billion in yield loss and treatment costs annually (Rice 2004, Sappington et al. 2006). The most significant *Diabrotica* species in the Corn Belt region is the western corn rootworm, *Diabrotica virgifera virgifera* LeConte (Gray et al. 2009). Larval feeding on corn roots by this insect pest can lead to root injury, decreased plant growth, and reduced yield (Godfrey et al. 1993, Gray and Steffey 1998, Urías-López and Meinke 2001). The western corn rootworm was not considered a serious pest of corn until the late 1920s–1940s, when it became a problem in northwestern Kansas and southwestern Nebraska (Bare 1930, Tate and Bare 1946, Bryson et al. 1953). Contributing factors included planting of continuous corn, made possible by development of irrigation systems and the introduction of synthetic fertilizer (Meinke et al. 2009). This facilitated an increase in western corn rootworm densities and the initiation of range expansion that now covers many corn growing areas east of the Rocky Mountain region of North America (Gray et al. 2009, Meinke et al. 2009). From the 1950s to 1990s, a large market developed around the manufacture and the subsequent use of soil-applied or foliar-applied insecticides as standard western corn rootworm management tactics in continuous corn (Levine and Oloumi-Sadeghi 1991).

Recent advancements in biotechnology led to the development of transgenic crops that produce insecticidal proteins derived from the bacterium *Bacillus thuringiensis* (Bt). The rootworm-active Bt toxin Cry3Bb1 was registered and introduced commercially in corn hybrids during 2003. Since 2003, the Bt toxins Cry34/35Ab1 (2005), mCry3A (2006), and eCry3.1Ab (2012), which target *Diabrotica* species, were also registered in the United States (EPA 2003, 2005, 2007, 2012a,b, Vaughn et al. 2005, Gatehouse 2008, Tabashnik et al. 2009). Transgenic Bt corn hybrids have been widely adopted by growers and largely replaced soil and foliar insecticides as the primary tactics used in continuous corn for management of corn rootworms. Rootworm-active Bt pyramids were granted registrations more recently in the United States (i.e., Cry3Bb1 and Cry34/35Ab1 [2009], mCry3A and Cry34/35Ab1 [2011], mCry3A and eCry3.1Ab [2013]; Environmental Protection Agency [EPA] 2012a, 2013) and are gradually replacing single Bt trait market share in the U.S. Corn Belt.

All registered Bt events that are active against the western corn rootworm are considered less than high dose, as defined by the EPA (i.e., these Bt events fail to

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PLOS | ONE

RESEARCH ARTICLE

Evidence of Field-Evolved Resistance to Bifenthrin in Western Corn Rootworm (*Diabrotica virgifera virgifera* LeConte) Populations in Western Nebraska and Kansas

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Citation: Pereira AE, Wang H, Zukoff SN, Meinke LJ, French BW, Siegfried BD (2015) Evidence of Field-Evolved Resistance to Bifenthrin in Western Corn Rootworm (*Diabrotica virgifera virgifera* LeConte) Populations in Western Nebraska and Kansas. PLoS ONE 10(11): e0142299. doi:10.1371/journal.pone.0142299

Editor: Mario Soberón, Instituto de Biotecnología, Universidad Nacional Autónoma de México, MEXICO

Received: August 18, 2015

Accepted: October 20, 2015

Published: November 13, 2015

Data Availability Statement: All the data are available in the tables and figures.

Funding: This work was supported by: 1- Monsanto Corn Rootworm Knowledge Grant (No. 69292): The recipients were BDS and LJM. Monsanto staff provided some field insect collections. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. 2- Department of Entomology/Institute of Agriculture and Natural Resources: The recipient was AEP as an assistantship for the PhD program.

Abstract

Pyrethroid insecticides have been used to control larvae or adults of the western corn rootworm (WCR), *Diabrotica virgifera virgifera* LeConte, a key pest of field corn in the United States. In response to reports of reduced efficacy of pyrethroids in WCR management programs in southwestern areas of Nebraska and Kansas the present research was designed to establish a baseline of susceptibility to the pyrethroid insecticide, bifenthrin, using susceptible laboratory populations and to compare this baseline with susceptibility of field populations. Concentration-response bioassays were performed to estimate the baseline susceptibility. From the baseline data, a diagnostic concentration (LC_{99}) was determined and used to test adults of both laboratory and field populations. Larval susceptibility was also tested using both laboratory and field populations. Significant differences were recorded in adult and larval susceptibility among WCR field and laboratory populations. The highest LC_{50} for WCR adults was observed in populations from Keith 2 and Chase Counties, NE, with LC_{50}s of 2.2 and 1.38 μg/vial, respectively, and Finney County 1, KS, with 1.43 μg/vial, as compared to a laboratory non-diapause population (0.24 μg/vial). For larvae, significant differences between WCR field and laboratory populations were also recorded. Significant differences in mortalities at the diagnostic bifenthrin concentration (LC_{99}) were observed among WCR adult populations with western Corn Belt populations exhibiting lower susceptibility to bifenthrin, especially in southwestern Nebraska and southwestern Kansas. This study provides evidence that resistance to bifenthrin is evolving in field populations that have been exposed for multiple years to pyrethroid insecticides. Implications to sustainable rootworm management are discussed.

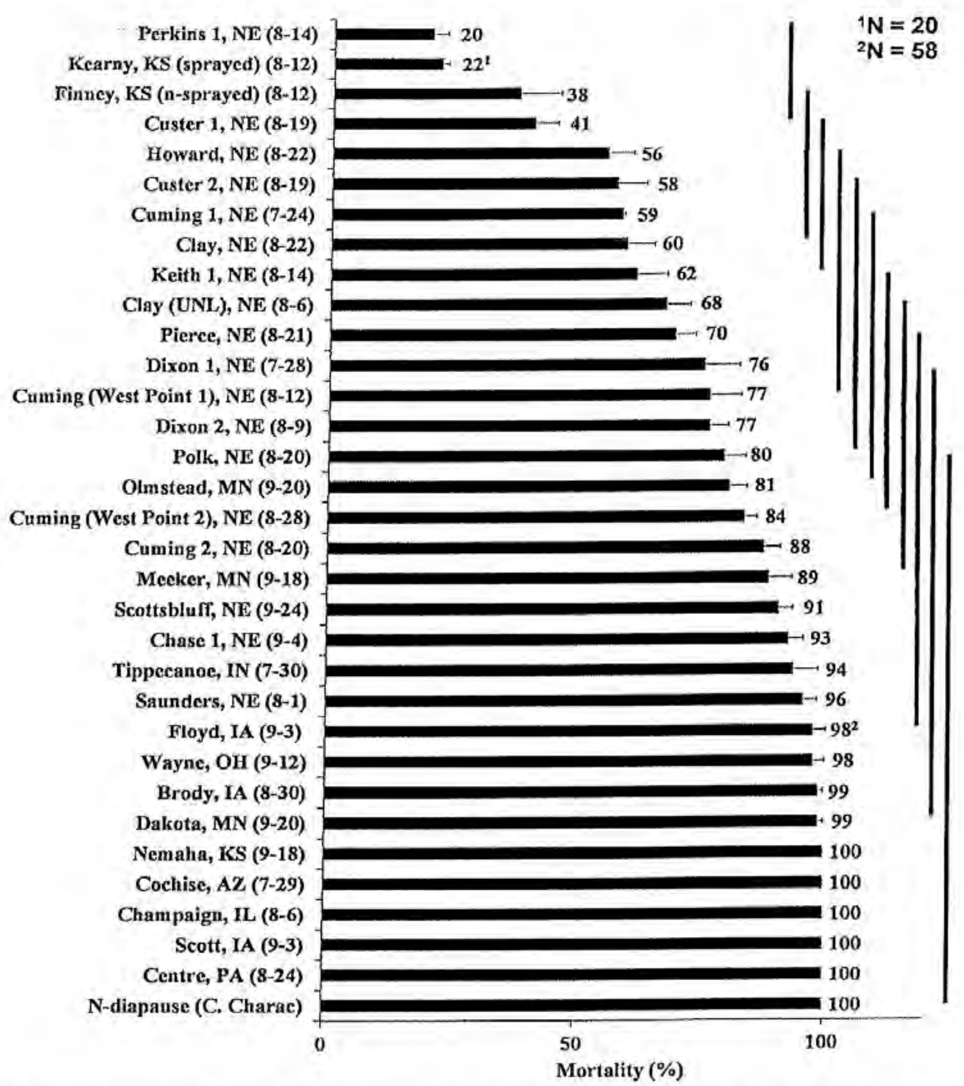

Fig 2. WCR adult mortalities of 32 different field populations from counties throughout the U.S. Corn Belt collected in 2013 (collection date) plus a susceptible laboratory population (non-diapause, Crop Characteristics®) after exposure to diagnostic concentration of bifenthrin (0.77 µg of bifenthrin/vial) corresponding to the LC_{99} calculated from 10 WCR lab populations. Means and standard errors are result of 10 replicates (vial), with 10 beetles per vial (unless otherwise stated). Means and standard errors are the result of 10 replicates (vials) with 10 beetles per vial (unless otherwise stated). Population means encompassed by the same solid vertical bars are not significantly different and were compared by least squared means with Tukey adjustment at $p \leq 0.05$ using PROC GLIMMIX in SAS 9.3.

doi:10.1371/journal.pone.0142299.g002

Journal of Economic Entomology, 109(2), 2016, 847–853
doi: 10.1093/jee/tov383
Advance Access Publication Date: 9 January 2016
Insecticide Resistance and Resistance Management
Research article

Monitoring Susceptibility of Western Bean Cutworm (Lepidoptera: Noctuidae) Field Populations to *Bacillus thuringiensis* Cry1F Protein

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Received 22 September 2015; Accepted 27 November 2015

Abstract

Zea mays L. (maize) hybrids producing the Cry1F protein from *Bacillus thuringiensis* were first commercialized in the United States in 2003. These products demonstrated varying levels of moderate control, but not immunity to *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae) (western bean cutworm). Susceptibility of western bean cutworm to Cry1F protein was assessed in field populations collected in the mid- and western United States in 2003, 2004, 2013, and 2014 using diet bioassay. A meta-analysis of 32 western bean cutworm field collections assessed for susceptibility to Cry1F was conducted to investigate changes in susceptibility over time. Based on meta-analysis results, these data suggest a 5.2-fold increase in median lethal concentration (LC_{50}) response to Cry1F in the 2013–2014 populations compared with collections that were assessed 10 yr earlier. Widespread use of Cry1F-producing maize hybrids over the past 10 yr may have contributed to favoring western bean cutworm populations with tolerance to the Cry1F protein.

Key words: maize pest, field collection, bioassay, tolerance, resistance

Western bean cutworm, *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae), is a historic pest of dryland beans, *Phaseolus vulgaris* L., and sporadic pest of maize, *Zea mays* L., in the western Corn Belt of the United States (Douglass et al. 1957, Blickenstaff and Jolley 1982). Its eastward expansion across the United States was documented in Minnesota and Iowa in 1999 and 2000, Missouri, Illinois, and Wisconsin in 2004, reaching Indiana, Michigan, and Ohio in 2006, and continuing into Ontario, Pennsylvania, New York, and Quebec by 2008 and 2009 (Rice 2000, Michel et al. 2010). Western bean cutworm has been recorded in multiple states in the United States as well as in Ontario and Quebec, Canada (O'Rourke and Hutchison 2000, Dorhout and Rice 2004, Jesse et al. 2010, Michel et al. 2010, Paula-Moraes et al. 2013). The reasons for the eastern expansion of this pest are unknown, but possibilities include reduced tillage that could increase survival of overwintering larvae, climate change (Jesse et al. 2010), and widespread use of transgenic corn hybrids that produce insecticidal proteins, which reduce intraguild feeding competition from other ear-feeding pests, such as *Helicoverpa zea* (Boddie) that compete with western bean cutworm (Dorhout and Rice 2010, Jesse et al. 2010). The long-term impact of the eastern expansion of the western bean cutworm is yet to be realized. Speculation on whether natural mortality factors such as pathogens, predators, and parasitoids eventually catch up with western bean cutworm as it moves eastward has been noted (Dorhout and Rice 2004).

Western bean cutworm is a univoltine pest in the United States; it overwinters as prepupae beneath the soil surface, and completes development beginning in early spring the following year. As a pest of maize, oviposition and egg-hatch are generally synchronized with maize anthesis, and newly hatched larvae feed on the tassel, silk, soft ear tissue, or pollen if it is available. Later instars typically move to the ear and are found feeding on developing kernels. Larvae are not cannibalistic, and several larvae can be found damaging a single ear.

Transgenic maize hybrids developed for control of Lepidopteran pests have varying levels of control of western bean cutworm. Eichenseer et al. (2008) demonstrated that Bt maize hybrids expressing the Cry1F protein from *Bacillus thuringiensis*, commercialized in 2003, had less damage than non-Bt hybrids, although the Cry1F plants were not immune to damage. Baseline susceptibility studies conducted in the early 2000s suggested that western bean cutworm is moderately susceptible to purified Cry1F protein

Emerging and invasive pests

**Justin McMechan, Extension Crop Protection and Cropping Systems Specialist,
Eastern Nebraska Research & Extension Center, Robert Wright, Extension Entomologist, Lincoln,
& Tom Hunt, Extension Entomologist, UNL Haskell Ag Lab, Concord, NE**

Japanese Beetle

The distribution of Japanese beetle in Nebraska has been increasing over the last few years and they are more frequently found in corn and soybean fields. Yield losses in soybeans are primarily attributed to defoliation by skeletonizing leaves and leaving only the leaf veins. Japanese beetle will defoliate corn leaves, however, yield losses are typically associated with silk clipping.

In soybeans, insecticide applications are recommended when leaf defoliation exceeds 30% during vegetative and 20% during the reproductive stage. Additional information can be found in Managing Soybean Defoliators, NebGuide G2259.

The University of Illinois Extension recommends that corn ears with three or more Japanese beetles or silks clipped to less than ½ inch with pollination at less than 50% completion should consider an insecticide application. Japanese beetles are not equally distributed in fields, with the highest populations occurring at the field margins. Information on insecticide options is available in the 2016 Guide to Weed Management from the University of Nebraska.

Corn Aphids

Post-tassel scouting of corn fields this year revealed high populations of aphids in parts of Nebraska. Corn fields can be infested with a number of different aphid species such as the bird-cherry oat aphid, English grain aphid and greenbug. There is relatively little research on the impact of corn aphids other than the corn leaf aphid.

Corn leaf aphid infestations are typically found in the whorl of corn plants prior to tasseling. The economic impact of corn leaf aphid is primarily attributed to the removal of photosynthates and the secretion of honeydew which reduces plant photosynthesis. Scouting for corn leaf aphid in corn fields should begin three weeks prior to tasseling. Krupke et al. (2016) suggests an insecticide application when aphid populations exceed 15 aphids/plant prior to tasseling with corn plants under water stress. Post-tassel application should be made if aphids cover 50% of tassels prior to 50% pollination with corn plants under water stress. The presence and abundance of predators and parasitoids should be considered prior to applying a pesticide.

High populations of aphids after pollination have raised questions about late season insecticide applications. Potter and Ostlie (2015) identified several complicating factors that make it difficult to determine the economic returns of these treatments. These complications are due to the unpredictable nature of corn leaf aphids which may move from a field in mass if the host plants become unsuitable. In some cases, aphid infestations are a sign of other crop stressors that limit crop yields that are not remediated by insecticide applications. In addition, the height of corn plants at the time of application may reduce coverage allowing for rapid reinfestation of aphids as spray residual declines.

Potter and Ostlie (2015) indicated that fungicides and insecticides applied earlier in the season may increase aphid numbers. Fungicides could reduce the infection of beneficial fungi and insecticides can remove beneficial predators and parasitic wasps allowing aphid populations to build rapidly.

Soybean defoliators

In many areas of the state we had a mix of insects feeding on soybeans at different times during the growing. These include grassshoppers, adult Japanese beetles, bean leaf beetles, and several caterpillars. In north central Kansas and south central Nebraska we had reports of green cloverworms damaging soybeans in August. Also in August we had reports of yellow woolly bear caterpillars defoliating soybeans in south central and southeastern Nebraska.

General guidelines can be used for defoliating insects that lack species-specific thresholds or when two or more different defoliating species are present and are expected to continue feeding. In vegetative (pre-flowering) stages, consider treatment if the insects are present and feeding, and defoliation will exceed 30 percent. In pod-forming or pod-filling stages, consider treatment if the insects are present and defoliation will exceed 20 percent.

These percentages can vary 5-10 percent, according to the stage or type of insect(s) present, environmental conditions, the specific stage of the soybean, and the size and condition of the canopy. For example, a larger canopy (leaf area) can tolerate more defoliation than a smaller canopy due to the greater leaf area in the larger canopy. Experience will have to be your guide when using these thresholds.
See Managing Soybean Defoliators, NebGuide G2259 for more information.

Millipedes and sowbugs in soybeans

Periodically we have received reports of millipedes and sowbugs (also known as pillbugs) damaging germinating or seedling soybeans. Typically, these reports are from fields with high levels of corn residue, and in years that are cool and moist, which delay soybean growth and encourage feeding by these organisms at the soil surface.

See Whitworth et al. (2008) and http://cropwatch.unl.edu/millipedes-feeding-soybeans-unl-cropwatch-may-25-2012

Millipedes and sowbugs have been reported damaging cotyledons and stems prior to emergence of the seedling, and in some cases killing the seedling. In many cases these fields were planted into corn residue from last year. Some of the damaged fields had a neonicotinoid seed treatment which apparently did not provide high levels of control. This is not surprising as millipedes or sowbugs are not listed as a pest controlled by neonicotinoid seed treatments (e.g. Cruiser, Poncho, Gaucho).

Millipedes and sowbugs are encouraged by high levels of organic matter on the soil surface. It is possible the mild winter has also led to higher than usual numbers. Their usual feeding habits are on decaying organic matter.

There is little information on chemical control efficacy against millipedes or sowbugs in crops. In at least one case, multiple applications of a pyrethroid insecticide had little apparent effect. Usually millipedes and sowbugs move deeper in the soil as soil surface temperatures increase and soil surface moisture decreases.

When damage is found, probably the main decision to make is whether there is enough damage to warrant replanting.

Stink Bugs in Corn and Soybeans

Over the past 15 years there has been a trend of increasing stink bug populations in Nebraska soybean and reproductive stage corn.

There are three stink bug species we typically see in Nebraska corn and soybean, the green stink bug, brown stink bug, and red-shouldered stink bug. All are shield-shaped as nymphs and adults and have piercing sucking mouthparts. Green stink bugs do not overwinter in Nebraska, but migrate north in late spring to early summer. Brown and red-shouldered stinkbugs appear to overwinter in Nebraska.

Stink bugs damage reproductive stage corn by piercing the husk and feeding on the developing kernels from kernel formation through milk stage, although they can feed through the hard dough stage. Damage appears as missing or shrunken kernels. Severe damage causes ears to curve. Treatment thresholds are 1 stink bug per 4 plants prior to pollination, and 1 stink bug per 2 plants after pollination up to early dough stage.

Stink bugs injure soybeans by puncturing various plant parts and extracting plant fluids. They prefer young tender growth and developing seeds, causing deformation and abortion of seeds and pods and predisposing the ear various pathogens. Injury can also cause delayed maturity and deformed leaf growth. Yield and quality losses depend on when the bugs injure soybean. Treatment thresholds are 1 stink bug per row-foot during the reproductive stages, and if using a sweep net, 3.6 stink bugs per 15 sweeps (i.e., 0.25 bugs/sweep).

In corn and soybean injury often appears first on field borders as the stink bugs move into the field. With time the stink bugs can move throughout the field.

References

R. Jeff Whitworth, Phil Sloderbeck, and Holly Davis, 2008. Pillbugs, Kansas State University Agricultural Experiment Station and Cooperative Extension Service MF-2855

Krupke, C. H., J. L. Obermeyer, and L. W. Bledsoe. 2016. Corn insect control recommendations. Purdue University Extension. E-219-W.

Ohnesorg, W. J. and T. E. Hunt. 2015. Managing soybean defoliators. University of Nebraska-Lincoln Extension. NebGuide G2259. http://extensionpubs.unl.edu/publication/9000016369652/managing-soybean-defoliators/

Potter, B. and K. Ostlie. 2015. Aphids in corn: the dilemma of post-pollination infestations. Minnesota Crop News. University of Minnesota Extension. http://blog-crop-news.extension.umn.edu/2015/08/aphids-in-corn-dilemma-of-post.html

Hunt, T., B. Wright, and K. Jarvi. 2014. Stink Bugs Reported in Corn and Soybeans. UNL CropWatch, http://cropwatch.unl.edu/stink-bugs-reported-corn-and-soybeans

Western Bean Cutworm Update

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Western bean cutworm (WBC) is not a new pest to Nebraska. Traditionally, WBC has largely been limited to areas in the western Great Plains, but in the last 15 years, WBC has rapidly spread eastward through the Corn Belt to as far as Pennsylvania. This has driven new research on WBC, particularly in corn. In this article we will present information on WBC biology and management. The following is an updated version of the NebGuide G2013, Western Bean Cutworm in Corn and Dry Beans.

Western Bean Cutworm in Corn and Dry Beans

Western bean cutworm is a sporadic, but sometimes significant pest of corn and dry beans. Larval feeding damages both crops through reduced yield and quality. In corn, direct feeding losses may be compounded by fungal infections associated with larval feeding and waste products. In dry beans, damaged or "worm-chewed" beans are a significant quality factor for both processed and bagged dry beans. Western bean cutworm infestations occur every year in western Nebraska and the surrounding region, but can be found in high numbers throughout the state. Effective control of this potentially destructive pest includes scouting, use of economic thresholds, proper timing of chemical applications, and an understanding of which Bt products in corn will provide suppression or protection against western bean cutworm. These components are described below.

Life History

Western bean cutworm has one generation per year with moth emergence usually beginning in early July. The peak of moth flight often occurs during the third week of July. The emergence date can be predicted by calculating growing degree days. Starting heat unit accumulations on May 1, using a base air temperature of 50°F, growing degree days for 25 percent, 50 percent, and 75 percent moth emergence are 1319, 1422, and 1536, respectively. Populations vary from year to year, but there is a tendency for greater populations to occur every six to eight years. Throughout the western Great Plains region, western bean cutworm populations are greater in fields with sandy soils. Western bean cutworm moths are about 3/4 inch long with a wing span of about 1 1/2 inches. The body is light brown, and the wings are generally dark brown with a distinctive pattern. The front wings have a broad white or cream stripe that runs two-thirds of the length of the leading edge. Behind this stripe is a central white spot and, further away from the body, a half-moon shaped spot. The hind wings are cream colored without markings. When at rest, the wings are swept back over the body. The moths are strong fliers and are known to travel several miles. Female moths emit a pheromone (scent) that attracts males for mating. After mating, eggs are usually laid on field corn, popcorn, sweet corn, or dry beans. Tomatoes and fruits of nightshade and ground cherry are acceptable but non-preferred hosts. Eggs are laid in masses of about 85 eggs per mass, although they range from as few as 2 eggs to as high as 345 eggs per mass. The eggs are 0.03 inches in diameter, dome shaped with ridges and reticulations. When first laid, the eggs are pearly white, but within two days they turn tan. Egg development usually takes five to seven days and the eggs turn dark purple shortly (less than 24 hours) before hatching. After egg hatch, the larvae remain clumped near the egg mass for several hours, feeding on the chorion (shells) of the eggs. The larvae then typically move up the plant to protected feeding sites, usually in the whorl or developing tassel. Larvae feed for about 31 days and develop through five instars on the host plant. First instar larvae are quite mobile and may infest several adjacent plants. They are dark brown with faint crosshatched markings on their backs. As the larvae develop, they become light tan to pink and the crosshatch markings on their backs become more distinct. Third instar and older western bean cutworm larvae also can be differentiated from other cutworms and caterpillars feeding on the host plant by three characteristic dark brown stripes immediately behind the head. Larvae continue to feed through the fifth instar after which they drop to the ground, burrow 3 to 6 inches into the soil, and construct an earthen overwintering cell (the sandier the soil, the deeper the burrow). They spend the winter inside this cell in a pre-pupal stage. Larvae pupate in late May followed by adult emergence starting in early July.

Infestations on Corn

Western bean cutworm females often enter the whorl of the plant where they lay eggs on the upper surface of corn leaves. Fields still in the whorl stage are preferred for oviposition (egg-laying). Most eggs hatch (usually over 80%), but only a small percentage of the larvae actually survive to maturity. Newly hatched larvae move to the whorl where they feed on the flag leaf, the flowers of the tassel, and other yellow tissue. Once tasseling begins, newly hatched larvae feed within the tassel and leaf axils on the upper part of the plant, or sometimes the green silks of the developing ear. Once pollen shed is complete and the tassels dry up, the larvae move to the silks. Larvae are generally aggregated around the egg-infested plant, but larvae from one egg mass may infest several plants down the row and in adjacent rows in an area 6 to 10 feet in diameter. Once at the ear, larvae continue to feed on the silks and move into the ear to feed on the kernels of the developing ears. Fourth instars feed primarily on kernels near the ear tip. If the ear tips are crowded, some larvae may move to the outside of the ear, chew through the husks, and initiate feeding on the kernels. Reports of yield reduction due to WBC are quite variable, ranging from 3.7 to 14.9 bu/ac, and dependent on plant population, plant stage infested, and possibly research methodology. Western bean cutworm larvae are not cannibalistic, thus infestations of multiple larvae per ear may be observed. In years with severe infestations, two or more larvae per ear may occur, and although unusual, corn ears infested with 10 or more larvae have been recorded.

Infestations on Dry Beans

Western bean cutworm eggs are laid on the lower surface of bean leaves within the dense canopy of foliage. First instar larvae may disperse up to 12 feet along a row and 10 feet across rows. Larvae remain on the leaves until they are about 1/2 inch long. They feed at night on young leaf material and blossoms. As the larvae grow and pods develop, they begin to feed in the pods and on the developing seeds. Larger larvae leave the pods during the day, seeking protection in the soil. If the larvae have not completed development when the beans are cut, they may congregate under the windrow and feed on the pods and seeds until harvest. Economic injury levels for yield loss are difficult to determine because of the uncertain impacts on product quality and market price (as well as varying levels of damage for difference bean market classes), but the economic injury level for dry beans is about 1 percent damaged seed in the marketed product. This damage level would result from about 4 to 6 percent damaged pods in the field. There is some evidence that western bean cutworm damage may be less severe in dry beans with a more upright growth type. This is likely due to the pods being further from the ground where the cutworms overnight.

Sampling Corn

Western bean cutworm moths can be detected with black light or pheromone traps. Based on light trap catches, most of the eggs are laid during the peak moth flight in mid to late July. Light traps should be monitored regularly until after the adult population peaks. Field scouting should be initiated when western bean cutworm moths are first noticed. The upper surface of the upper leaves of corn plants should be examined for egg masses and/or small larvae. Before pollen shed, the tassels also should be inspected for small larvae. When scouting for western bean cutworm, check randomly selected plants across the field at locations that are representative of all areas of the field. Egg laying will vary with plant growth stage; therefore, portions of a field planted to hybrids with different maturities should be sampled separately. As you move through the field check for egg masses on single plants with a targeted sample size of 50-100 plants to determine the percentage of plants infested with egg masses. If 4-8 percent of field corn plants have egg masses and/or small larvae, consider an insecticide application. This action threshold or infestation level may need to be adjusted based on the crop's value and control costs. Lower crop values and higher insecticide costs would suggest use of the higher action threshold value. If an insecticide application is required, timing is critical. If the eggs have hatched, insecticide applications should be made after 95 percent of the plant tassels have emerged, but before the larvae have a chance to enter the silks. Once larvae have moved into the silks and ear tip to feed, insecticide control is more difficult. If the eggs have not hatched and plants have tasseled, the application should be timed for when most of the eggs are expected to hatch. Purple eggs should hatch within about 24 hours. Some Bt corn hybrids have proteins active against western bean cutworms (for example, Cry 1F and VIP3A). They appear to control the larvae, although not entirely, so they should be scouted to insure efficacy is adequate.

Speed Scouting Tools: Spreadsheet & Mobile App

To help farmers determine when treatment is warranted, specialists at the University of Nebraska–Lincoln and University of Minnesota joined to develop a new decision aid tool, **Western Bean Cutworm Speed Scouting Spreadsheet EC1585**. This Excel® spreadsheet uses a speed scouting method, which can cut the number of plants that need to be counted in a given field from 100 to about 50. This free resource is also available as a mobile app for Apple (Fig. 1) and can be found by typing "Western Bean" into the Apple search box.

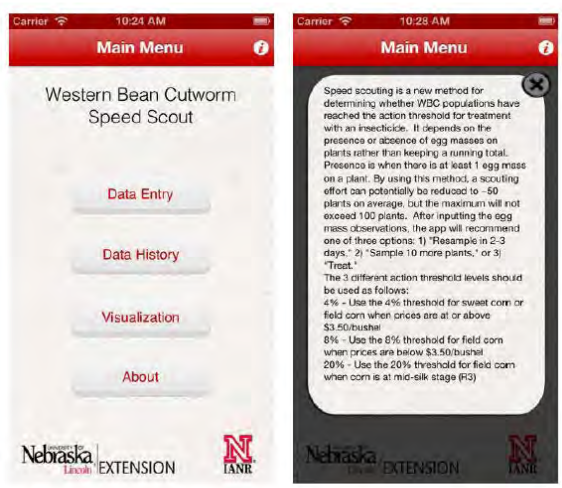

Figure 1. Screenshots from the WBC Speed Scout mobile app

Sampling Dry Beans

Dry beans cannot be effectively scouted for western bean cutworm eggs or small larvae; therefore, it is necessary to use less direct methods to establish a field's damage potential. Pheromone trap catches may be used to provide an estimate of infestation potential, proper timing of field scouting activities, and optimum timing for initiation of control methods. Inexpensive and effective pheromone traps may be constructed from a one-gallon plastic milk jug and pheromones may be purchased from a commercial supplier. Pheromones and light traps can be purchased through suppliers such as Gempler's, Inc., www.gemplers.com, phone (800) 382-8473 or Great Lakes IPM, www.greatlakesipm.com, phone (800) 235-0285. Traps are constructed by cutting out the side panels of the jug, leaving a 2-inch bottom reservoir to be filled with a 4:1 mixture of water and antifreeze and a couple drops of dish soap. Moths become trapped in this liquid and can be counted. Pheromone lures may be secured with a pin to the undersurface of the milk jug cap. Scentry™ pheromone lures are recommended because of the variability seen with other brands. Traps should be mounted at a 4-foot height on posts in two locations at the edge of the bean field. If possible, install traps near lush vegetation, such as a growing corn or sugarbeet field. It also may help to place the traps in the northwest and southeast corners of the field. These steps will ensure that moths will not avoid the traps due to lack of vegetation and the prevailing winds will spread the pheromone over the field, increasing the chance of drawing moths from the field being monitored. Pheromone traps should be set out in early July. Moths captured in each trap should be counted regularly and the total accumulated over time until the moth flight peaks. During the moth flight, the traps should be emptied and moths counted at least every third day. Longer trapping periods may be acceptable during periods of minimal activity, but in years with high moth counts the traps can quickly exceed their capacity and may need to be counted daily. To ensure optimum moth capture, a fresh antifreeze mixture should be added each time the traps are counted. The date of the peak moth flight should be recorded and the cumulative number of moths, caught from the initiation of the flight until the peak, should be calculated. If the cumulative catch at the peak of the moth flight is less than 700 per trap, the risk of significant damage is low. If the number is between 700 and 1,000 moths per trap, the risk of damage is moderate and additional sampling information will be needed to reach a decision. If the total moth count exceeds 1,000 per trap, the risk for damage is high. However, not all high-risk fields will develop economically threatening damage, so additional information will be helpful in reaching a treatment decision. If an insecticide treatment is required, the application should be made 10 to 21 days after the peak moth flight. Treatment decisions often require further information to better establish damage potential of higher risk fields. Significant cutworm infestations in nearby corn fields may signal a potentially damaging population in the neighboring dry beans. Additional information on damage potential can be gained by checking bean pods for feeding damage about three weeks after the peak moth flight. At this time, pod feeding by the partially grown larvae will just be starting. If pod feeding is noticeable (0.5 to 1 percent or more pod damage), an insecticide application should be considered and, if necessary, administered quickly to prevent further damage.

Pest Management

Cultural Control

Few cultural methods effectively control western bean cutworms. Disturbing the soil by plowing or disking is thought to reduce overwintering larval survival; however, the effectiveness of this practice on a broad scale has not been tested.

Host Plant Resistance

A few dry bean varieties have some resistance to feeding damage but the agronomic characteristics of these varieties are not favorable for commercial production.

Biological Control

Studies at UNL indicated that western bean cutworm eggs are susceptible to fungal infections that can reduce egg hatch by as much as 10% in dry bean and 25% in corn. An introduced egg parasitoid, *Trichogramma ostriniae*, has been shown to reduce WBC egg hatch by as much as 30-59% in corn and 48-50% in dry beans. This is the first research to show the relationship between this parasitoid and western bean cutworm. One interesting observation from 2015 was that a single western bean cutworm egg can produce at least 5 parasitoids.

In 2016, we conducted field releases of *T. ostriniae* in two dry bean fields in western Nebraska. We released about 1 million *T. ostriniae* per location and monitored them in each field with sticky traps and by sentinel egg masses. Traps and egg masses were placed and monitored over 4 dates in July following the release of *T. ostriniae*. Over the monitoring period only ~100-300 total *T. ostriniae* were recovered on sticky traps and very few adult *T. ostriniae* were recovered from egg masses. For this parasitoid to be effective in dry bean fields, it is clear that far more parasitoids will need to be released. This work will be repeated again next year with larger numbers of *T. ostrinae*.

Early instar western bean cutworms are exposed on the plant and vulnerable to predators. Thus, there are several predators that help reduce western bean cutworm infestations. Damsel bugs, ladybird beetle adults, lacewing larvae, spiders and perhaps other predators feed on both eggs and larvae up to the third instar. In 2015 and 2016, studies of the pink spotted ladybeetle found that this common predator will readily consume WBC egg masses (Fig. 2); further study is being done to investigate how we can use this to our advantage for biological control.

Figure 2. Pink spotted lady beetles preying on WBC eggs

After the third instar of larval development, predation by birds can be beneficial. Blackbirds can cause high levels of mortality on western bean cutworm larvae found in the ear tips of corn plants, especially when the majority of ears are infested with cutworms. Although birds will kill and eat WBC larvae, they may also destroy a significant amount of grain in the process (Fig. 3). In addition to these natural enemies, western bean cutworm larvae are susceptible to a naturally occurring disease caused by the microsporidian, *Nosema* sp. Although these naturally occurring control methods are important in reducing western bean cutworm infestations, outbreaks that can cause economic loss in corn and dry beans are still common and may require insecticide applications for adequate control.

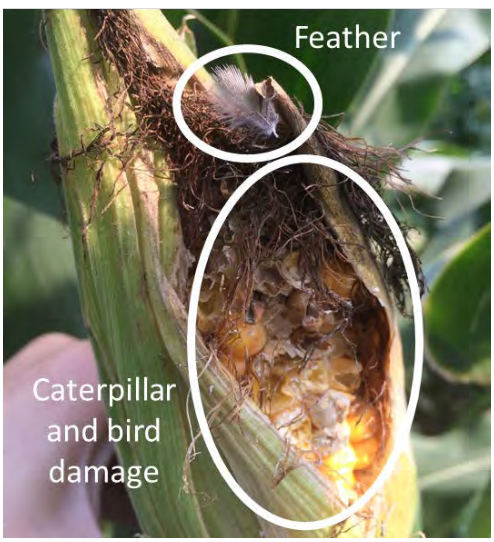

Figure 3. Corn ear with WBC damage followed by bird predation.

Chemical Control

Insecticide controls target the larval stage of western bean cutworms. Liquid insecticides applied by airplane or through a center pivot irrigation system typically provide acceptable control. **If chemigation is used, nozzle height or nozzle selection must ensure that product is adequately applied to the tassels, where early instar larvae feed.** Treatment in corn should target early instar larvae that are still active on the plant because effectiveness decreases as larvae mature and move into the ear to feed. There is some evidence that synthetic pyrethroid insecticides will force larvae out of protective areas due to the irritation properties of the active ingredient. These insecticides may be more effective should the larvae reach the silks prior to treatment. Foliar insecticides that contain *Bacillus thuringiensis* as the active ingredient do not control western bean cutworms. Current insecticide recommendations are available from your local Extension office or on the University of Nebraska–Lincoln Department of Entomology website at *entomology.unl.edu*. **The incidence of spider mites in a field should be considered when choosing an insecticide.** Some synthetic pyrethroid insecticides may result in an increase (flare) of spider mite infestations. These products do not control the mites but will increase their dispersal within the canopy. Synthetic pyrethroids are also highly toxic to the natural enemies of spider mites, eliminating the population-regulating effect of these beneficial organisms. If spider mites are present and a synthetic pyrethroid is to be applied, the field should be sampled for the potential development of mite infestation and/or a miticide should be considered to be included in the spray mixture.

Bt Traits- Nebraska Perspective on Cry1F Performance

In October 2016, a group of six extension entomologists from Michigan State University, Purdue University, The Ohio State University, Cornell University, and Pennsylvania State University published an open letter to the seed industry describing poor performance of Cry1F Bt corn against western bean cutworm (WBC) in their states in 2016. The Cry1F protein is present in products such as Herculex 1, Herculex XTRA, AcreMax, and SmartStax. In their letter they strongly encouraged a change in the labeling for these products, in particular a removal of the designation of "control" for this pest from the Cry1F protein.

While the letter reports problems with field performance of Cry1F against WBC occurring for the first time in the eastern Corn Belt in 2016, crop consultants and farmers in Nebraska have been dealing with similar issues for several years. When the Cry1F trait was first introduced to the market in 2001, other Lepidoptera were the primary target. The Cry1F trait was marketed as providing only about 80% control of WBC.

While it continues to be effective against other labeled pests, such as European corn borer, fall armyworm, and black cutworm, recent research has shown that its effectiveness against WBC has decreased in some areas. In regions where problems have been observed (particularly southwest and central Nebraska), it is recommended that fields with Cry1F products be scouted for WBC and insecticide treatment be considered when 5%-8% of plants in a field have egg masses or larvae.

Bt Traits- VIP3A

As seeds are now being selected for 2017, it is important to consider that Cry1F is not the only type of Bt protein being marketed as providing some protection against western bean cutworm. Products that express the VIP3A protein, such as Agrisure, Viptera, and Leptra, provide effective control and should not need to be treated, although it is always advised to inspect Bt cornfields to ensure adequate efficacy. See the Handy BT Trait Table for a list of commercially available Bt corn hybrids and the proteins they express.

Western Bean Cutworm Populations in 2016

UNL Extension Entomologists operate a network of black light traps across Nebraska to monitor WBC and other moth populations each summer. These traps are located in Concord (Northeast), Clay Center (Southeast), and North Platte (West Central). In 2016, North Platte had high moth flights (cumulative 2,659 moths compared with 3,572 in 2015) compared to more moderate numbers in Clay Center (907 cumulative in 2016 and 470 in 2015) and Concord (95 cumulative in 2016 and 34 in 2015). At North Platte, single night trap catches peaked at 222 moths on July 18, 2016 (lower than the 287 moths on July 15, 2015). At Clay Center, moth flight peaked at an average of 111/night over the weekend of July 9-11, 2016 (higher than the 88 moths on July 14, 2015). At Concord, moth flight peaked at 15 on July 12, 2016 (higher than the 4 moths on July 22, 2015) (Fig. 4).

Resistance Management Concerns

Scattered reports from southwest and north central Nebraska of greater than expected damage from western bean cutworm to corn hybrids expressing the Cry1F protein and/or following pyrethroid insecticide applications have prompted investigation into the possibility of Bt resistance issues. UNL Entomologists have been exploring this issue by collecting problematic field populations and conducting bioassays; this work will continue in 2017. If you have experienced greater than usual damage to Cry1F Bt corn due to WBC or a lack of control of WBC using pyrethroid insecticide applications, please contact Julie Peterson or Tom Hunt. It is important to follow resistance management recommendations when making WBC control decisions: follow recommended treatment thresholds and apply insecticides judiciously, rotate the insecticide mode of action chosen, and read and follow pesticide labels and refuge requirements for Bt crops.

New Tool to Predict WBC Flights: Degree-Day Model

One of the challenges with controlling insect pests in field crops is knowing when the damaging stage of the insect will be present in the field. Scouting for insects and making an effective treatment, if the pest is above the economic threshold, can be a challenge because the time when the insect is present and damaging a crop can vary from year to year. This variation occurs because insect development depends on variable weather conditions such as air and soil temperature. Important stages in insect life cycles, such as egg hatch, pupation, adult flight, and reproduction can be predicted based on environmental temperatures.

By using a degree-day model, you can account for the effect of temperature on insect development and approximate when certain insect development events will occur by measuring degree-days. Degree-days are units that measure how much heat an insect has been exposed to within an upper and lower temperature threshold. These temperature thresholds establish the range of temperatures that allow for insect growth and development. By studying insect development in the laboratory and the field, entomologists can determine these thresholds, as well as the number of degree-days that must be accumulated in order for a specific insect species to reach a certain stage in their development. These numbers will vary depending on the insect species.

One common way to measure degree-days is by taking the average temperature of each day and subtracting the lower threshold from that average:

[(Actual Minimum Temp + Actual Maximum Temp)/2] – Lower Threshold

1) If the average temperature [(Minimum Temp + Maximum Temp)/2] is lower than the Lower Threshold, change the average temperature to the Lower Threshold before subtracting the Lower Threshold.
2) If the average temperature [(Minimum Temp + Maximum Temp)/2] is higher than the Upper Threshold, change the average temperature to the Upper Threshold before subtracting the Lower Threshold.

A degree-day model will determine on which calendar date to start counting degree-days. After this date, degree-days from each day are accumulated to give the total cumulative degree-days.

Aiming to improve predictions of cumulative WBC moth flights and efficiency of field scouting, UNL entomologists Thomas Hunt and Bob Wright, along with researchers from University of Minnesota, Roger Moon and Bill Hutchison, and Anthony Hanson, PhD student, developed a new model for the flight of western bean cutworm. It was published in 2015 in the Journal of Economic Entomology. Previously, extension entomologists, crop consultants, and growers throughout the Midwest had been using a model developed in 1979 by entomology master's student Tarik Ahmad and former UNL Entomology Professor Dr. Ken Pruess.

Our new model improves upon this one greatly, and was developed and validated using data from black light traps in North Platte, Concord, Clay Center, and Aurora. Researchers found that the best model for predicting timing of western bean cutworm flight used simple degree-day calculations beginning on March 1, with a 38°F lower threshold and a 75°F upper threshold. The new cumulative flight model indicated that 25% of moth flight should be completed when 2,577 degree-days F have accumulated. Field scouting to estimate egg density is recommended at this time.

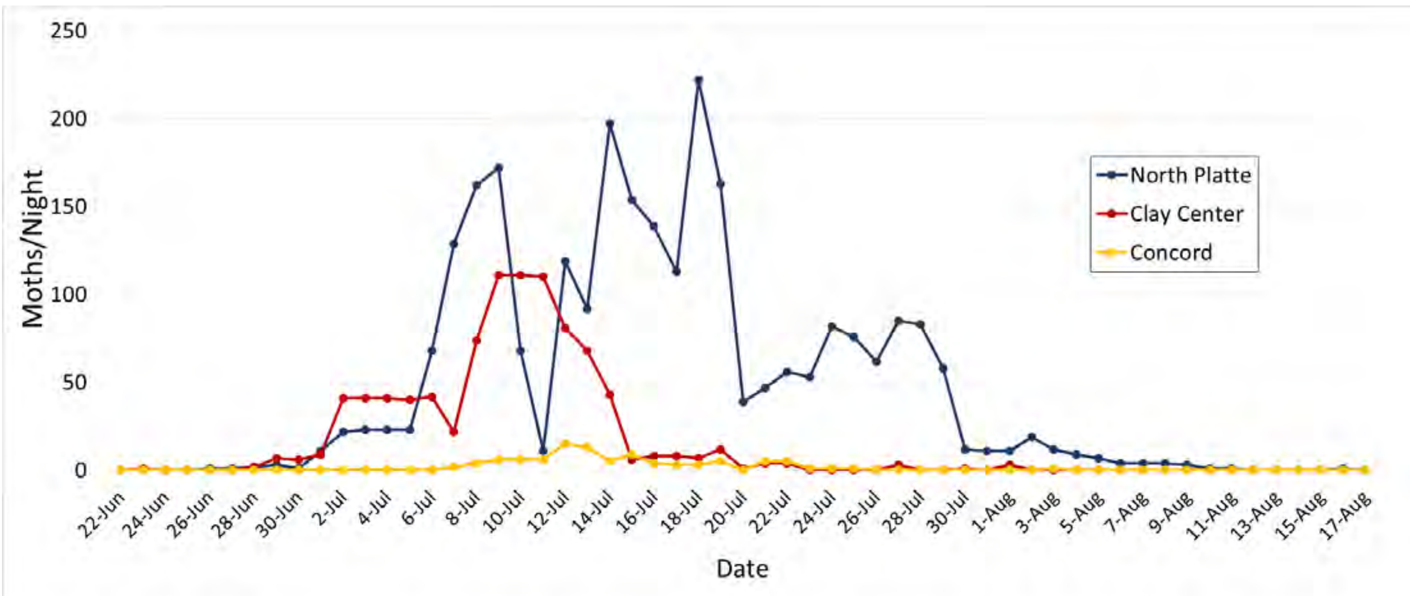

Figure 4. Number of western bean cutworm moths caught per night at North Platte, Clay Center, and Concord in 2016.

Watch for European corn borer in non-traited corn

Robert Wright and Thomas Hunt
Nebraska Extension Entomologists, Lincoln and Concord

The adoption of Bt corn hybrids in Nebraska and other states has resulted in a great reduction of the density of European corn borers. Many people have commented on their reduced abundance. However, they are still present, and we have received reports of damaging levels of European corn borer in some parts of Nebraska on corn without Bt proteins active against European corn borer larvae, e.g., white corn, popcorn, and organic corn. This article will provide an overview of European corn borer biology and management.

Life cycle

European corn borers have two generations per year in Nebraska and overwinter as mature larvae in corn stalks and other crop residue. Moths emerge in May/June, mate, and lay eggs in whorl stage corn. Larvae feed on the leaf surface, then move down into the whorl. As new leaves emerge, 'shot-hole' feeding damage is seen. Mature larvae molt into pupae in the stalk, then second generation moths emerge in July/August. Larvae of both generation cause damage from tunneling in the corn stalk, resulting in reduced grain yield, and harvest losses from stalk breakage or ear drop.

Monitoring

The use of black light traps or pheromone traps can give you an early warning of moth activity in your area, and help target when scouting for eggs and larvae should occur. Nebraska Extension runs black light traps during the growing season at Concord, Clay Center and North Platte NE. We anticipate adding a trap location at the Agricultural Research and Development Center, Ithaca NE in 2017. We report our light trap data at http://entomology.unl.edu/fldcrops/lightrap

Degree day models have been developed for European corn borers (see Table below). To use this information, you need to initiate degree day accumulations (base 50°F) with the first capture of a moth in your area with a light trap or pheromone trap.

Scouting and economic thresholds

Information on scouting procedures and economic thresholds are available in Wright (2013a, b) cited below. A downloadable spreadsheet for calculation of economic thresholds for second generation corn borers is available (Ohnesorg and Wright 2102), and one for first generation corn borers is under development and should be available in 2017.

Resources

Wayne Ohnesorg and Robert Wright. 2012. Second Generation European Corn Borer Scouting Spreadsheet. Nebraska Extension Circular EC1584. http://extensionpubs.unl.edu/publication/9000016368340/second-generation-european-corn-borer-scouting-spreadsheet/

Robert Wright. 2013a. First Generation European Corn Borer Scouting and Treatment Decisions, Nebraska Extension NebGuide 1782. http://extensionpubs.unl.edu/publication/9000016365143/second-generation-european-corn-borer-scouting-and-treatment-decisions/

Robert Wright. 2013b. Second Generation European Corn Borer Scouting and Treatment Decisions, Nebraska Extension NebGuide 1783. http://extensionpubs.unl.edu/publication/9000016365143/second-generation-european-corn-borer-scouting-and-treatment-decisions/

Table 5.2 Accumulated Degree-Days (Developmental Threshold of 50°F) from Initial Capture of Moths in the Spring for First Occurrence of Life Stages and General Activity of European Corn Borer.

Accumulated Degree-Days[a]	First Occurrence of Stage or Event	Days to First Occurrence[b]	Mean Daily Temperature	General Activity
0	First spring moth			Mating and egg laying
First generation				
212	Egg hatch (first instar)	16.3	63	Pin hole leaf feeding
318	Second instar	6.6	66	Shot hole leaf feeding
435	Third instar	6.5	68	Midrib and stalk boring[c]
567	Fourth instar	6.6	70	Stalk boring
792	Fifth instar	10.2	72	Stalk boring
1,002	Pupa	8.8	74	Changing to adult
1,192	Adult moths	7.6	75	Mating and egg laying
Second generation				
1,404	Egg hatch (first instar)[d]	8.2	76	Pollen and leaf axil feeding
1,510	Second instar	4.1	76	Leaf axil feeding
1,627	Third instar	4.3	77	Sheath, collar, and midrib boring
1,759	Fourth instar	5.1	76	Stalk boring[c]
1,984	Fifth instar	9.0	75	Stalk boring

[a]Based on populations from Lowa, North Dakota, Missouri, Delaware, and Pennsylvania that were reared in the laboratory on stalk sections from whorl-stage corn by using a minimum developmental threshold of 50°F.

[b]Average number of days of development in most two-generation regions in order to reach the first occurrence of the stage or event since initiation of the previous stage that is listed, based on the mean daily temperature for the time of year when the previous life stage normally occurs.

[c]First-generation larvae bore into stalks earlier than second-generation larvae because the younger stalks are more tender than those of older, more mature plants.

[d]Peak egg hatch occurs 10 days or approximately 200 to 250 degree-days later than first hatch.

SOURCE: From Mason et al., 1996, *European Corn Borer Ecology and Management*. North Central Regional Extension Publication No. 327.

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First Generation European Corn Borer Scouting and Treatment Decisions

Robert J. Wright, Extension Entomologist

The decision to treat for European corn borer is complex and affected by many variables such as weather, plant maturity, borer survival and development, anticipated corn prices, insecticide efficac , and costs versus anticipated returns. This publication discusses the factors growers need to consider when assessing the need for control of first generation European corn borers in non-Bt corn.

European corn borer moths prefer the tallest plants for egg laying. Expect initial concentrations of egg-laying moths in fields where corn plants are taller than in surrounding fields. If most fields are about the same height, moths may disperse evenly throughout. Even late-planted corn can become damaged if rapid growth makes fields attractive late in the borer moth flight period. Plan to scout all cornfields for at least three to four weeks after peak moth flight, usually between early June and early July. Also, some varieties of corn are more susceptible than others. Consider locally adapted varieties that yield well and have some resistance to the borer.

Begin routine scouting during the moth flight, egg-laying, and early hatching period. To determine the need to treat for first generation borer, examine at least 25 corn whorls at each of four locations in each field. Pinhole or shot-hole leaf damage means early signs of feeding by corn borer larvae *(Figure 1)*. Record the percentage of total plants with whorls damaged by corn borer feeding. Also, pull up and unroll several whorls at each site and record the number of live worms present. Calculate the average number of live larvae per damaged plant (total live larvae divided by number of damaged plants examined). Enter data from your sampling into the provided worksheet. This will give you an estimate of the **maximum** number of borers that might survive to produce tunnels in the plant. Remember that mortality of young borers is normally high. If making a treatment decision when most borers are small, scouting figur s may overestimate the fin l borer population. It may be better to delay the treatment decision until just before borers leave whorls and enter stalks; borers begin to enter stalks when they are half-grown.

Caution: Borers that have left the whorl and entered the stalk cannot be controlled. If most have left the whorl, it is too late to attempt control. Be certain to sample enough plants at enough locations to ensure that estimates are typical of the field. Twenty-five plants in four locations in each field is a **minimum sample**.

Figure 1. Shot-hole feeding damage by European corn borer larvae in whorl stage corn (UNL Department of Entomology).

To make a decision on first generation European corn borer treatment the following information is needed:

1. Average percentage of damaged whorls in the field and average number of live worms per damaged plant. These numbers help provide an estimate of the possible maximum number of cavities per plant at the end of the first generation.
2. Cost per acre of the insecticide application (product and application costs).
3. Anticipated dollar value of the grain per bushel.
4. Estimated percentage control given by a particular insecticide.

Example: An average of one borer cavity per plant is capable of causing an approximate 5 percent yield loss. Using the worksheet example, it is known from scouting that 50 percent of the plant whorls are damaged with an average of two live worms per damaged plant. Calculate that 50% x 2.0 = 1.0 worm per plant, if all worms survive. Assume 75 percent control and $3.00 value per bushel of corn with a yield expectation of 150 bushels per acre.

Management Worksheet for First Generation Corn Borer		
	Example field	***Your estimates***
1. Yield potential for this fiel	150 bu/A	______ bu/A
2. Number of larvae/plant = average live larvae/plant x average % damaged plants (2 larvae x 50% damaged plants = 1 larvae/plant)*	1 larvae/plant	____ larvae/plant
3. Potential yield loss (1 larvae/plant x 5% loss/larva = 5% loss in yield, 5% x 150 bu = 7.5 bu loss/A)	7.5 bu/A	________ bu/A
4. Dollar loss/A (7.5 bu/A x $3.00 per bu = $22.50 loss/A).	$22.50	$____________
5. Preventable loss (if chemical is 75% effective; $22.50 x 75% = $16.87/A)**	$16.87	$____________
6. Chemical ($8.00/A) and application costs ($4.00/A). Estimate your own cost or call dealer/applicator. TOTAL = $12.00/A	$12.00	$____________
7. Compare preventable loss ($16.87/A) with treatment cost ($12.00/A). Subtract latter ($12.00/A) from former ($16.87/A) to find dollars saved by trea - ment per acre ($4.87/A).	+$4.87	$____________

If preventable loss (No. 5) exceeds total cost of treatment (No. 6), you may benefit from an insecticide application for first generation corn borer.

*To determine the need for treatment, it is essential to obtain an estimate of the final population of borers in each field. Ideally, this final population estimate and the treatment decision should be made after egg-laying, when the oldest borers are approaching the third stage (about half-grown), and before the oldest larvae have left the whorl. Remember that natural insect mortality caused by weather (low temperatures, low relative humidity, wind, or driving rain), other insects, diseases, and resistance factors in the corn plant is often high, especially in the very earliest borer stages. Occasionally, such mortality may be as high as 90 percent. However, warm, wet, and humid, mild conditions can increase survival considerably. Therefore, due to these variables, it is nearly impossible to support the use of an "average percentage of surviving borers" and plug it into the formula. As it is, the above formula tells what would happen if all the borers observed did survive to invade the stalk and complete a tunnel. The later the treatment decision can be made without compromising control, the more natural mortality will occur and the greater the likelihood of making a correct treatment decision.
**A reasonable expectation for insecticidal control of first generation European corn borer under typical field conditions is approximately 75 percent. Percent control can vary considerably, depending on several factors, including timing of application, product choice, and application method. Research has shown that granules generally work better than liquids for first generation European corn borers, with the exception of ce ter pivot applications.

Resources

European Corn Borer Ecology and Management. 1996. C.E. Mason et al. North Central Regional Extension Publication 327, Iowa State University, Ames.

Handbook of Corn Insects. 1999. K.L. Steffey et al. (eds.). Entomological Society of America.

Acknowledgment

Modified from *First Generation European Corn Borer Scouting and Treatment Decisions*, University of Nebraska–Lincoln Extension NF364, by R.J. Wright and J.F. Witkowski.

This publication has been peer reviewed.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.

Index: Insects & Pests
Field Crop Insects
2007, Revised November 2013

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Second Generation European Corn Borer Scouting and Treatment Decisions

Robert J. Wright, Extension Entomologist

The decision to treat for European corn borer is complex and affected by many variables such as weather, plant maturity, borer survival and development, anticipated corn prices, insecticide efficac , and costs versus anticipated returns. This publication discusses the factors growers need to consider when assessing the need for control of second generation European corn borers in non-Bt corn.

Fields having green silks and shedding pollen during the peak period of moth flight are most susceptible to second generation European corn borer infestation. To determine the need to control second generation European corn borers, begin scouting when the second flight of moths appears, usually in mid-July. Scout fields regularly, at least once every three to five days, especially during the early half of the moth flight period. Select a minimum of 50 plants per field, choosing plants from several different parts of the field. Examine the underside of leaves for white borer egg masses *(Figure 1)*. These masses, usually found on leaves in the middle third of the plant (frequently near the midrib), normally hatch in about five days. Each egg develops a black spot just before hatching *(Figure 2)*.

Application timing is critical for reasonable control. Best control (approximately 50-70 percent, depending on timing, application method, and product choice) is realized when application is timed to first significant egg hatch and when young larvae still are located in the leaf axils. Larvae that have bored behind the leaf axil, into the sheath or are in or on the ear unlikely will be controlled. As the plant approaches blister stage and beyond, potential economic benefits of an insecticide application rapidly decline

The following worksheet can help determine whether treatment of second generation European corn borers in corn is economical. For this worksheet you need to know:

1. Average number of egg masses per plant in fiel
2. Crop stage
3. Expected yield
4. Expected value of corn
5. Expected percent control with insecticide
6. Cost of control (product plus application costs)

This worksheet will be useful in closely evaluating the many factors influencing the cost/benefit relationships involved in treating second generation European corn borers. Average values are suggested in the worksheet and may need to be modified in certain situations

Figure 1. European corn borer egg mass (UNL Department of Entomology).

Figure 2. Black head stage European corn borer egg mass (UNL Department of Entomology).

- Borer survival is suggested to be three borers per egg mass. On average, European corn borer egg masses contain 20 eggs, although this may vary from 10 to 40. Three borers per 20 eggs equals a 15 percent survival rate. Larval survival will vary with weather conditions and field type (dryland versus irrigated). In irrigated corn, larval survival is likely to be 20 percent or more, but in dryland corn, it's likely to be 10 percent or less. Exposure to hot, dry weather greatly decreases egg survival.
- Yield loss per borer is suggested to be 4 percent per borer for infestations before silks turn brown, and 3 percent per borer after silks turn brown, but before blister stage. These values account only for physiological yield loss (reduced yield from corn borer damage to water and nutrient uptake through the stalk) and do not consider the potential for yield loss due to stalk breakage or ear drop.
- Percent control with insecticides is suggested to be equal to 70 percent. This is a good average value for second generation European corn borer control, although if your data suggests higher or lower control levels under your conditions, change this value.

The best control that can be achieved usually will prevent much of the stalk and leaf sheath tunneling, but will not necessarily prevent invasion of the ear tip. This is especially true if the borer flight period is extended or a partial third generation occurs. Stalk protection is critical for the plant to fully develop the ear. While late worms that attack the ear tip do reduce grain quality, they do not reduce yields as seriously as borers that tunnel in stalks. Early harvest and selection of a corn variety that has good ear retention should minimize ear drop.

Generally, liquid and granular formulations of the same insecticide are equally effective against second generation European corn borer larvae. However, if other insects (except spider mites) are present and/or European corn borer moth numbers are high, liquid formulations are preferred over granules because of their broader spectrum of activity and the added advantage of obtaining some moth control. If spider mites are present, select an insecticide that is least likely to contribute to rapid increases in mite numbers.

Use the following worksheet to determine whether it is profitable to treat for second generation European corn borer. In the example, the field has a yield potential of 150 bushels per acre, corn value is assumed to be $3 per bushel, one egg mass per plant is found in green silk stage corn, and the cost of insecticide and its application totals $12 per acre.

Resources

European Corn Borer Ecology and Management. 1996. C.E. Mason et al. North Central Regional Extension Publication 327, Iowa State University, Ames.

Handbook of Corn Insects. 1999. K.L. Steffey et al. (eds.). Entomological Society of America.

Acknowledgment

Modified from *Second Generation European Corn Borer Scouting and Treatment Decisions*, NF365, by R.J. Wright and J.F. Witkowski, University of Nebraska–Lincoln Extension.

Management Worksheet for Second Generation European Corn Borers		
An online version of this worksheet is available at *http://entomology.unl.edu/fldc ops/index.shtml*		
	Example	*Your estimates*
Number of egg masses per plant x 3 borers per egg mass* = borers per plant	1 egg mass per plant x 3 = 3 borers per plant	
Borers per plant x 4% yield loss per borer** = percent yield loss	3 x 4% = 12 % yield loss	
Percent yield loss x expected yield (bu per acre) = bushels per acre loss	12% x 150 bu per acre = 18 bu per acre	
Bushels per acre loss x sale price ($/bu) = $ potential loss per acre	18 bu/acre x $3/bu = $54	
$ loss per acre x 70% control*** = $ preventable loss per acre	$54 x 70% = $37.80	
$ preventable loss per acre - $ cost of control (product + application costs) = $ profit (+) or loss (-) per acre if treatment is applie	$37.80 – 12.00 = $25.80	
If preventable loss exceeds cost of control, insecticide treatment likely will result in economic benefit		

*Assumes survival rate of three borers per egg mass; may vary with weather and egg mass size.
**Use 3 percent loss per borer per plant if infestation occurs after silks are brown. The potential economic benefits of treatments decline rapidly if infestations occur after the corn reaches the blister stage.
***70% is an average, use another value if desired.

This publication has been peer reviewed.

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Index: Insects & Pests
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2007, Revised November 2013

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

E-268

The Effectiveness of Neonicotinoid Seed Treatments in Soybean

Neonicotinoid insecticides are highly water soluble, and plants can absorb them and move them through their "circulatory system" from the root zone up into leaves and other tissues. This quality has made neonicotinoids a popular insecticidal seed treatment of many crops (Figure 1). In 2011, more than 80 percent of corn, more than 50 percent of cotton, and about 40 percent of soybean acres were planted with neonicotinoid-treated seed, a total area described as "roughly the size of California." (Douglas and Tooker 2015). Neonicotinoid seed treatments of soybean rank only behind corn in total acreage.

This publication reviews the current research regarding the efficacy of these neonicotinoid seed treatments, their non-target effects, and the potential role for neonicotinoid seed treatments in soybean production.

THIS IS A JOINT PUBLICATION OF:

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Figure 1. Neonicotinoid-treated soybean seed before soil covering.

Do Neonicotinoid Seed Treatments Work in Soybean?

Neonicotinoid seed treatments offer soybean plants a narrow window of protection — a maximum of three weeks after planting (McCornack and Ragsdale 2006). **As such, they can be useful for managing early-season pests in targeted, high-risk situations.**

Examples of such high-risk situations include:

- *Fields transitioning to soybean production from pasture, Conservation Reserve Program (CRP) land, or grassland to soybean production*. Such fields tend to have higher populations of long-lived soil pests, such as wireworms or white grubs, which cannot be controlled with foliar insecticides.

- *Fields with recently incorporated animal manure, green cover crops, or weeds*. These fields tend to be more attractive to seedcorn maggot, because females lay eggs in rotting organic material.
- *Second (double) crop or specialty (food-grade or seed) soybean.* During soybean aphid outbreaks, aphids may migrate from mature soybean plants to colonize later-planted plants in a double-crop situation. In food-grade or seed soybean, early-season insect pests can vector diseases that affect crop quality. For example, bean leaf beetle transmits bean pod mottle virus.

These high-risk scenarios are uncommon in northern states. Seed and seedling pests such as wireworms, white grubs, and seedcorn maggots rarely reach economically damaging levels in the vast majority of soybean fields (Figure 2). Adult bean leaf beetles are frequently encountered in newly emerged soybean, but they rarely cause more than cosmetic injury to plants (Figure 3). It is critical to remember that soybean plants are resilient and can tolerate considerable early-season damage without suffering economic loss.

Figure 2. Wireworm feeding seldom reaches economically damaging levels.

Recent field studies support this point: yield benefits attributed to neonicotinoid seed treatments are inconsistent or absent (Seagraves and Lundgren 2012; Gaspar et al. 2014, 2015).

The U.S. EPA extensively reviewed published and unpublished data regarding the yield benefits and concluded that "neonicotinoid seed treatments likely provide $0 in benefits to growers" (USEPA 2014).

Figure 3. Early-season bean leaf beetle feeding on untreated soybean seedlings (left) and on neonicotinoid seed-treated seedlings (right). This minor feeding does not reduce yield.

Seed Treatments Not Timed for Major Pests

Soybean aphid is the most important insect pest of soybean in northern states, and it is listed on labels for neonicotinoid seed treatments. Recall that neonicotinoid seed treatments protect soybean seedlings for a short time window after planting (approximately three weeks).

However, soybean aphid populations usually increase in midsummer during the late-vegetative and bloom stages of soybean (Hodgson et al. 2005, Ragsdale et al. 2007). In other words, populations increase to threshold levels weeks *after* the short window that neonicotinoid seed treatments protect plants (Figure 4).

A suite of predators and parasitoids (Figure 5) frequently suppress early-season aphid infestations before they reach threshold levels (Rutledge et al. 2004, Yoo and O'Neil 2008). Research has repeatedly demonstrated that following the well-established and widely implemented treatment threshold of 250 or more aphids per plant to time foliar insecticide applications remains the most effective and economical approach for soybean aphid management (Ragsdale et al. 2007, Johnson et al. 2009, Song and Swinton 2009).

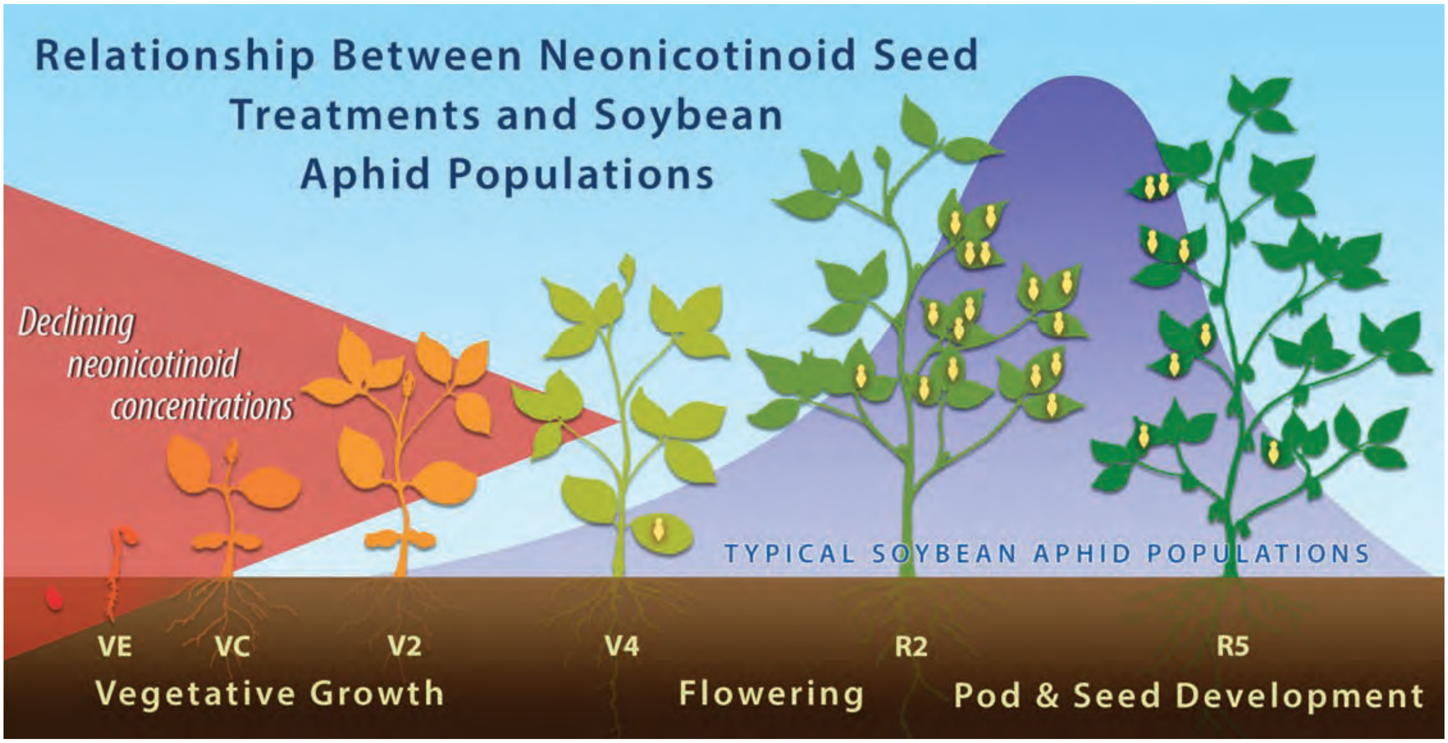

Figure 4. The relative concentration of the neonicotinoid thiamethoxam (the active insecticidal ingredient in CruiserMaxx® seed treatment) decreases rapidly after planting (represented by the red triangle). There is little or no insecticide remaining in soybean plants by the time soybean aphid populations typically begin to increase (represented by the purple-blue curve).

Figure 5. Predators, such as (A) an *Orius* nymph, (B) Asian lady beetle, (C) aphid midge larva, and (D) parasitic wasps typically suppress early-season infestations of soybean aphid.

To summarize: For typical field situations, independent research demonstrates that neonicotinoid seed treatments do not provide a consistent return on investment (Hodgson and VanNostrand 2012, 2013, 2014; Seagraves and Lundgren 2012; McCarville et al. 2014). **The current use of neonicotinoid seed treatments in soybean and other crops far exceeds pest pressures.**

Neonicotinoid Risks

Neonicotinoid seed treatments pose risks to **non-target organisms** in two main ways: off-target movement and environmental persistence. In **target pest populations**, neonicotinoid seed treatments pose the threat of resistance development.

Off-target Movement

Planter dust, which is generated during and shortly after planting neonicotinoid-treated seeds, contains high concentrations of neonicotinoid insecticides (Figure 6). Dust can move beyond field margins and land on flowers and other vegetation and potentially expose non-target insects (including honey bees and other pollinators) (Krupke et al. 2012, Stewart et al. 2014, Krupke and Long 2015).

Neonicotinoids are **highly soluble in water**, which facilitates movement beyond field borders via tile drainage and runoff. Studies also show that neonicotinoid contamination in water bodies has a negative effect on arthropod communities, which are the bases of local food webs (van Dijk et al. 2013, Hallmann et al. 2014, Hladik et al. 2014, Main et al. 2014).

Environmental Persistence, Biological Effects

Neonicotinoid residues from seed treatments may be found in the soil for months or even years after planting (USEPA 2003, Bonmatin et al. 2014). Researchers are currently exploring the possible effects of these residues. There is evidence that neonicotinoid residues disrupt biological control (Seagraves and Lundgren 2012, Douglas et al., 2014) or may be absorbed by the host plants of other insects, including milkweed (Figure 7), the food source for monarch butterfly caterpillars (Pecenka and Lundgren 2015).

Neonicotinoids can also make other organisms toxic. This phenomenon was documented in slugs, which are not sensitive to neonicotinoids, but ingest them when they feed on plants grown from treated seeds.

Figure 6. (A) Planter dust generated when planting treated seed contains a very high concentration of neonicotinoids that (B) can move off-target, and (C) potentially harm beneficial organisms.

When these “toxic” slugs are attacked by ground beetles, their principal natural enemies (Figure 8), the insecticide passes to the predator, disrupting biological control of the slugs and lowering yield (Douglas et al. 2015).

The same study demonstrated that in slug-infested fields, soybean grown *without* neonicotinoid seed treatments produced higher plant populations and yields than their treated counterparts. This study has important management implications, since slugs are emerging as a key pest in no-till cropping systems in many parts of the northern soybean production region.

Figure 7. Non-target plants (such as milkweed) can absorb neonicotinoid residues and affect non-target insects (such as monarch butterfly caterpillars).

Figure 8. Ground beetles typically control slug populations. But slugs that feed on plants grown from neonicotinoid-treated seeds can pass the insecticide to the beetles.

Resistance Development

Resistance is a potential consequence of consistent exposure to any pesticide. When growers repeatedly plant neonicotinoid-treated seeds in fields where no economic levels of target pests occur, the rate at which resistance will occur accelerates.

In addition, foliar neonicotinoids applied to soybean during the season will further increase pressure on pests to evolve resistance. Researchers have documented neonicotinoid resistance in several key pest species in other cropping systems (Bass et al. 2015).

Pest Management Recommendations

Figure 9. Scouting for insect pests is the tried and true approach.

Most insect pests of soybean have well-established scouting guidelines and thresholds (Figure 9). Specific recommendations are available from university extension service websites and publications (consult your state extension service). When pest problems occur, the best management is based on an integrated approach that can include rotating crops, conserving natural enemies, using soybean varieties with resistance to pests (soybean aphid) or disease (bean pod mottle virus), and scouting and applying insecticides at established thresholds.

Scouting and selectively using any insecticide (including neonicotinoid seed treatments) offers the long-term benefit of extending the useful lifespan of that product. Selective use also reduces short-term production costs.

Growers frequently face limited choices regarding seed treatments. Popular soybean varieties are often offered only with a pre-applied package of seed treatments. Growers who desire untreated soybean seed, or seed treated only with fungicides, should let their seed dealers know as early as possible when ordering seed for the next growing season.

References

Bass, C., I. Denholm, M.S. Williamson and R. Nauen. 2015. The global status of insect resistance to neonicotinoid insecticides. Pesticide Biochemistry and Physiology. DOI:10.1016/j.pestbp.2015.04.004.

Bonmatin, J.-M., C. Giorio, V. Girolami, D. Goulson, D.P. Kreutzweiser, C. Krupke, M. Liess, E. Long, M. Marzaro, E.A.D. Mitchell, D.A. Noome, N. Simon-Delso, and A. Tapparo. 2014. Environmental fate and exposure; neonicotinoids and fipronil. Environmental Science and Pollution Research. DOI: 10.1007/s11356-014-3332-7.

Douglas, M.R. and J.F. Tooker. 2015. Large scale deployment of seed treatments has driven rapid increase in use of neonicotinoid insecticides and preemptive pest management in US field crops. Environmental Science and Technology. DOI: 10.1021/es506141g.

Douglas, M.R., J.R. Rohr, and J.F. Tooker. 2014. Neonicotinoid insecticide travels through a soil food chain, disrupting biological control of non-target pests and decreasing soybean yield. Journal of Applied Ecology. DOI: 10.1111/1365-2664.12372.

Gaspar, A.P., D.A. Marburger, S. Mourtzinis and S.P. Conley. 2014. Soybean seed yield response to multiple seed treatment components across diverse environments. Agronomy Journal 09/2014; 106(6):1955-1962. DOI:10.2134/agronj14.0277.

Gaspar, A.P., P.D. Mitchell and S.P. Conley. 2015. Economic risk and profitability of soybean fungicide and insecticide seed treatments at reduced seeding rates. Crop Science 01/2015; DOI:10.2135/cropsci2014.02.0114.

Hallmann, C.A., R.P.B. Foppen, C.A.M. van Turnhout, J. de Kroon, and E. Jongejans. 2014. Declines in insectivorous birds are associated with high neonicotinoid concentrations. Nature. 511: 341-344.

Hladik, M.L., D.W. Kolpin, and K. Kuivila. 2014. Widespread occurrence of neonicotinoid insecticides in streams in a high corn and soybean producing region, USA. Environmental Pollution. 193: 189-196.

Hodgson, E.W., R.C. Venette, M. Abrahamson, and D.W. Ragsdale. 2005. Alate production of soybean aphid (Homoptera: Aphididae) in Minnesota. Environmental Entomology. 34: 1456-1463.

Hodgson, E.W., and G. VanNostrand. 2014. 2014 Yellow Book Report of insecticide evaluation for soybean pests, 21 pp. Department of Entomology, Iowa State University, Publication 296-14.

Hodgson, E.W., and G. VanNostrand. 2013. 2013 Yellow Book Report of insecticide evaluation for soybean pests, 25 pp. Department of Entomology, Iowa State University, Publication 294-13.

Hodgson, E.W., and G. VanNostrand. 2012. 2012 Yellow Book Report of insecticide evaluation for soybean pests, 35 pp. Department of Entomology, Iowa State University, Publication 291-12.

Johnson, K.D., M.E. O'Neal, D.W. Ragsdale, C.D. DiFonzo, S.M. Swinton, P.M. Dixon, B.D. Potter, E.W. Hodgson, and A.C. Costamagna. 2009. Probability of cost-effective management of soybean aphid (Hemiptera: Aphididae) in North America. Journal of Economic Entomology. 102: 2101-2108.

Krupke C.H., G.J. Hunt, B.D. Eitzer, G. Andino and K. Given. 2012. Multiple routes of pesticide exposure for honey bees living near agricultural fields. PLoS One 7: e29268.

Krupke, C.H. and E.Y. Long. 2015. Intersections between neonicotinoid seed treatments and honey bees. Current Opinion in Insect Science. 110 DOI: 10.1016/j.cois.2015.04.005

Main, A.R., J.V. Headley, K.M. Peru, N.L. Michel, A.J. Cessna, and C.A. Morrissey. 2014. Widespread use and frequent detection of neonicotinoid insecticides in wetlands of Canada's prairie pothole region. PLoS One. DOI: 10.1371/journal.pone.0101400.

McCarville, M.T., M.E. O'Neal, B.D. Potter, K.J. Tilmon, B.P. McCornack, J.F. Tooker, and D.A. Prischmann-Voldseth. 2014. One gene versus two: A regional study on the efficacy of single gene versus pyramided resistance for soybean aphid management. Journal of Economic Entomology. 107: 1680-1687.

McCornack, B.P., and D.W. Ragsdale. 2006. Efficacy of thiamethoxam to suppress soybean aphid populations in Minnesota soybean. Crop Management. DOI: 10.1094/CM-2006-0915-01-RS.

Pecenka, J.R., and J.G. Lundgren. 2015. Non-target effects of clothianidin on monarch butterflies. Science of Nature. 102: 19.

Ragsdale, D.W., B.P. McCornack, R.C. Venette, B.D. Potter, I.V. MacRae, E.W. Hodgson, M.E. O'Neal, K.D. Johnson, R.J. O'Neil, C.D. DiFonzo, T.E. Hunt, P.A. Glogoza, and E.M. Cullen. 2007. Economic threshold for soybean aphid (Hemiptera: Aphididae). Journal of Economic Entomology. 100: 1258-1267.

Rutledge, C.E., R.J. O'Neil, T.B. Fox, and D.A. Landis. 2004. Soybean aphid predators and their use in integrated pest management. Annals of the Entomological Society of America. 97: 240-248.

Seagraves, M.P., and J.G. Lundgren. 2012. Effects of neonicotinoid seed treatments on soybean aphid and its natural enemies. Journal of Pest Science. 85: 125-132.

Song, F., and S.M. Swinton. 2009. Returns to integrated pest management research and outreach for soybean aphid. Journal of Economic Entomology. 102: 2116-2125.

Stewart, S.D., G.M. Lorenz, A.L. Catchot, J. Gore, D. Cook, J. Skinner, T.C. Mueller, D.R. Johnson, J. Zawislak, and J. Barber. 2014. Potential exposure of pollinators to neonicotinoid insecticides from the use of insecticide seed treatments in the Mid-Southern United States. Environmental Science & Technology. 48(16): 9762-9769.

[USEPA] United States Environmental Protection Agency, Office of Pesticide Programs. 2003. Factsheet Clothianidin. EPA Publication 7501C; www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-044309_30-May-03.pdf#_ga=1.133079692.360028879.1443119586.

[USEPA] United States Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention. 2014. Benefits of neonicotinoid seed treatments to soybean production. http://tinyurl.com/o29umwf.

van Dijk, T.C., M.A. van Staalduinen, and J.P. van der Sluijs. 2013. Macro-invertebrate decline in surface water polluted with imidacloprid. PLoS One. DOI: 10.1371/journal.pone.0062374.

Yoo, H.J.S., and R.J. O'Neil. 2009. Temporal relationships between the generalist predator, *Orius insidiosus*, and its two major prey in soybean. Biological Control. 48(2): 168-180.

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Dec. 2015

SUGARCANE APHID

A NEW SORGHUM PEST IN NORTH AMERICA

Michael J. Brewer[1], Robert Bowling[2], J. P. Michaud[3], and Alana L. Jacobson[4]

The sugarcane aphid is a serious economic problem on grain sorghum in Mexico and the Caribbean, the southern states along the US Gulf Coast, and in more northern locations after the aphids migrate from the south.

DISTRIBUTION

The sugarcane aphid, first detected in 2013 on grain sorghum along the Gulf Coast of Texas and Louisiana, spread to grain and forage sorghums in more than 400 counties in 17 states by the end of 2015—more than 90 percent of US grain sorghum acreage. The rapid geographic expansion across sorghum production regions was assisted by wind dispersing winged aphids from infested southern regions to more northern locations. In North America, their presence was previously restricted to sugarcane, and the cause of this recent invasion onto sorghum is unknown.

SEASONAL OCCURRENCE

Populations overwinter on remnant and ratoon (stubble and sprouts) sorghum in more southern regions with mild winters. Johnsongrass, a common alternative host, is more cold-tolerant than sorghum and also serves as a winter refuge plant.

Winged aphids carried on the wind can spread locally to nearby fields and also over long distances to more northern regions, coinciding with grain sorghum coming into production.

After a colony establishes, wingless daughters of winged aphids mature and reproduce at a prolific rate—populations exceeding 10,000 aphids on a single plant have been observed. The aphid gives birth to live young.

Aphid colonies can expand from small, non-damaging patches to damaging populations covering much of the underside of leaves. As sorghum matures, aphids are also found on stems and in the heads. Warm, dry weather is particularly conducive to population increase on sorghum.

[1]Texas A&M AgriLife Research, [2] Texas A&M AgriLife Extension Service, [3]Kansas State University, and [4]Auburn University

APHID IDENTIFICATION

Sugarcane aphids range from gray to tan or light yellow. They are typically gray during cool periods and light yellow in warm summer conditions. The aphid has short, dark cornicles (tailpipe-like structures), dark tarsi (feet), and slender antennae that darken near the tip.

Winged sugarcane aphids look similar to wingless ones, but have black markings that run crossways on their backs, conspicuous dark veins in their wings, and black, hardened structures at the base of their wings (Fig. 1). With 10-power magnification, it is easy to distinguish both winged and wingless forms from other aphids that infest sorghum.

Figure 1. Top: Aphid nymphs, wingless adults, black aphid mummies (aphids killed by a parasitic wasp), and white caste aphid skins from molts on a leaf. **Bottom:** The same aphids as above enlarged, and a winged aphid to the right. Notice the leaf remains green during initial infestation. **Insert:** Body detail of wingless aphid. Source: T. Ahrens and M. Brewer, Texas A&M AgriLife

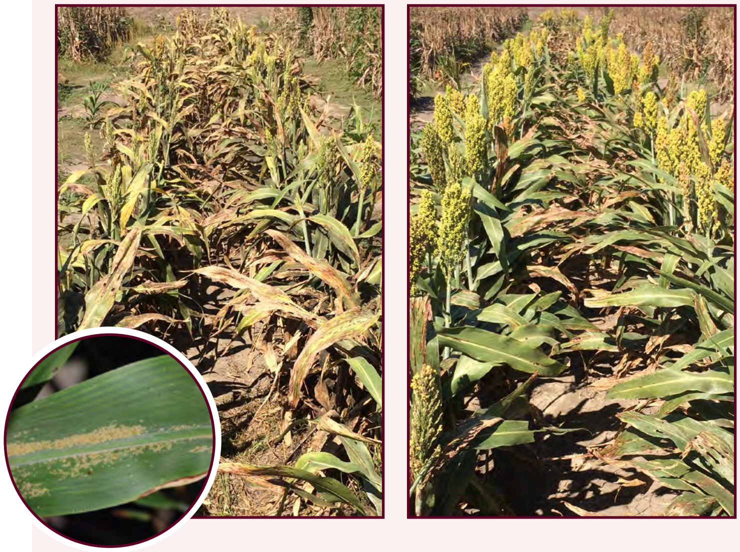

Figure 2. Left: Grain sorghum damage caused by heavy sugarcane aphid pressure above 500 aphids per leaf (insert shows underside of infested leaf). **Right:** Crop infested with less than 50 aphids per leaf. Source: J. Gordy and M. Brewer, Texas A&M AgriLife

DAMAGE

Sorghum damage results from a combination of loss of plant nutrients, increased plant water stress, induced leaf chlorosis, and reduced photosynthesis because of the buildup of sooty mold on the honeydew the aphids excrete.

Initially, sorghum foliage remains green despite the presence of numerous aphids (Fig. 1). An uncontrolled infestation can reduce the number of heads and seed weight, increase head sterility, delay plant development and maturity, and lead to plant death (Fig. 2). Additional loss of grain sorghum at harvest is possible because heads fouled with sticky honeydew can affect grain quality and harvest efficiency. In forage sorghum, mold can reduce sorghum quality and honeydew buildup can cause cutting and baling problems.

MANAGEMENT

In southern areas, begin weekly aphid monitoring for first detection soon after plants emerge. In more northern areas, use information from southern latitudes about crop maturity and aphid population growth to help time monitoring. Once a field is infested, evaluate aphid risk twice a week to determine if and when to treat with insecticides. Contact local pest management professionals for information on insecticide choice and application timing.

Some sorghum hybrids show reduced damage from sugarcane aphids. Resistant hybrids will likely become a major sugarcane aphid management tool. Insecticide-treated seed is effective in protecting young plants, but not if aphids arrive after the seed treatment wears off.

Natural enemies of sugarcane aphids include lady beetles, syrphid flies, green and brown lacewings, and aphelinid parasitoids (black mummified aphids, Fig. 1). Field observations indicate that even in the presence of natural enemies, aphid populations can increase to damaging levels. Selecting insecticides specific to aphids or sucking bugs can help conserve these natural enemies.

As more sorghum hybrids with at least partial aphid resistance become available and natural enemies fully adapt to this new aphid as prey, the combined impact of sorghum resistance and natural enemies should improve aphid management.

ADDITIONAL RESOURCES

Scan these QR codes to learn more.

United Sorghum Checkoff Program. 2016.

The Sugarcane Aphid: Management Guidelines for Grain and Forage Sorghum in Texas. A. Knutson, R. Bowling, et al. 2016.

"Sugarcane Aphid (Homoptera: Aphididae): A New Pest on Sorghum in North America." *Journal of Integrated Pest Management.* R. Bowling, M. Brewer, et al. 2016. (Search title, available fall 2016).

ACKNOWLEDGMENTS

Thanks to the Texas Grain Sorghum Board, United Sorghum Checkoff Program, and USDA-NIFA (Southern IPM and Crop Protection and Pest Management Programs).

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G2236

The Spotted Wing Drosophila, An Invasive, Small Fruit Fly in Nebraska

James A. Kalisch, Extension Associate, Department of Entomology
Robert J. Wright, Extension Entomologist

The spotted wing drosophila is an invasive fruit fly species now appearing in Nebraska. Its description and methods to control it are provided in this publication.

The spotted wing drosophila (SWD), *Drosophila suzukii*, is a small fruit fl , about 3 mm in length, which closely resembles the familiar and common fruit fl , *Drosophila melanogaster*. It is an exotic, invasive pest from Japan and eastern Asia that actually injures ripening, sound fruit and has the potential to be an annual, devastating pest in fruit production in the United States and Nebraska.

Distribution

Since SWD was first discovered in 2008 in California on strawberries and raspberries, it has quickly spread across the continent, most recently across the Great Plains states late in 2013. It has been increasing in population locally and across the country and is generally considered to be well established as a pest requiring management annually.

Identificatio

SWD can be identified most easily by a conspicuous black spot near the tip of each wing of the adult male (*Figure 1*). Confirming the identity of a female requires magnification in order to see the ovipositor at the tip of the abdomen, which is hardened and has two rows of saw-like teeth that lacerate the skin of fruits in order to insert eggs into the flesh *Figure 2*).

Figure 1. Spotted wing drosophila male

Figure 2. Spotted wing drosophila female

Life Cycle

There are several generations of SWD per season. Adults overwinter in protective habitats and emerge in late spring. After mating, females seek out thin-skinned fruits and deposit around a dozen eggs per day, ultimately laying an estimated 300 eggs over their lifespan. Eggs take 2-3 days to hatch, and larvae (maggots) reach maturity in several days to a few weeks, depending on temperature. Pupation occurs within dried-up fruit or in soil litter, and the pupal stage may last as little as three days. At an optimal temperature of 28°C (82°F), development from egg to adult can take just over one week! Thus, under ideal summer conditions, population growth of SWD can be explosive and potentially injurious to many crops reaching maturity toward late summer.

Fruit Damage

After egg-laying, the wounds created by the females begin to sink and form depressions. Fungal rots may be introduced through wounds and induce decay. Larval feeding on fruit, yeasts and rot organisms further causes discolored regions and collapse of fruit (*Figure 3*). Creamy-white, mature larvae and pupae may be evident within fruit or on fruit surfaces.

Figure 3. Sour cherry in advanced stages of decay. (Bruce Barrett, University of Missouri)

Fruits Attacked

A wide variety of cultivated thin-skinned fruit crops are vulnerable to attack by SWD, including strawberry, blueberry, blackberry, raspberry (*Figure 4*), cherry, plum, chokecherry, black chokeberry (*Aronia*), peach, apricot, and grapes. Also apple, pear and tomato, especially if damaged, are attractive to infestation.

Figure 4. SWD on raspberry. (Hanna Burrack, North Carolina State University)

Late-bearing fruit varieties are more susceptible to attack, as highest populations of SWD occur in late summer. A number of wild and ornamental berries serve as hosts as well. These include elderberry, wild plum and cherry, currants, buckthorn, serviceberry, dogwood, snowberry, mulberry, grape, pokeweed, black nightshade, groundcherry (*Physalis* spp.), and asparagus.

Monitoring

The utilization of traps for early detection and to monitor numbers of SWD over the season is extremely valuable as a management tool. However, trapping does not guarantee that the very first SWD flies in the area will be intercepted by the traps before they attack fruit.

Traps using apple cider vinegar as an attractant can easily be made and maintained. They can be built from used beverage containers or plastic jars (*Figure 5*). Recent research has indicated that the traps should be placed in shaded areas among host crop plants and that red-colored traps are more attractive.

Essentially a trap consists of a container with secure lid and several 1/8-inch holes drilled into it at the top. Smaller holes at opposing sides on the top are drilled to accommodate attachment of a wire or string for hanging the trap. Pour about a half-inch of apple cider vinegar into the trap. Beneath the center of the lid, attach a sticky card trap piece, obtained at a local garden center or hardware store, into the jar interior to capture adults as they fly into the jar.

Figure 5. SWD apple cider vinegar jar trap

Replace the vinegar and sticky card as needed. Report your first capture of SWD flies to your local Extension office so that such information can be circulated to benefit other growers. Once flies are first captured and confirmed as SWD, management measures can be taken to reduce fly numbers and protect fruit crops by methods compatible with integrated pest management (IPM). Continue to check traps through the season as a monitoring tool for the benefit of other fruit crops nearing maturity.

Checking for Larvae in Fruits

Fruits suspected of being infested with larvae can be placed in the bottom of a zipper-top, heavy-duty food storage bag. Gently crush them by hand. Add a 10 percent sugar solution (1 tablespoon of sugar to 1 cup of water) to the bag. Close it and shake the bag vigorously for several seconds. Let the bag rest and wait for larvae to float to the top

Cultural Methods of Management

Consistently irrigate crops as needed to reduce splitting of fruit skins. Ruptured skin invites fly infestation. Planting thicker-skinned varieties of fruit crops also helps minimize cracking. Since SWD flie prefer fruit that is ripe to overripe, be sure to harvest ripe fruit frequently, or slightly before fruits begin to ripen. Remove any damaged, overripe, infested or fallen fruit immediately and dispose of it so it is not accessible to flies. An effective method of disposal which kills flies and maggots in infested fruit is to seal small amounts of infested fruit in heavy-duty black trash bags, then place them out in full sunlight for at least a week. This will cause the fruit to overheat and kill all life stages of SWD. Finally, a physical method of preventive control is to cover plants or individual developing fruits with fine netting, bags, or cloth just prior to ripening to exclude flies from access to fruit. However, the key is to be absolutely sure the crop up to that point has been free of fly infestations. Covers do prevent bees from pollinating flowers, so if the crop continuously produces flowers, netting would not be appropriate.

Insecticidal Control

A number of insecticides are available for use on various fruit crops for SWD control in Nebraska. Homeowners have a much narrower choice of products than commercial growers. Many are restricted-use insecticides, largely due to toxicity to fish and aquatic organisms, and require certification to apply. It is most important to **read product labels** and to note the waiting period required after treatment to re-enter fields or plantings, and to harvest fruit. Examples of insecticides, each with its respective waiting period for the fruit crops, are listed in *Table I*.

Table I. Insecticides for spotted wing drosophila control

Insecticide Active Ingredient (AI) (R) = Restricted Use	*Waiting Period (Pre-Harvest Interval) in Days*					
	Blueberry	*Cherry*	*Grapes*	*Plum*	*Raspberry, Blackberry*	*Strawberry*
acetamiprid	1	7	3	7	1	1
azadirachtin (neem oil)	0	0	—	0	0	0
bifenthrin (R)	1	—	30	—	3	0
carbaryl	7	3	7	3	7	7
fenpropathrin (R)	3	3	21	3	3	2
lambda-cyhalothrin (R)	—	14	—	14	—	—
malathion	1	3	3	—	1	3
permethrin (R)	14	3	—	—	14	14
phosmet	3	7	7	14	—	—
pyrethrins	0	—	0	—	0	0
spinetoram	3	7	7	7	1	1
spinosad	3	7	7	7	1	1
zeta-cypermethrin (R)	1	14	1	14	1	—

NOTE: A dash (—) in a table cell means that the insecticide was not labelled for this fruit crop.
In order to protect valuable pollinators such as honey bees, bumble bees and many other kinds of wild bees, look at product labels for instructions regarding safety to pollinators, if any. Also, try to apply insecticides when pollinators are least active, as in the very early morning or in the late evening.

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Index: Insects & Pests
Other Pests
Issued April 2014

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

Panhandle Year In Review

Jeff Bradshaw, Extension Entomology Specialist

Some of the most notable insect concerns in 2016 were locally-intense grasshopper infestations and ear-feeding caterpillars in corn. There were also a few producers that were concerned with insects such as grass veneers and sod webworm moths being mistaken for sunflower head moth and march flies being mistaken for sawflies.

Below I've provided some images or injury associated with these insects with a brief summary of their biology.

Codling Moth

Figure 1. Codling moth larva in an apple.

Sometimes you can bite off more than you want to chew. The PHREC Entomology Lab saw samples or had more calls from codling moth this year. As an adult, this moth has about a 0.5 to 0.75-inch wingspan. As a larva (Fig. 1) it is about 0.5 to 0.75 inches in length and has a pinkish coloration. This moth has two generations per year in Nebraska and after the female moth lays eggs on the surface of small, developing apples in the spring, the larvae will bore into the flesh of the apple where they will feed and remain until mature. Once the larvae reach maturity they will exit out of the apple and drop to the ground. Proper sanitation practices (e.g., picking up fallen apples throughout the growing season) can greatly facilitate the management of this insect in our area.

For further information see, *Codling moth management in apple* included in these proceedings.

Garden Symphylan

Figure 2. Healthy sugar beet (left) and sugar beet stunted by garden symphylan (right).

The garden symphylan is a sporadic pest of several crops. Common crops in rotation under irrigation in our region such as corn, sugar beet, and dry beans are all potential hosts for this arthropod. This pest persists under high-residue, moist conditions. At the field scale, symptoms will appear as patches of severely-stunted plants (Fig 2.). If left unchecked, these areas will continue to grow over years.

Data on control options are weak due to the sporadic nature of the pest. However, some at-plant insecticides have shown promise.

Woolybear caterpillars

Figure 3. Woolybear caterpillars on radish cover crop.

Although occasionally a pest in soybean the yellow woolybear is not a common pest in the Nebraska panhandle. This picture shows two or three species of woolybear caterpillars that were found feeding on a demonstration covercrop plot of radish in Grand Island. Although these were not in the panhandle, I think it provides a good example that cover crops might have pests too or that they could serve as a reservoir for pests of crop in rotation with cover crops.

Grasshoppers

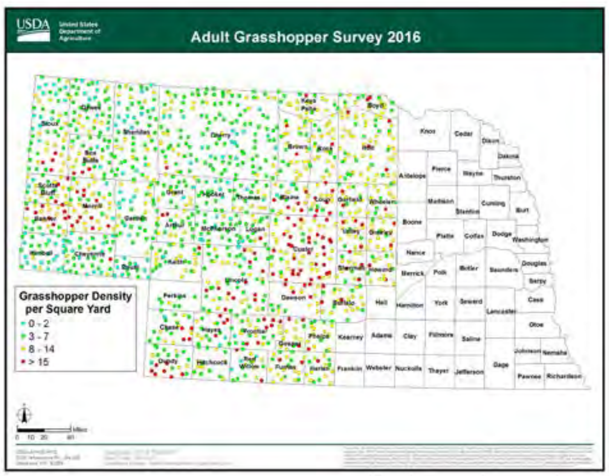


Figure 4. Map from USDA-APHIS showing distribution of adult grasshopper densities in Nebraska in 2016.

Eventually we are going to have to start thinking about grasshoppers again once their populations begin to cycle back into an outbreak configuration. Some areas of the panhandle saw grasshopper abundance on rangeland that were greater than 15 adult grasshoppers per square yard (Fig. 4). However, problematic populations were more common in central Nebraska in 2016.

Corn earworm

Figure 5. Corn earworm larva.

Some locations in the panhandle saw moderate increases of ear-feeding caterpillars (e.g., western bean cutworm and corn earworm) (Fig. 5). Some of this can be prevented if the grower is aware of the right traits to plant.

Figure 6. Corn ear injury from ear-feeding caterpillar.

Once ear-feeding caterpillars get into the ear, they are protected from insecticides (Fig. 6). Therefore, either planting the proper Bt-protected variety or using the proper timing of insecticide at the correct threshold for treatment, will save you money.

Grass veneers and Sod Webworms

While not a pest grass veneers and sod webworm moths were very abundant in June. They are pests on grasses and turf and not on field crops. However, some growers that noticed them in their sunflowers were concerned that they were sunflower head moths.

Figure 7. A species of grass veneer that was common this fall.

Lygus Bugs in Field Pea

Figure 8. Adult lygus bug.

Lygus bugs (Fig. 8) are currently not a major pest in Nebraska. However, they are present and as our field pea acres continue to increase, this should be an insect to be aware of while scouting field peas and sugar beets.

Wheat Stem Sawfly

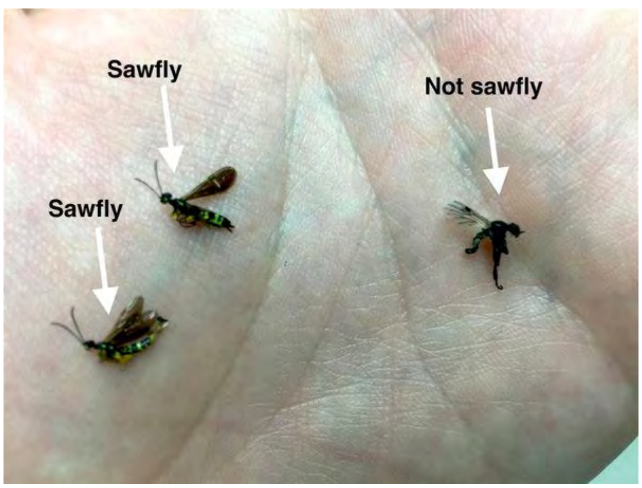


Figure 9. Wheat stem sawflies (left) and Mach fly (right).

There were heavy populations of March flies (Fig. 9) in and around wheat fields in early June. Some growers were concerned that these were wheat stem sawfly. Note the difference between the wheat stem sawfly and flies before letting panic set in. However, we are still seeing very high populations of wheat stem sawflies in panhandle counties.

Wheat Stem Sawfly Parasitoids

Figure 10. Adult *Bracon cephi*, a parasitoid of the wheat stem sawfly.

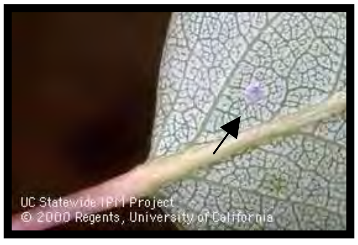
We began to see *Bracon cephi* (a parasitoid of the wheat stem sawfly) emerging from field-collected samples in January. This suggests that it is possible for this important beneficial insect to overwinter in residue in Nebraska wheat fields. Based on research from Montana, this insect pupates primarily in the upper portion of the wheat stem; therefore, stripper-header combines may conserve their numbers and thereby increase wheat stem sawfly parasitism. The might not be the only method that we might use in our agricultural systems to conserve this parasitoid. Research is currently funded by the Nebraska Wheat Board to understand the role of landscape conservation practices in conserving this parasitoid.

Codling Moth Management in Apple

THE CODLING MOTH is the most serious insect pest of apple in the Midwest because the larvae feed inside the apple, leaving an unsightly hole that can promote internal rotting. Because growers have a low tolerance (<1%) for codling moth injury (more than one damaged fruit in 100 is usually considered unacceptable), control strategies usually consist of frequent applications of broad-spectrum insecticides throughout the growing season. However, codling moth can also be managed successfully using IPM techniques that include cultural controls, mating disruption, and well-timed applications of reduced-risk insecticides.

Causal Organism

The codling moth (*Cydia pomonella*) is found in most of the major fruit-producing regions of the United States. The adult is approximately one inch long with a mottled grayish brown body. It can be distinguished from other moths by coppery areas at the tips of the wings. Newly emerged larvae are white with black heads, and mature larvae are about 3/4 inch long with light pink bodies and brown heads.



Egg

Mature Larvae

Adult Moth

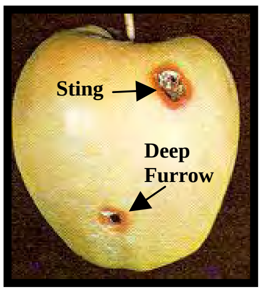
Ecology and Life Stages

The codling moth over-winters as a mature larva in a dense, silken cocoon found under loose bark or in debris underneath the tree. These larvae pupate in the spring and begin to emerge during the bloom or petal-fall stages of apple development. This emergence is often called the "first" or "spring flight".

Eggs are laid primarily on leaf surfaces near the fruit. They hatch one to three weeks later, depending on the air temperature. Newly-hatched larvae usually enter the apple fruit through its calyx or sides, and feed on the flesh and seeds of the apples.

Full grown larvae burrow out of the apple and form silken cocoons in which to pupate. There are between two and three generations each year in the Midwest.

Damage

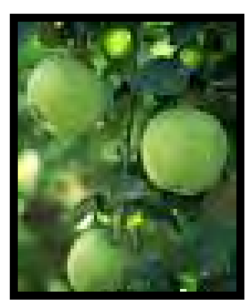


Larvae bore into the fruit and begin chewing their way to the core, where they feed on the seeds. They push their waste material (frass) out the entrance and exit holes; this type of damage is often referred to as a *deep entry*. Sometimes a larva will bore into the fruit a short distance, and then either die or move to another location to feed, leaving a little shallow hole called a *sting*. Small amounts of frass may or may not be present at sting sites.

Cultural Methods for Codling Moth Management:

Traditional codling moth control is achieved with regular, frequent sprays of organophosphate insecticides. Because these pesticides may pose human and environmental health risks, several new reduced-risk and Integrated Pest Management (IPM) options have been tested in the Midwest in recent years. There are several cultural techniques that can be used to reduce the number of insecticide applications necessary for control of the codling moth.

1. <u>Pruning and Thinning</u>. Pruning and thinning each spring can aid in codling moth control. These strategies allow for improved insecticide spray penetration and coverage. When every apple is thoroughly covered with the insecticide, the moths and larvae are more likely to come into contact with poisoned fruit surfaces, and the insecticide is more likely to come into contact with eggs.



2. <u>Removal of Alternate Hosts</u>. In addition to apple trees, pear and walnut trees can act as a refuge for codling moths. These trees should either be removed from sites near the orchard, or included in any codling moth treatments applied to the rest of the orchard. In addition, aples that will not be picked from young nursery trees should be removed early in the season.

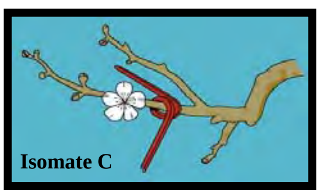
Cultural Methods for CM Management, continued:

3. <u>Removal of Dropped Fruit</u>. Codling moth-infested fruit often drop from the tree early in the season. Raking and removing these apples from the orchard will prevent larvae maturing in these dropped apples. Picking infested apples off the tree is also an effective preventative measure, but is only practical in small orchards.

Mating Disruption:

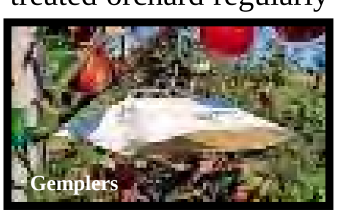
Mating disruption is a relatively new codling moth control tactic that can be very effective in certain orchards. In this technique, the female sex pheromone of the codling moth is released in enormous quantities in the orchard, preventing the male moth from locating the female for mating. This technique is safe for non-target insects and doesn't leave pesticide residues on the fruit. The efficacy of mating disruption is conditional, however, and you should be aware of the following factors:

1. <u>Dispenser Choice and Rate</u>. There are several commercial products designed to release synthetic codling moth sex pheromone. In the most common type of dispenser, the pheromone is located in a reservoir from which it is released slowly into the orchard over several weeks (see diagram at left). These products usually require a rate of 200-400 dispensers per acre. Other products have a sprayable pheromone that can be applied via an airblast sprayer and typically last for 2 weeks before subsequent sprays are needed. There are also mechanical devices ('puffers') that will emit large quantities of pheromone into the orchard atmosphere, allowing air flow to distribute the pheromone.



2. <u>Orchard Choice</u>. Research has demonstrated that codling moth mating disruption is most effective in larger orchard blocks (>10 acres). In smaller orchards, mating disruption may not provide reliable control. Ideally, the orchard should also be relatively square and level, and the trees should be of approximately equal size. In addition, the area should also have a moderate to low codling moth population.

3. <u>Pheromone Traps</u>. Because mating disruption does not kill the moths, it is important to monitor the treated orchard regularly to be sure that control is occurring. The easiest way to monitor moth activity in the orchard is through sex pheromone traps. In orchards under a regular spray program, pheromone traps loaded with a 1-mg lure and placed in the lower to mid-level of the canopy are sufficient for monitoring purposes. However, in mating disruption blocks the pheromone traps should be loaded with a 5- to 10- mg lure, and the traps should be placed in the upper canopy of the tree (no later than the bloom period). Use one trap for every 2-3 acres under mating disruption. A cumulative trap capture of more than 10 moths during the first generation suggests that mating disruption is not working (too high a moth population is present) and that supplemental insecticide sprays should be applied.



Mating Disruption, continued:

4. <u>Fruit Checks</u>. In addition to the use of sex pheromone traps to monitoring moth populations, it is also important to monitor fruit for codling moth damage throughout the season in orchards under mating disruption. This will allow you to make an "emergency" insecticide application if mating disruption does not suppress the moth population to economically acceptable levels. When the pheromone traps begin trapping moths in the spring, 20-25 trees from border rows and the center of the plot should be examined for stings and deep entries. If more than 0.5% of the inspected apples are damaged, an additional insecticide treatment should be applied.

5. <u>Timing</u>. Traps and dispensers should be placed in the orchard before the moths appear. Moths emerge in the spring just after petal fall, so dispensers should be deployed in the orchard no later than the bloom period. Degree day and biofix calculations (see below) can be used when deciding when to rate fruit.

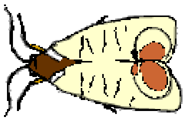
Chemical Methods for Codling Moth Management:

Well-timed insecticides are often the most effective method for managing codling moth. In fact, in orchards with very high populations of codling moth, insecticide use is the only method to achieve consistent control. Several lower-risk insecticides, such as insect growth regulators (IGRs) and other new products, have recently been labeled for use against codling moth. Efficacy trials conducted in Iowa and Missouri during 2001 and 2002 have demonstrated that many of these newer compounds can be successfully used to control codling moth, especially in orchards with low moth densities. In addition, the incorporation of these lower-risk compounds in rotation with other products help to slow the build-up of codling moth resistance to many insecticides.

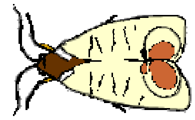
1. <u>Spray Timing by Degree Days and Trap Catches</u>. The key to the successful application of any codling moth insecticide is timing. The life stage and relative size of a codling moth population can be determined using the degree day model and pheromone traps. Pheromone traps should be checked twice per week to determine **biofix**, or the initial emergence of over-wintering first generation moths. Biofix occurs when there is an average of more than three moths caught in a trap over a 3- to 5-day period. For the rest of the season, these traps can be an effective way to monitor not only population cycles, but also the relative success of insecticide sprays.

Trap counts can be used in combination with degree-days (DD) to accurately pinpoint the stage of moth development. The degree day model is based on a developmental threshold of 50˚ F for moth development and works as follows: Begin calculating degree-days at biofix. Calculate the maximum and minimum temperatures for each day and fit them into the following equation: [(Max + Min)/2]-50. For example, on a day when the maximum temperature is 84˚ F and the minimum is 62˚ F, the total degree-day count would be 23 DD. The daily DD counts should be summed and accumulated as the season progresses.

Chemical Methods for CM Management, continued:



The codling moth developmental model (using degree-days) indicates that first generation (over-wintering) moths lay their eggs around 100 DD after biofix. By 250 DD after biofix, the eggs are beginning to hatch, and about half of the larvae have emerged. This is a time when many insecticides for codling moth control are first applied. The second flight of moths usually begins between 1,000 and 1,250 DD.



2. Insect Growth Regulators. The use of some insect growth regulators (IGRs) has been effective in managing codling moth. These compounds usually disrupt the pest insect's normal growth and development at an immature stage, and are not usually toxic to non-target organisms. Timing is often critical for the successful use of IGRs. For example, methoxyfenozide (trade name Intrepid) causes a premature lethal molt of caterpillars. It should be applied at the initiation of egg-laying (100-200 DD after biofix) and again two weeks later. Further sprays can be applied when pheromone trap catches indicate that they are necessary. Another IGR, pyriproxyfen (Esteem), mimics the juvenile hormone and suppresses embryogenesis. It can be used to control first generation codling moth and should be applied at 100 DD following biofix and again 14 days later.

3. Reduced Risk Insecticides. Besides IGRs, there are several other reduced-risk insecticides that have also been tested for codling moth control. Some examples of these types of pesticides include acetamiprid (trade name Assail) and spinosad (trade name SpinTor).

4. Other Insecticides. The codling moth spray schedule used by most commercial Midwest growers is a 2-week alternation of organophosphates, such as azinphos-methyl (trade name Guthion) and phosmet (trade name Imidan). However, the use of Guthion has been severely restricted on apple, and Imidan is facing similar restrictions. Furthermore, there have been several reports of codling moth resistance to Guthion in the Midwest. Nevertheless, azinphosmethyl and phosmet continue to be the most commonly used insecticides for codling moth. This is because other broad-spectrum insecticides, such as synthetic pyrethroids and carbamates (Danitol and Sevin, respectively), that are also labeled for codling moth, may be harmful to beneficial insects and/or are labeled for limited use in the orchard.

An understanding of the biology and population dynamics of codling moth is very important to the successful management of this pest in your orchard, especially when using IPM tactics that depend on accurate pest monitoring (e.g. mating disruption and IGRs). Well-timed applications of appropriate insecticides can be combined with cultural strategies in an IPM program for safe, effective codling moth control.

More Information:

• For diagnosis of codling moth damage to your apples, fill out the "plant disease identification form" available at your county extension office or online at

www.extension.iastate.edu/Publications/PD31.pdf (Iowa)
http://plantclinic.cropsci.uiuc.edu/dffcrops.pdf (Illinois)
http://agebb.missouri.edu/pdc/ (Missouri)
http://www.entomology.wisc.edu/entodiag.html (Wisconsin)

• Then send this form and a plastic-wrapped apple in a sturdy box to:

Plant Disease Clinic
323 Bessey Hall
Dept. Plant Pathology
Iowa State University
Ames, IA 50011

Plant Clinic
University of Illinois
1401 W. St. Mary's Rd.
Urbana, IL 61802

Insect Diagnostics Clinic
Dept. Entomology
Univ. Wisconsin-Madison
1630 Linden Drive
Madison, WI 53706-1598

Plant Diagnostic Clinic
42 Agriculture Building
University of Missouri
Columbia, Missouri
65211

• For more information on codling moth, see the Midwest Apple IPM web page at:

www.public.iastate.edu/~appleipm

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Regional Pest Alert

Brown Marmorated Stink Bug

The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is an exotic insect new to North America. Large numbers of adult BMSB were first identified in fall 2001 in Allentown, PA; however, undetermined sightings likely date as far back as 1996. This Asian native, sometimes called the yellow-brown or East Asian stink bug, has since been found in several Pennsylvania counties, in New Jersey on plant material and in blacklight traps, and in western Maryland on buildings in 2003. In 2004, BMSB also was detected in West Virginia. The list of positive states will continue to expand as awareness increases.

Origin of BMSB

BMSB is a known pest of fruit trees and legumes in its native China, South Korea, Japan, and Taiwan. The adults might have entered the United States as stowaways in packing crates from Asia. The first Western Hemisphere identification was made in October 2001; however, there are reports that indicate it was present in the same area as early as 1996.

Host Range

BMSB is polyphagous, with a long list of host plants including many fruit and shade trees and other woody ornamentals as well as legumes and various vegetables. In Asia, it has been reported as a significant pest of fruit trees and soybean, *Glycine max*. Asian hosts include *Pyrus* spp. (pear), *Prunus* spp. (cherry, peach, and apricot), *Malus* spp. (apple), *Morus* spp. (mulberry), *Ficus* spp. (fig), *Diospyros* spp. (persimmon) as well as *Arctium* spp. (burdock). The expanding host list in the United States includes *Pyrus serotina* (Asian pear), *Prunus persica* (peach), *Paulownia tomentosa* (empress tree), and *Buddleia* spp. (butterfly bush, where leaf feeding was observed). Other U.S. plants on which BMSB feeding is known include *Catalpa* spp., *Rosa rugosa*, *Phaseolus* spp. (bean), *Abelia* spp., *Lonicera* spp. (honeysuckle), *Acer platanoides* (Norway maple), *Vitis* spp. (grape), and *Rubus* spp., (raspberry).

Adult brown marmorated stink bug on fruit

Brown marmorated stink bug nymph

Potential Impact and Spread

Adult BMSB can fly and thereby expand their range; but, as with many other pests, dissemination also could be accomplished by hitchhiking on vehicles and through commerce. Human activity will undoubtedly speed the spread of this pest. Because of its wide host range and the damage resulting from its feeding, BMSB has the potential to have a very tangible impact on agricultural crops, particularly those that are not normally treated for insect pests during the growing season. Currently, it is believed that BMSB is increasing its local population levels and will likely extend its range to other northeastern states in the near future. Surveys are ongoing in several states to detect and monitor this pest and its potential impact on agriculture. However, because this stink bug initially feeds on common landscape ornamentals, homeowners are likely to be the first to spot new infestations.

Northeastern IPM Center

APHIS

Life History and Identification

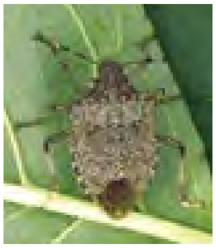
BMSB overwinters as adults in houses and other protected places. Adults emerge from their overwintering sites in April. This typically shaped stink bug ranges in length from 14 to 17 mm and is dark mottled brown. The last two antennal segments have alternating broad light and dark bands. The exposed abdominal edges also have alternating dark and light banding. From June to August, females lay clusters of 20–30 light green, barrel-shaped eggs on the undersides of leaves. Newly hatched nymphs are yellowish mottled with black and red. Older nymphs are darker with banded legs and antenna, like the adults. Adult BMSB are most similar in appearance to *Brochymena*, a very common group of native grey-brown stink bugs. However, *Brochymena* spp. lack the alternating light and dark antennal markings. *Brochymena* spp. also have distinct teeth on the lateral edges of the pronotum, whereas the lateral pronotal edges of BMSB are smooth.

Damage

BMSB feeding can cause small necrotic areas on leaves and fruit. Fruit damage may include water-soaked lesions and/or cat-facing damage, ranging from mild to severe. In addition to plant damage, BMSB can become a major nuisance to people as adult bugs congregate in overwintering sites, invading houses and other buildings, in a manner similar to boxelder bugs, Asian ladybird beetles, and cluster flies. When disturbed, the bugs produce a characteristic odor that adds to their nuisance potential.

If you suspect you have encountered BMSB, contact your State Department of Agriculture, University Diagnostic Laboratory, or Cooperative Extension Service. Specimens should be collected and positively identified before any action is taken.

Brown marmorated stink bug nymph feeding on Asian pear



(above) Newly hatched brown marmorated stink bug nymphs on egg mass

(left) Adult brown marmorated stink bug

Northeast 1862 Land-Grant Universities

University of Connecticut University of Delaware University of Maine University of Maryland University of Massachusetts University of New Hampshire Rutgers University Cornell University Pennsylvania State University University of Rhode Island University of Vermont West Virginia University

For more information and images of BMSB, visit **http://northeastipm.org/bmsb.**

This publication was produced and distributed in cooperation with USDA–CSREES Integrated Pest Management Centers, Maryland Department of Agriculture, USDA-APHIS, and the Land-Grant University System. For more information regarding the development of this document, contact Carol A. Holko at **holkoca@mda.state.md.us** or by phone at 410-841.5920.

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Northeastern IPM Center

What's New in Entomology: West Central Nebraska

Julie A. Peterson, Extension Entomology Specialist

Grasshoppers at Field Edges

Grasshoppers can be a concern to farmers and ranchers, particularly in areas with less than 25 inches of annual rainfall (typically the western half of Nebraska). Populations can fluctuate in cycles, with 2-4 years of high numbers followed by 2-4 years of low numbers. These cycles are affected by disease and environmental conditions, such as food availability and rainfall. In 2016, surveys conducted by the USDA-APHIS showed that the highest grasshopper populations in Nebraska were found in select areas of central, southwest, and Panhandle regions (Fig. 1). Additional information and support tools to determine when and if grasshopper controls are needed can be found at
http://entomology.unl.edu/grasshoppers/index.shtml.

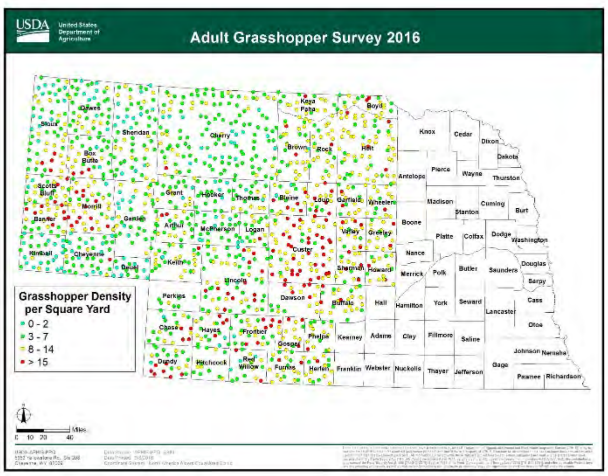


Figure 1. Map from USDA-APHIS showing distribution of adult grasshopper densities in Nebraska in 2016.

Table 1. Treatment guidelines based on number of grasshoppers (nymphs and adults) per square yard (from NebGuide G1627).

Grasshopper Population	Within Field	Field Border	Treatment Necessary?
Non-economic	0-2	5-10	No
Light	3-7	11-20	Questionable: depends on size, species, type of crop
Moderate	8-14	21-40	Probably
Abundant	15+	41+	Yes

Out of the more than 100 grasshopper species found in Nebraska, only four species are responsible for almost all damage to crops: 1) migratory, 2) differential, 3) twostriped, and 4) redlegged. Wheat, alfalfa, soybean, and corn can all be fed on by grasshoppers. Populations are often highest at the edges of fields. In 2015, some growers in southwestern Nebraska experienced grasshopper populations around field edges that warranted treatment. Treatment thresholds for this pest are determined by estimating the number of grasshoppers per square yard (Table 1). Details on best methods for scouting can be found in the NebGuide G1627: A Guide to Grasshopper Control in Cropland.

Western Bean Cutworm

The western bean cutworm (WBC) is a destructive insect pest that can cause severe yield loss (up to 40% and 10%, respectively) in corn and dry beans; see "Western Bean Cutworm Update" for more information. Although WBC infestations are found in western Nebraska every year, moth flights and pest pressure have been particularly high in these areas in recent years. A black light trap set up to monitor WBC and other moth populations each summer in North Platte, NE indicated that flights were lower in 2016 than 2013-15, but higher than 2010-12 (Figure 2). Single night trap catches peaked at 222 moths on July 18, 2016 compared to 287 moths on July 15, 2015. These high moth flights have resulted in high oviposition rates in some corn fields in southwest and central Nebraska counties.

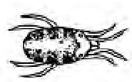
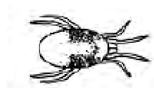
Scattered reports from southwest and north central Nebraska of greater than expected damage from western bean cutworm to corn hybrids expressing the Cry1F protein and/or following pyrethroid insecticide applications have prompted investigation into the possibility of Bt resistance issues. UNL Entomologists have been exploring this issue by collecting problematic field populations and conducting bioassays; this work will continue in 2016. If you have experienced greater than usual damage to Cry1F Bt corn due to WBC or a lack of control of WBC using pyrethroid insecticide applications, please contact Julie Peterson.

Spider Mites

Economically significant numbers of spider mites were found on corn in 2016 in the Kearney, McCook, and Imperial areas. Typically, spider mite populations are favored by hot, dry weather, sandy soils, drought-stress in crops, use of insecticides, and loss of natural enemies. Two species of spider mites are found in Nebraska: 1) Banks grass mite (BGM) and 2) two-spotted spider mite (TSM). A third type of mite, known as the carmine mite (for its dark red appearance) can also be found in Nebraska; it has recently been determined that this is a red color morph of the two-spotted spider mite (Fig. 3). These two species vary in biological attributes that are important for pest management, such as host range and susceptibility to insecticides (see Table 2).

Figure 3. The dark red carmine mite, which is now considered to be the same species as twospotted spider mite. Photo: Sarah Zukoff.

Table 2. Comparison of mite species: adapted from NebGuide: Spider Mite Management in Corn and Soybeans.

	Banks grass mite (BGM)	**Two-spotted spider mite (TSM)**
Appearance (adult females)	 Dark green pigment spots extend down length of body; body more elongate	 Dark green pigment in two distinct spots on front 1/2 of body; body more rounded
Webbing	Produces spider-like silk webbing	Produces spider-like silk webbing, tending to produce more webbing than BGM
Host Range	Almost exclusively grasses, such as corn & sorghum	Many grass species (corn, sorghum), plus soybeans, fruit trees, vegetables, and ornamentals
Timing	Appear earlier in the season	Tend to appear mid- to late-season
Location on Crop	Mostly lower leaves, moving upwards as the infestation grows	Can feed over the entire plant
Overwintering Location	Primarily the crowns of winter wheat and native grasses	Primarily alfalfa and other broadleaf plants along crop field borders
Susceptibility to Insecticides	Moderately susceptible to many common miticides	Have developed resistance to some products, control is less consistent

Insecticide applications to corn fields for western bean cutworm or western corn rootworm adults can lead to spider mite flair ups by eliminating the beneficial organisms that feed on spider mites, usually keeping their populations in check. Many beneficial predators will attack spider mites, including predatory mites, mite destroyer and other ladybeetles, predatory thrips, minute pirate bugs, lacewing larvae, and hoverfly larvae (Fig. 4).

Figure 4. Ladybeetle larva, ladybeetle eggs, and hoverfly larva on Banks grass mite colonies near Paxton, NE. Mites did not need to be treated at this field due to control by predators.

Dectes Soybean Stem Borer

This grey, elongate beetle with long antennae (Fig. 5) has historically been a pest of commercial sunflowers in the central U.S. However, it has been using soybean as a host more recently, being first found damaging soybean in south central Nebraska in 2000. In 2015, this insect was found at damaging levels in soybeans near McCook and North Platte, further west and north than previous records.

Figure 5. Adult *Dectes* stem borer on soybean near North Platte, NE.

Female beetles lay eggs singly into the petioles of soybean leaves from late June to August. When larvae hatch, they feed and tunnel through the petiole and into the main stem. Feeding in the petiole will cause the leaf to wilt and die; observing single, dead leaves in an otherwise healthy canopy is an early sign of *Dectes* stem borer presence. Larvae will tunnel and feed in the main stem before girdling the stem near the base to make an overwintering cell. This girdling behavior weakens the stem, which can lead to lodging and subsequent yield loss due to harvesting difficulties. Larvae will spend the winter in the soybean stubble, pupate, and emerge the following June, completing the single generation per year.

Effective chemical controls have been difficult to develop due to the long emergence and egg-laying period of adults and the internal feeding habit of larvae. However, several cultural control practices are listed below:

- Targeting fields with suspected stem borer infestation for earliest harvest to avoid lodging
- Weed management to reduce alternative hosts, such as wild sunflower, ragweed, and cocklebur
- Use of commercial sunflowers as a trap crop, due to their preference over soybeans
- Burying of soybean stubble by tillage
- Crop rotation (avoiding continuous soybean)- more effective in areas where soybean acreage is limited
- Selection of longer season soybean varieties

Moths in Soybean Fields

Small moths were observed in large numbers in some soybean fields in 2016. It is important to note that not all of the moth species that take refuge in a soybean field have larvae that cause defoliation damage to the crop. For example, smartweed borers were observed early in the mornings in soybean fields of southwest Nebraska. These moths are related to European corn borer and their appearance is very similar, except that they are about ½ the size of ECB moths (Fig. 6). They are likely found in soybean fields due to seeking cool, damp locations to rest during the day. The larvae of the smartweed borer feed on a variety of weedy plants such as smartweed, ragweed, cocklebur, snakeroot, and similar plants. While they can also feed on corn, they have not been reported as corn pests in Nebraska.

Figure 6. Smartweed borers can be found in soybean fields, but their larvae do not cause soybean defoliation.

There have also been moths reported in soybean fields that do belong to species whose larvae can cause defoliation damage. This includes green cloverworm and yellow wooly bear (Fig 7). However, the presence of moths alone does not warrant treatment, but is an indication to scout for actively defoliating larvae and damage to the plant. Management decisions should be based on economic thresholds for soybean defoliation, which can be found using this worksheet: http://cropwatch.unl.edu/2016/soybean-defoliation-worksheet.

Figure 7. Green cloverworm and yellow wooly bear moths; photo credits: Robert Aguilar, Yvonne Metcalfe.

For More Information See the Following NebGuides:

- A Guide to Grasshopper Control in Cropland, G1627
- A Guide to Grasshopper Control on Rangeland, G1630
- Western Bean Cutworm in Corn and Dry Beans, G2013
- Soybean Stem Borers in Nebraska, G2082
- Managing Soybean Defoliators, G2259

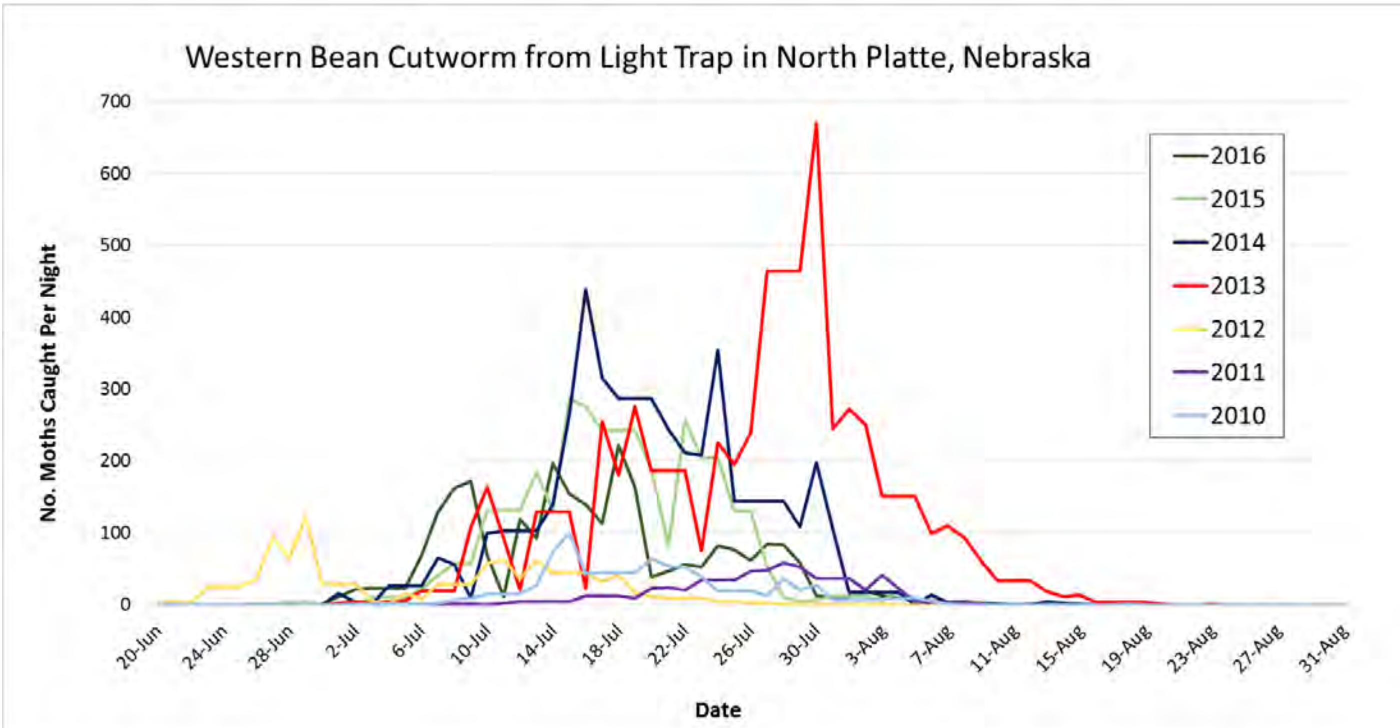


Figure 2. North Platte light trap data for western bean cutworm populations over the past 7 years.

Applying Pesticides Safely

Clyde L. Ogg, Pesticide Safety Educator, Frank Bright, Extension Assistant, and Greg Puckett, Extension Assistant

The world of pesticides is continually evolving. In spite of this, there are many basic principles that commercial and noncommercial applicators should always follow when handling or using pesticides.

It is vital to become familiar with how a product should be used by reading and following its label in order to apply a pesticide properly. The label also provides information about the necessary protective clothing needed when mixing and loading or applying that pesticide, and other precautions that should be taken, such as protecting non-targets like fish, bees, pets, wildlife, livestock or endangered species. Proper storage, transportation, and disposal procedures for a pesticide can also be found there. Remember that the label is the law!

Ensuring the health and safety of applicators and workers is essential. Using personal protective equipment required by the label and following the Worker Protection Standard can help applicators and employers comply with pesticide laws and regulations. An applicator using proper notification procedures about restricted entry intervals and time of application provides the information necessary for an employer to inform and protect employees who may be working in a pesticide treated area. If there is an accidental poisoning or exposure, refer to the pesticide's label for help, consult a medical professional, and call the Poison Center (800-222-1222), National Pesticide Information Center (800-858-7378), or other pesticide helpline to report the incident.

For more information on these and other related topics, see the NebGuides and Extension Circulars following this article:

- *Pesticide Laws and Regulations G479*
- *Worker Protection Standard for Agricultural Pesticides EC3006*
- *Nebraska Pesticide Container and Secondary Containment Rules G2033*
- *Understanding the Pesticide Label G1955*
- *Spray Drift of Pesticides G1773*
- *No Drift Zone: Driftwatch Brochure*
- *Protective Clothing and Equipment for Pesticide Applicators G758*
- *Pesticide Safety: Choosing the Right Gloves G1961*
- *Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications G2083*
- *Pesticides and the Endangered Species Protection Program G1893*
- *Protecting Pesticide Sensitive Crops G2179*
- *Bee Aware: Protecting Pollinators from Pesticides EC301*
- *Rinsing Pesticide Containers G1736*
- *Cleaning Pesticide Application Equipment G1770*
- *Managing Pesticide Spills G2038*
- *Managing the Risk of Pesticide Poisoning & Understanding the Signs & Symptoms EC2505*
- *Safe Transport, Storage, and Disposal of Pesticides EC2507*

The Pesticide Safety Education Program, through the University of Nebraska–Lincoln Extension, is responsible for developing and revising training programs and materials for the commercial/noncommercial applicator. The UNL Pesticide Education Office's website offers a wide variety of resources for the pesticide applicator, including links to register for initial licensing training, recertification training, and to purchase training manuals. For more information:

- Visit the Pesticide Safety Education Program website at http://pested.unl.edu
- Call the Pesticide Education Office toll-free at 800-627-7216 or 402-472-1632 for questions about training dates, study materials, or pesticide education.
- Contact the Nebraska Department of Agriculture toll-free at 877-800-4080 or 402-471-2394 for questions on regulatory issues, license status, or compliance interpretation.
- Connect with us on social media:

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Facebook

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Twitter

http://youtube.com/UNLExtensionPSEP

YouTube

NebGuide

Published by University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

Know how. Know now.

G479
(Revised April 2013)

Pesticide Laws and Regulations

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This NebGuide provides general information on federal and state laws and regulations regarding pesticide applicator certification, licensing, and pesticide use in Nebraska.

A succession of federal laws has addressed pesticides and their use in the United States. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was first approved in 1947 and has undergone several revisions. FIFRA and the Nebraska Pesticide Act, which was enacted in 1993, are the principal statutes governing the use of pesticides in Nebraska. Additional state laws governing the use of pesticides in irrigation water and facilities handling bulk pesticides are administered by the Nebraska Department of Environmental Quality.

FIFRA

Congress intended FIFRA to protect both people and the environment by providing for the controlled use of pesticides. The law encompasses pesticide registration, classification, labeling, distribution, use, disposal, and other topics. Those sections pertaining to pesticide users broadly address key issues: user categories, recordkeeping, certifi ation, and penalties for violations.

General Provisions

FIFRA requires pesticide manufacturers to register each of their products with the U.S. Environmental Protection Agency (EPA) either as a general use (GUP) or restricted use (RUP) pesticide with the exception of a few minimum-risk active ingredients. In some cases, a pesticide's active ingredient may be used in both general and restricted use pesticides.

Restricted use pesticides can be used only by certifie applicators (or noncertified individuals working under the direct supervision of a certified applicator during a once-in-a-lifetime, 60-day exemption from licensing). In most cases, anyone can use general use pesticides according to the label without being certified. FIFRA defines two types of certified applicators: private applicators and commercial applicators. The Nebraska Pesticide Act further define noncommercial applicators in order to address those individuals who do not commercially apply pesticides, and do not meet the definition of private applicato .

From a FIFRA perspective, a private applicator is defined as a certified applicator who uses or supervises the use of a restricted use pesticide to produce an agricultural commodity on property he or she owns or rents, on an employer's property, or on the property of another person *if* there is no compensation other than trading personal services.

FIFRA defines a commercial applicator as any person who uses or supervises the use of restricted use pesticides for any purpose other than as provided in the definition of a private applicator.

Federally registered product labels contain sections that address personal protection; protection of others; and protection of sensitive sites, such as groundwater, surface water, and endangered species. Some pesticide labels direct an applicator to protect endangered species (plant or animal) as per an online bulletin. The online bulletin is considered a legal extension of the container label and must be followed.

Nebraska Pesticide Act and Regulations

The Nebraska Pesticide Act was enacted in 1993. It designates the Nebraska Department of Agriculture (NDA) as the lead state agency responsible for administering the Nebraska Pesticide Act under FIFRA and gives several other state agencies specific responsibilities. The Act requires registration of pesticides sold in Nebraska and state certification and licensing of those wishing to purchase and use any restricted use pesticide and, in certain situations, general use pesticides. It identifies the University of Nebraska Lincoln–Extension as responsible for providing training for private, commercial, and noncommercial applicators. People who attend these training sessions are considered competent to apply pesticides and are certified Once certified, each must become licensed to purchase and use restricted use pesticides, and in some cases, general use pesticides.

Nebraska's pesticide law and related regulations differ from that of FIFRA in several aspects. One difference is that in Nebraska, a pesticide license is required for applicators and mixer/loaders of all restricted use pesticides, although the NDA has allowed mixer/loaders to operate without licensing so long as they complete NDA-developed training every three years and document they took the training. The application of general use pesticides by a commercial applicator in the Ornamental and Turf, and the Structural categories requires a pesticide license, as does outdoor disease vector control in the Public Health Pest Control category. Under the Nebraska Pesticide Act, people wishing to be licensed as private applicators are not required to take an examination. It also stipulates that the minimum age for licensing is 16. Custom farmers are classified as commercial pesticide applicators.

Nebraska law also creates a type of pesticide applicator called noncommercial applicator. This type includes any person who applies RUPs "... only on lands owned or controlled by his or her employer or for a governmental agency or subdivision of the state." In addition, any employee of a political subdivision of the state applying GUPs or RUPs for outdoor vector control must obtain a license in the Public Health category prior to applying such pesticides and are classified by NDA as noncommercial applicators. A pesticide applicator applying pesticides for hire on behalf of a governmental agency must be classifie as a commercial applicator in the Public Health category.

All pesticide applicator licenses are good for a maximum of three years unless revoked by NDA. In order to renew a license, a state license fee must be paid to the NDA by private and commercial applicators before the license expires. Nebraska's law and regulations set the fee for commercial applicators at $90 and $25 for private applicators. This fee is payable to the NDA and must be paid before the license is granted in order to purchase and use restricted use pesticides or general use pesticides as identified above. There is no state license fee for noncommercial applicators.

Pesticide Applicator Licensing

People seeking initial certification (a prerequisite of licensing) as commercial or noncommercial pesticide applicators in Nebraska can attend training provided through UNL Extension and/or complete self-study training materials. In either case, the candidate must successfully pass both a general standards core exam and one or more specifi category examinations. These exams are proctored by the NDA, not UNL. A pesticide license is valid for three years. To become recertified and then eligible to pay the state license fee to obtain the pesticide license, the person must attend either a UNL Extension recertification training program or an equivalent training program approved by NDA. A person wishing to recertify by training must attend that training before the license expires. Any applicator also may recertify by examination.

To become certified as a private applicator, individuals can:

1. Complete an approved training program provided by UNL Extension.
2. Complete a self-study workbook or an online training program provided by UNL Extension.
3. Voluntarily complete and pass an examination administered by the NDA.

Then, the private applicator is eligible to pay the state license fee to obtain the pesticide license. The same options also apply to recertification, which is required every three years.

Commercial and Noncommercial Pesticide Applicator Categories

1. Agricultural Pest Control — Plant
1a. Fumigation of Soil
2. Agricultural Pest Control — Animal
3. Forest Pest Control
4. Ornamental and Turf Pest Control
5. Aquatic Pest Control
5s. Sewer Use of Metam Sodium
6. Seed Treatment
7. Right-of-way Pest Control
8. Structural/Health Pest Control
8w. Wood Destroying Organisms
9. Public Health Pest Control
10. Wood Preservation
11. Fumigation
12. Aerial Pest Control (includes Ag Pest Control Plant category)
14. Wildlife Damage Control

Two subcategories (Regulatory and Demonstration/Research) expand the scope of an applicator's primary category(ies) such as Agricultural Pest Control (1 or 2) or Ornamental and Turf Pest Control (4). The Wildlife Damage Control category (14) covers the chemical control of vertebrate pests such as prairie dogs in pastures or rangeland, coyotes in pastures/holding pens, moles and ground squirrels in lawns/parks/golf courses, etc., when using RUPs. The management of vertebrate pests invading structures with pesticides is covered by the Structural/Health Pest Control category (8).

Direct Supervision

In general, a person must be licensed to use a restricted use pesticide. An individual required to be licensed may use such pesticides as an unlicensed applicator for a period of up to 60 consecutive days beginning on the firs date of the pesticide application. The 60-day exemption is allowed once in that applicator's lifetime. In order to use pesticides as an unlicensed applicator, the individual or his or her employer must apply to NDA for an applicator license within 10 days of making the first pesticide use. Both the licensed and unlicensed applicator are liable for any violations. The licensed applicator, as a supervisor, must possess the correct license category for the work being done and must do the following:

1. Determine the level of experience and knowledge of the unlicensed person in the use of a pesticide.
2. Provide verifiable (documented) detailed guidance on how to conduct each pesticide use performed under his/her direct supervision.
3. Accompany the unlicensed person to at least one site that typifies each different pesticide use the unlicensed individual performs.
4. Be in direct two-way communication with the unlicensed applicator during the application.
5. Be able to be physically on the pesticide use, storage, or mixing/loading site, if needed, within three hours.

Recordkeeping Requirements — Commercial and Noncommercial Applicators

Nebraska Department of Agriculture regulations require commercial and noncommercial applicators of restricted use pesticides and commercial applicators applying general use pesticides for structural pest control to record the following:

1. Name and address of the person for whom the pesticide was applied.
2. Name, address, and pesticide license number of the person making the application. If an unlicensed person makes the application, information must be recorded both for that person and the supervising applicator.
3. Location of pesticide application.
4. Specific name of target pest(s), i.e., insect, weed, or disease.
5. Application site, i.e., name of crop or commodity, type of field, type of surface, etc
6. Day, month, year, and time of application.
7. Trade name and EPA registration number of the pesticide applied.
8. Rate of pesticide applied per unit of measure, i.e., pounds per acre, ounces per 1,000 square feet, etc. For spot treatment, indicate mixture rate.
9. Total amount of pesticide applied to site.
10. Area or size of treated site, i.e., acres, cubic feet, square feet, linear feet, crack and crevice, trap or bait placement, or spot treatment.
11. Method of disposal of any unused, diluted pesticide. If no unused pesticide remained, indicate such.

NDA regulations further recommend that wind speed and direction be recorded along with ambient air temperature, and where applicable, soil, grain, and water temperature. It also is recommended that commercial applicators applying general use pesticides for lawn care purposes keep pesticide application records. Information for each commercial or noncommercial pesticide application must be recorded within 48 hours of the application and kept for a minimum of three years. They may be kept in any format.

For the protection of the grower, his/her family, and employees, application information for any agricultural pesticide, including the restricted entry interval (REI) and personal protective equipment (PPE) required for applicators, must be provided to the grower prior to the application. Application records of RUPs custom applied for a grower either must be provided to the grower within 30 days or held on behalf of the grower.

Licensed commercial applicators can hold the records of restricted use pesticide applications for their clients as long as the client has signed a statement stipulating who is holding the records. Commercial applicators should provide their clients with a copy of the signed statement. Commercial applicators must make these application records available to their clients upon request in a timely manner and maintain separate records for each client.

Recordkeeping Requirements — Private Applicators

Private applicators shall maintain records for a period of three years of each restricted use pesticide application and must include the following:

1. Brand or product name and EPA registration number of the pesticide applied.
2. Total amount of pesticide applied.
3. Location of application; size of area treated; and the crop, commodity, stored product, or site to which a pesticide was applied. Location may be recorded using any of the following designations:
    a. County, range, township, and section.
    b. An accurate identification system using maps and/or written descriptions.
    c. An identification system established by a USDA agency such as the Farm Service Agency or the Natural Resource Conservation Service (with maps or a field numbering system)
    d. The legal property description.
4. Month, day, and year of application.
5. Name and certification number of licensed applicator who made or supervised the application.

Spot treatments — Recordkeeping

Restricted use pesticide applications made on the same day in a total area of less than 1/10 of an acre are considered spot treatments. For these applications, the records must include:

1. Brand or product name and EPA registration number.
2. Total amount applied.
3. Location noted as “spot application” with a concise description of location and treatment; for example, “Spot application, noxious weeds were spot sprayed throughout fields 5 and 6.
4. Month, day, and year of the application.

Since NDA regulations do not specify a time limit for record preparation, federal standards are applied. Therefore, private applicators in Nebraska must prepare RUP application records within 14 days after the application and *must maintain them for a minimum of three years.* Applicators can keep required RUP records in any format.

Access to RUP Application Records

Related sections of FIFRA and the Nebraska Pesticide Act give NDA the authority to inspect private, commercial, and noncommercial applicator records and establishments. Attending licensed health care professionals or those acting under their direction, USDA representatives and state regulatory representatives with credentials have legal access to the records. Authorized people can copy the records, but the licensed pesticide applicator must retain the originals.

Recordkeeping Requirements — Distributors/Dealers

The Nebraska Department of Agriculture requires sellers of RUPs to hold a Nebraska pesticide dealer's license and to be registered with the NDA. Dealers who distribute RUPs must keep a record of each transaction involving an RUP for three years. These records must be made available for inspection upon request by NDA or EPA. NDA regulations require that such records include:

1. Name and address (residence or principal place of business) of the person to whom the RUP was made available. No dealer may make an RUP available to an unlicensed person unless he/she can document that the distribution is to a licensed dealer or the RUP will be used by a certified/licensed applicato .
2. The name and address (residence or principal place of business) of the licensed applicator or dealer who will use the RUP, if different from Section 1 above.
3. The number on the person's license or dealer license number, the state that issued the applicator certificate expiration date, and the category of certification, if applicable.
4. The product name, EPA registration number, and if applicable, the state special local needs (SLN) registration number on the pesticide label.
5. The quantity of pesticide sold.
6. The transaction date.

Whenever an unlicensed person is making the purchase, EPA recommends that dealers also examine one of the following at the time of sale:

1. The original of the pesticide applicator's license and the driver's license or other identification of the person for whom the buyer is purchasing the RUP.
2. A photocopy or other facsimile of the applicator's license, a signed statement from the licensed applicator authorizing the purchase, and proper identification of the buye .
3. A photocopy or other facsimile of the applicator's license, a copy of a signed contract or agreement between the applicator and the purchaser that provides for the proper use of the restricted pesticides, and the proper identification of the buye .

Violations and Penalties

NDA's pesticide regulations specify a broad range of actions for violations of the Nebraska Pesticide Act. Administrative fines imposed for violations are established using a system of base fines that are adjusted in accordance with the gravity of the offense and the business size. Base fines range from $1,000 to $2,500, depending on the nature of the violation. Base fines for subsequent violations range from $2,000 to $5,000, again depending on the violation.

Gravity adjustments are made using numerical factors that increase the seriousness of the violation. The cumulative total of the "gravity values" is used to determine the percentage of base value that will be assessed for a violation. Size of business also is considered in setting the penalty amount. The Nebraska Pesticide Act also includes civil penalties for criminal or repeat intentional violations. These penalties have a maximum of $15,000 for each violation.

Resources

University of Nebraska–Lincoln Pesticide Safety Education Program, *http://pested.unl.edu*

Nebraska Department of Agriculture Pesticide Program, *http://www.agr.ne.gov/pesticide/*

Nebraska Pesticide Act and Pesticide Regulations, as amended (Title 25, Chapter 2), *http://www.agr.ne.gov/regulations/plant/actbm.pdf* for the law; *http://www.agr.ne.gov/regulations/plant/tilw.pdf* for the regulations

Federal Insecticide, Fungicide and Rodenticide Act, as amended, *http://www.law.cornell.edu/uscode/text/7/chapter-6*

This publication has been peer reviewed.

UNL Extension publications are available online at *http://extension.unl.edu/publications.*

Index: Pesticides, General Regulations

1979, 2002-2007, Revised April 2013

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

Worker Protection Standard for Agricultural Establishments

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This NebGuide describes the federal Worker Protection Standard (revised 2015), to help owners or operators of agricultural operations determine if it applies to their businesses, and provide information on how to comply. Some changes take effect Jan. 2, 2017, with the remainder effective as of Jan. 2, 2018.

The U.S. Environmental Protection Agency (EPA) issued the Worker Protection Standard (WPS) to protect employees working on agricultural establishments from exposure to agricultural pesticides, both general and restricted use. Similar to the goal of the Occupational Safety and Health Administration (OSHA), WPS was put in place to provide employees with a safe workplace; the obligation for safety falls on the employer. WPS requires employers to protect two types of agricultural employees: agricultural workers and pesticide handlers (see definitions below), as well as others who may be in the vicinity of a pesticide application. WPS is part of the pesticide label; it is enforceable when a pesticide with a label referencing WPS is used to produce an agricultural crop or commodity. Any farm or community garden that produces agricultural plants for sale, trade, or use in another location meets the definition of an agricultural establishment under the rule, and is subject to WPS.

The EPA manual *How to Comply with the Worker Protection Standard for Agricultural Pesticides−What Employers Need to Know* provides detailed information about WPS. Employers will find this manual to be a valuable resource for compliance. Access information is listed in the **Resources** section at the end of this publication.

Key Terms

Understanding key terms used in WPS is important for compliance. Here are definitions for some key terms.

General terms

Agricultural employer – any person who is an owner of, or is responsible for the management or condition of, an agricultural establishment, and who employs any worker or handler.

Agricultural establishment – any farm (including a vineyard, sod farm, etc.), forest operation, or nursery engaged in the outdoor or enclosed space production (greenhouse, polyhouse, mushroom house, hoop house, high tunnel, etc.) of agricultural plants.

Agricultural owner – any person who possesses or has interest (fee, leasehold, rental, or other) in an agricultural establishment.

Agricultural plants –plants grown or maintained for commercial or research purposes. Examples include plants for food, feed, or fiber; trees; turfgrass; flowers; shrubs; ornamentals; and seedlings. Horticultural plants grown for future transplant are included. Pasture or rangeland used for grazing are not included.

Workers – those who perform tasks related to the production (pruning, rogueing, detasseling, etc.) and harvesting of plants on agricultural establishments who may work in areas where pesticide residues are present. Crop advisors are considered workers if they perform crop advising tasks after the restricted entry interval (REI).

Handlers – those who mix, load, transfer, and apply agricultural pesticides; clean or repair pesticide application equipment; dispose of pesticides or containers; act as flaggers; perform crop advising tasks during a pesticide application or during the REI; or may have direct contact with concentrated pesticides or tank mixes.

Commercial pesticide handling establishment – any enterprise, other than an agricultural establishment, that provides pesticide handler or crop advising services to agricultural establishments.

Crop advisors – those who assess pest numbers or damage; pesticide distribution (the performance of a pesticide on a crop after application such as the spray pattern or coverage and/or its effectiveness); or the status, condition, or requirements of agricultural plants. Crop advisors include crop consultants, crop scouts, and integrated pest management (IPM) monitors.

Labor contractor – person, other than a commercial pesticide handler employer, who employs workers or handlers to perform tasks on an agricultural establishment for an agricultural employer or a commercial pesticide handler employer.

Employ – to obtain, directly or through a labor contractor, the services of a person in exchange for a salary or wages, including piece-rate wages, without regard to who may pay or who may receive the salary or wages. It includes obtaining the services of a self-employed person, an independent contractor, or a person compensated by a third party, except that it does not include an agricultural employer obtaining the services of a handler through a commercial pesticide handler employer or a commercial pesticide handling establishment.

Immediate family – the agricultural owner's spouse, parents, stepparents, foster parents, father-in-law, mother-in-law, children, stepchildren, foster children, sons-in-law, daughters-in-law, grandparents, grandchildren, brothers, sisters, brothers-in-law, sisters-in-law, aunts, uncles, nieces, nephews, and first cousins.

First cousin – the child of a parent's sibling (the child of an aunt or uncle).

Terms regarding personal protective equipment (PPE):

Chemical-resistant – made of material that prevents any measurable movement of the pesticide being used through the material during use.

Waterproof – made of material that prevents any measurable movement of water or water-based solutions through the material during use.

Chemical-resistant suit – a loose-fitting, one- or two-piece chemical-resistant garment that covers, at a minimum, the entire body except head, hands, and feet.

Coveralls – a loose-fitting, one- or two-piece garment that covers, at a minimum, the entire body except head, hands, and feet.

Protective eyewear – goggles; a face shield; safety glasses with front, brow, and temple protection; or a full-face respirator.

Chemical-resistant apron – an apron that covers the front of the body from mid-chest to the knees, made of material that prevents any measurable movement of the pesticide being used through the material.

Chemical-resistant headgear – a chemical-resistant hood or chemical-resistant hat with a wide brim.

Terms regarding application

Closed system – an engineering control used to protect handlers from pesticide exposure hazards when mixing and loading pesticides.

Enclosed cab – a cab with a nonporous barrier that totally surrounds the occupant(s) of the cab and prevents dermal contact with pesticides that are being applied outside of the cab.

Enclosed space production – production of an agricultural plant indoors or in a structure or space that is covered in whole or in part by any nonporous covering and that is large enough for a person to enter, such as a greenhouse, polyhouse, mushroom house, hoop house, high tunnel, and similar structure.

Outdoor production – production of an agricultural plant in an outside area that is not enclosed or covered in any way that would obstruct the natural air flow.

Application Exclusion Zone (AEZ) – the area surrounding the pesticide application equipment that must be free of all people other than appropriately trained and equipped handlers during pesticide applications.

WPS Labeling

All pesticide products affected by the WPS carry a statement in the Agricultural Use Requirements section on the label (Figure 1). This statement informs users that they must comply with all WPS provisions. If you are using a pesticide product with WPS labeling to produce an agricultural plant, you must follow WPS requirements. WPS requirements are not in effect if an agricultural pesticide is used for a nonagricultural use as allowed by the label.

Who Are Affected by WPS?

Examples of employers who may be required to follow WPS are listed below.

- Managers or owners of an agricultural establishment
- Labor contractors (crop advisors, destasselers, etc.)
- Commercial pesticide handling establishments, including self-employed applicators

Most provisions of the WPS are protections that employers must provide to their employees and, in some instances, to themselves. The task being performed will determine whether or not an employee is a worker or handler, and will determine the amount of protection the employer must provide. Owners of agricultural establishments and their immediate families are exempt from many, but not all, of the WPS requirements (refer to the EPA manual *How to Comply*). The owners of agricultural establishments still must provide all of the applicable protections for any employees or other persons on the establishment who are not members of their immediate family.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE), and restricted-entry interval (REI). The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard.

Do not enter or allow worker entry into treated areas during the REI of **24 hours.**

PPE required for early entry into treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water, is:

- Coveralls worn over short-sleeved shirt and short pants
- Chemical-resistant gloves made of any waterproof material
- Chemical-resistant footwear plus socks
- Chemical-resistant headgear for overhead exposure
- Protective eyewear

Figure 1. The pesticide label contains information regarding WPS requirements when a product is used to produce agricultural plants on farms, forests, nurseries, or enclosed spaces, such as greenhouses.

Exceptions

The WPS does not cover pesticides applied on an agricultural establishment in the following circumstances:

- on pastures or rangeland unless forage is harvested for hay;
- on livestock;
- for control of vertebrate pests, such as rodents, unless directly related to the production of agricultural plants;
- on plants grown in home gardens and home greenhouses;
- on plants that are in golf courses (except those areas set aside for plant production) or right-of-way areas;
- on public or private lawns, although sod farms are covered by WPS;
- on plants already planted (not grown for distribution) for decorative or ornamental use, such as trees and shrubs in lawns;
- for mosquito abatement, or similar wide area public pest control;
- for structural pest control, such as termite control;
- for research uses of unregistered pesticides; or
- on harvested portions of plants or on harvested timber.

Regarding the last bullet, pesticide applications to harvested portions of agricultural plants or to harvested timber are outside the scope of WPS. Once a crop is harvested, WPS does not apply to workers performing activities related only to the harvested portion of the agricultural plant. Harvesting includes packing produce into containers in the field. For purposes of WPS, an agricultural plant is considered harvested when:

1. a desirable portion of the agricultural plant (seed, fruit, flower, stem, foliage, or roots) is detached from its parent; or
2. a whole agricultural plant is separated from its growth media (soil, water, or other media).

Pesticide applications on an agricultural establishment that are within the scope of the WPS include:

- applications to the "parent" portion of the agricultural plant that remains after the crop has been harvested, if the application is made to continue production of the parent plant or eliminate the parent plant;
- applications to the growth media that remains behind after the crop has been harvested, if the application is made to
    - continue production of the parent plant, or
    - eliminate the parent plant, or
    - prepare the media for replanting or reseeding of an agricultural plant;
- applications to agricultural plants (including transplants) that are in growth media;
- applications to agricultural plants or plant portions (seeds, roots, bulbs, cuttings, etc.) on an agricultural establishment immediately prior to or during planting, transplanting, or grafting.

Requirements of Agricultural Owners and Those Hired to Work on the Agricultural Establishment

The WPS covers a great deal of information, more than can be addressed in this publication. This section will cover some requirements that everyone who owns or works on an agricultural establishment must follow regarding personal protective equipment, restrictions during and after pesticide applications, and minimum age requirements. Some exemptions exist for immediate family members of the agricultural owners. These will be covered later in this publication.

1. **Wear appropriate personal protective equipment (PPE)**

The PPE and other work attire required for each pesticide are listed on the pesticide label for the tasks being performed. The required equipment for a specific pesticide is listed under the Hazards to Humans section on the label (Figure 2). These requirements may be different for applicators and mixer/handlers. If an applicator is using a closed system or working in an enclosed cab, some protective equipment exceptions are allowed unless expressly prohibited by the product labeling. Required equipment must be within the enclosed cab, however, to protect the person if the rig were to break down. Always use the PPE listed on the label. Refer to the *How to Comply* manual for additional details.

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALSWARNING

Causes substantial but temporary eye injury. Do not get in eyes or on clothing. Wear protective eyewear (goggles or face shield). Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse. May be fatal if swallowed. Harmful if inhaled or absorbed through skin. Do not breathe vapors or spray mist. Prolonged or frequently repeated skin contact may cause allergic skin reactions in some individuals.

Personal Protective Equipment (PPE)

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Barrier laminate or Viton® gloves.
- Shoes plus socks
- Protective eyewear

Figure 3. The Hazards to Humans section lists the required PPE for the pesticide product.

Restrictions during pesticide applications

During a pesticide application, handlers and/or their employers must make sure to:

- follow all label requirements,
- apply pesticides so that they do not contact anyone either directly or through drift, and
- ensure no one enters treated areas and the Application Exclusion Zone (AEZ) that is within the boundaries of the establishment.

In most cases, handlers who have been trained, wear the appropriate PPE, and are involved in the application are allowed to be in treated areas. Agricultural employers must keep workers and other people out of the treated area and the Application Exclusion Zone (AEZ) that are WITHIN the boundary of the establishment owner's property. The EPA realizes that handlers and employers cannot keep people out of an AEZ that extends beyond the boundaries of the establishment, however, the AEZ still applies beyond the boundary.

The AEZ is measured from the application equipment; it moves with the application equipment like a halo around the application equipment (Figure 3).

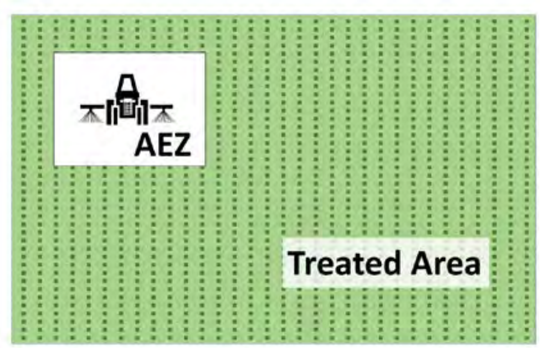

Figure 2. The AEZ is the white area around the application equipment shown above; it moves with the equipment. The AEZ generally is within the treated area, except when the application equipment is near the edges of the treated area.

The size of an AEZ depends on the type of application and other factors, including droplet size and height of nozzles above the planting medium. The AEZ is 100 feet for aerial, air blast, fumigant, smoke, mist, and fog applications. It also is 100 feet for spray applications using extremely fine, very fine or fine droplet sizes. An AEZ of 25 feet is required when the pesticide is sprayed using medium or larger droplet sizes and from more than 12 inches above the plants. An application that does not fall into one of these categories does not require an AEZ.

After Jan. 1, 2018, the handler must suspend the application if a person is in the AEZ for farms, forests, and nurseries. The requirement to suspend application is NOT limited by the boundary of the establishment owner's property. For example, if a person is walking next to the field that is being treated, and is within the AEZ, the pesticide application must temporarily stop (be suspended). Application may resume when the applicator can ensure that the pesticide will not contact any people in the AEZ that extends beyond the boundary of the establishment. The applicator can take measures to ensure that people are not contacted by the pesticides by:

- assessing wind and other weather conditions to confirm that people will not be contacted directly or through drift;
- adjusting the application method or using drift reduction measures;
- asking people to move out of the AEZ until the application is completed; or
- adjusting the treated area or path of the application equipment so that people will not be in the AEZ.

The above are required when the AEZ extends beyond the boundaries of the establishment. An applicator cannot resume application while workers or others ***on*** the establishment are within the AEZ.

2. **Restrictions during restricted-entry intervals (REIs)**
   WPS has established specific restricted-entry intervals for all pesticides covered by the WPS. The restricted-entry interval (REI) is the amount of time that must pass after a pesticide application before anyone other than a trained and equipped handler involved with the application may enter the treated area. The REI is listed on the pesticide label under Agricultural Use Requirements (Figure 4). It is based on the toxicity of the active ingredient and the worker tasks involved during the production of the agricultural plant.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE), and restricted-entry interval (REI). The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard.

Do not enter or allow worker entry into treated areas during the REI of 12 hours.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water, is:

- Coveralls
- Barrier laminate or Viton® gloves
- Shoes plus socks
- Protective eyewear

Figure 4. Information about the restricted-entry interval (REI) is in the Agricultural Use section of the pesticide label.

In most cases, REIs range from 4 to 72 hours. When the pesticide formulation or application is a mixture of active ingredients, base the REI on the active ingredient that has the longest REI.

During the REI, do not enter or allow workers, including members of the immediate family, to enter a treated area or contact anything treated with the pesticide(s) to which the interval applies.

Exceptions to REIs. In general, an agricultural owner/operator, family members, hired handlers, and hired workers must stay out of a treated area during the REI. This restriction has four exceptions: no contact, short-term activities, an agricultural emergency, and limited contact and irrigation activities. Each early-entry exception has certain conditions that must be met. For all of the early-entry exceptions, the agricultural employer must provide the worker with certain information, the required PPE, and decontamination supplies. Consult the EPA *How to Comply* manual for specifics.

3. **Minimum age requirements.** Any handler and any early-entry worker must be at least 18 years old. This minimum age does not apply to an adolescent working on an establishment owned by an immediate family member.

Basic Duties of Employers of Pesticide Handlers and Agricultural Workers

Some WPS requirements for employers are the same whether the employees are workers or handlers. The following describes some requirements.

Safety Information. For the benefit and safety of their employees, employers must provide basic safety information plus current and specific information about the pesticides being applied. All of the information must be displayed and made accessible at a central location on the agricultural establishment where it can be seen and read easily. The pesticide safety information (poster) also must be displayed and accessible at any permanent site with decontamination supplies, and at any location when 11 or more workers are present. The latter may be a bus or gathering area for detasselers, for example. Some information must be displayed and accessible after Jan. 1, 2018. The time delay allows for development of revised posters and displays. The current pesticide safety poster should be displayed in 2017.

The following information is required after Jan. 1, 2018.

- Seven concepts about preventing pesticides from entering a person's body:
    1. Follow directions/signs about keeping out of the AEZ and treated areas
    2. Avoid getting on skin or body
    3. Wash before eating, drinking, chewing gum or tobacco, or using the toilet
    4. Wear protective clothing
    5. Wash/shower with soap, water, shampoo
    6. Wash work clothes separately
    7. Wash immediately if spilled/sprayed on body
- Name, address, and telephone number of the Nebraska Department of Agriculture (NDA) or Tribal pesticide regulatory agency
- Name, address, and telephone number of a nearby emergency medical facility
- Instructions for employees to seek medical attention as soon as possible if they were poisoned, injured, or made ill by pesticides

The following information must be displayed and accessible by Jan. 2, 2017. The agricultural employer already knows or has access to this information.

- Facts about each pesticide application, displayed within 24 hours of the end of the application and before workers enter that treated area, including the:
    1. product name;
    2. EPA registration number and active ingredients;
    3. Safety Data Sheet (SDS);

4. crop or site treated, and location and description of the treated areas;
5. date and times the application started and ended; and
6. REI for the pesticide.

Employers must tell workers and handlers where the information is displayed and allow them access. Safety information must be kept legible and current. Information about an application and the associated SDS must remain displayed for 30 days after the REI expires. This information must be kept for two years after the REI expires.

Pesticide safety training. Prior to Jan. 2, 2017, workers and handlers had to receive training every five years. After that date, the employer must provide WPS safety training *each year* before employees begin work, unless handlers and workers are owners/immediate family members; state-certified pesticide applicators; or crop advisors certified or licensed as a crop advisor by a program acknowledged in writing by EPA, the NDA, or a Tribal agency. After Jan. 2, 2017, handlers must be trained *before* they perform any handling task on the establishment *unless* they have been trained within the past 12 months. After Jan. 2, 2017, workers will have to be trained *before* they perform any worker task in an area that has been treated with a pesticide or an REI has been in effect within the last 30 days, *unless* they have been trained as a worker or handler within the last 12 months. Training may be conducted by a certified pesticide applicator or by someone who has completed an EPA-approved train-the-trainer program. The training must be conducted in a manner and language that the employees can understand, using EPA-approved training materials. The trainer also must be on hand and able to answer questions after the training, especially if a video or other media is used.

A list of content required for worker and handler training as of Jan. 2, 2018 is in the EPA *How to Comply* manual. Until Jan. 2, 2018, WPS safety training content remains the same as under the existing rule and will not change ***although all training materials used after January 2, 2017 must be approved by EPA.*** By using EPA-approved training materials, the employer is assured that all required content is covered.

Training records must be kept for two years, and a copy provided to the worker or handler upon request. The records must include the trained worker's or handler's name and signature, the date of training, the trainer's name, evidence of the trainer's qualification to train, the employer's name, and which EPA-approved training materials were used.

Decontamination supplies. Employers must provide supplies so that workers and handlers can wash pesticides or their residues from their hands and bodies. Accessible decontamination supplies must be located within ¼ mile of all workers and handlers. One exception is that if worker or handler activity is more than ¼ mile from the nearest place of vehicular access or more than ¼ mile from any non-treated area, the decontamination supplies may be at the nearest place of vehicular access outside any treated area or area subject to a REI. For more details, refer to the EPA *How to Comply* manual. Decontamination supplies must include the following:

- 1 gallon of water for each worker and 3 gallons for each handler and each early-entry worker; measured at the beginning of the worker’s or handler’s work period;
- if a handler is mixing/loading a product that requires eye protection or using a closed system under pressure, eyeflush water (Figure 5) must be immediately available at the mix/load site for handler eye flushing; the system must be capable of delivering 0.4 gallons per minute for 15 minutes, or 6 gallons of water at a gentle flow for about 15 minutes at a mix/load site;
- if a handler is applying a product that requires eye protection, 1 pint of water must be immediately available to each applicator;
- plenty of soap and single-use towels; and
- a clean change of coveralls for use by each handler (not required for workers).

Figure 5. Water for eye flushing must be available for handlers when using a pesticide that requires eye protection. Haws Corporation photo.

Water must be safe and cool enough for washing and eye flushing. Employers may not use tank-stored water that also is used for mixing or diluting pesticides unless there are safeguards to prevent contamination, such as anti-backflow devices.

Employers must provide handlers with the previously mentioned supplies at each mixing site and at the place where PPE is removed at the end of a task. Supplies for handler decontamination may be in the treated area where the handler is working, as long as the materials are stored in closed containers. Worker decontamination supplies must not be located in areas being treated or under an REI.

Emergency medical assistance. When there is a possibility that a handler or worker has been poisoned or injured by a pesticide, an employer must promptly provide transportation to a nearby medical facility. Information about the medical facility must be displayed at a central location and, if applicable, at permanent decontamination supply sites and locations where 11 or more workers are present. In addition, the employer must give medical personnel who provide treatment the following information:

- the product name, EPA registration number, and active ingredients;
- the SDS;
- a description of how the pesticide was used; and
- information about the employee's exposure.

Enclosed space production. Owners and operators of greenhouses, polyhouses, mushroom houses, hoop houses, high tunnels, and other enclosed spaces have additional requirements. These include special application restrictions, ventilation criteria, early-entry restrictions, and additional handler protection. Consult the EPA *How to Comply* manual and the pesticide label for specifics.

Additional Duties for Employers of Workers

Notification regarding application. The employer must notify all workers on the establishment of any areas being treated with pesticides or that may be under an REI if workers will be on or within a quarter mile of the treated area. In most cases, employers may choose between oral warnings or posted warning signs (Figure 6) concerning the REI. In either case, employers must tell workers which warning method is being used. Some pesticide labels may require both oral and posted sign warnings. Notification must be provided before the application begins or at the start of the workers' work period if they will be coming on to the establishment when applications are ongoing or an REI is already in effect. For outdoor production, notifications must be posted for applications of a pesticide with an REI of more than 48 hours. All notifications regarding enclosed space applications of a pesticide with an REI of more than 4 hours must be posted. The exception is that if no worker will enter the enclosed space area from the start of the application until the end of any REI.

Restrictions during application. Employers must prohibit entry by workers or other persons into areas being treated. Only handlers who have had the appropriate training, are wearing the required equipment, and are involved in the application may enter the area during application. See the EPA *How to Comply* manual for special restrictions for employees who work in enclosed spaces.

Restrictions after applications. See information previously given in **Restrictions during restricted-entry intervals (REIs).**

Warning signs. The warning sign must have a white background with the words "DANGER" and "PELIGRO," plus "PESTICIDES" and "PESTICIDAS," at the top of the sign, and the words "KEEP OUT" and "NO ENTRE" at the bottom of the sign (Figure 6). The sign may have a language other than Spanish if that language is read by the majority of workers who do not read English. A circle containing an upraised hand on the left and a stern face on the right must be near the center of the sign. The inside of the circle must be red, except that the hand and a large portion of the face must be in white. The length of the hand must be at least twice the height of the smallest letters. The length of the face must be only slightly smaller than the hand. Additional information, such as the name of the pesticide and the date of application, may appear on the warning sign if it does not detract from the size and appearance of the sign or change the meaning of the required information.

Figure 6. The US EPA has specifications for warning signs. EPA photo.

Warning signs must be posted:

- if the REI is greater than 48 hours for an outdoor application or 4 hours for an enclosed space (e.g., greenhouse) or the label requires oral and posted notification;
- no more than 24 hours before the application and removed within 3 days after the end of the REI;
- where they can be seen at all normal entrances, paths, and trails to treated areas;
- at borders where worker housing areas are within 100 feet of the treated area; or
- if employees will come within ¼ mile of the treated site.

Oral warnings. Oral warnings must be delivered in a manner understood by workers, using an interpreter if necessary. For outdoor production, the agricultural employer must notify workers either orally or by posting signs if a product is used with an REI of 48 hours or less. For enclosed spaces, such as a greenhouse, the agricultural employer must notify workers either orally or by posting signs if a product is used with an REI of 4 hours or less. Oral warnings must contain the following information:

- the location and description of the treated area,
- the date and time that the REI is in effect, and
- specific directions indicating that workers must not enter the treated area or AEZ during the application and must stay out of the treated area during the REI.

Additional Duties for Employers of Handlers

Specific training for handlers. Before handlers perform any handling tasks, employers must inform them of all instructions on the pesticide labeling about safe use (Figure 7). In addition, employers must keep pesticide labels accessible to each handler during the entire handling task and inform handlers of how to use any assigned handling equipment safely before they use it.

Figure 7. Because handlers have more risk of exposure, including working with concentrated pesticides, their training has additional topics. UNL photo.

Safeguarding handlers. Before commercial handlers come to an agricultural establishment, inform them of areas on the establishment where pesticides will be applied or where an REI will be in effect, and the restrictions for entering those areas.

Equipment safety. Employers of handlers must make sure that equipment used for mixing, loading, transferring, or applying pesticides is inspected, and repaired or replaced as needed. Only appropriately trained and equipped handlers may repair, clean, or adjust pesticide-handling equipment that contains pesticides or pesticide residues.

Personal protective equipment. Employers must provide handlers with the PPE required by the pesticide labeling for each task. They also must provide handlers with a pesticide-free work area for storing personal clothing, as well as for changing into and out of PPE for each task. Employers must not allow any handler to wear or take home any used PPE. They must make sure PPE is worn and used correctly. If the labeling requires any handler to wear a respirator, the employer must provide respirator and fit testing, training, and medical evaluation that conforms to OSHA standards. Employers must keep records of the completion of the fit test, training, and medical evaluation.

Cleaning and maintenance of PPE. The employer must make sure that:

- PPE to be reused is cleaned, inspected, and repaired before each use or replaced as needed;
- PPE that is not reusable or cannot be cleaned is disposed of properly; and
- PPE should be washed, hung to dry, and stored separately from personal clothing and away from pesticide storage, treatment, or application areas.

Replacing respirator purifying elements. Particulate filtering facepiece respirators (known as dust/mist filters) must be replaced when breathing becomes difficult, if the filter is damaged or torn, when the respirator label or pesticide label requires it, or at the end of eight hours of cumulative use in the absence of any other instructions. Cartridges or canisters designed to remove vapors must be replaced when odor, taste, or irritation is noticed; when the respirator label or pesticide label requires it; when breathing becomes difficult; or at the end of eight hours of cumulative use in the absence of any other instructions.

Disposal of PPE. Discard coveralls and other clothing that are heavily contaminated with an undiluted pesticide having a DANGER or WARNING signal word according to directions on the pesticide label. If PPE cannot or will not be cleaned properly, make it unusable as apparel or unavailable for further use. Federal, state, and local laws must be followed when disposing of PPE that cannot be cleaned correctly.

Instructions for those who clean PPE. Employers must inform people who clean or launder PPE that it may be contaminated with pesticides. Employers must inform them of the potentially harmful effects of exposure to pesticides, how to protect themselves, how to clean the equipment correctly, and proper decontamination procedures after handling contaminated PPE. More information is available in EPA's *How to Comply* manual.

PPE regarding closed systems. The WPS has some exceptions to PPE requirements when a closed system (Figure 8) is used. The closed system is one that removes the pesticide from its original container and transfers the pesticide product through connecting hoses, pipes, and couplings that are tight enough to prevent exposure of handlers to the pesticide product, except for the negligible escape associated with normal operation of the system. Another exception to PPE requirements is allowed when loading intact, sealed, water-soluble packaging into a mixing tank or system. However, if the integrity of a water soluble packaging is dissolved, broken, punctured, torn, or allows its contents to escape, it is no longer a closed system and the labeling-specified PPE must be worn.

Figure 8. Because an enclosed system reduces the risk of pesticide exposure, the PPE requirements may be reduced. GoatThroat Pumps photo.

In addition, the handler employer must satisfy ***all*** of the following:

- Each closed system must have clearly written, legible operating instructions. These must include operating procedures for use, including the safe removal of a probe; maintenance, cleaning and repair; known restrictions or limitations relating to the system, such as incompatible pesticides, sizes (or types) of containers or closures that cannot be handled by the system; any limits on the ability to measure a pesticide; and special procedures or limitations regarding partially filled containers.
- The written operating instructions for the closed system must be available at the mixing or loading site to any handlers who use the system.
- Any handler operating the closed system must be trained in its use and operate the closed system according to its written operating instructions.
- The closed system must be cleaned and maintained as specified in the written operating instructions and as needed to ensure the system works properly.
- All PPE specified in the pesticide product labeling must be immediately available to the handler in case of an emergency.
- Protective eyewear must be worn when using closed systems operating under pressure.

Once all of the above are met, the exceptions to wearing the PPE as required by labeling are:

- Handlers using a closed system to mix or load pesticides with a signal word of “DANGER” or “WARNING” may substitute a long-sleeved shirt, long pants, shoes and socks, chemical-resistant apron, protective eyewear, and any protective gloves specified on the labeling for handlers for the labeling-specified PPE.
- Handlers using a closed system to mix or load pesticides other than those with a signal word of “DANGER” or “WARNING” may substitute protective eyewear, long-sleeved shirt, long pants, and shoes and socks for the labeling-specified PPE. Although the mixer/loader does not have to wear label-required gloves, those gloves must be available in case there is a problem with the closed system.

PPE regarding enclosed cabs. Handlers in enclosed cabs (Figure 9) may substitute a long-sleeved shirt, long pants, shoes, and socks for PPE for skin and eye protection specified by the labeling under certain conditions. These are:

- All of the PPE required by the pesticide product labeling for applicators must be immediately available to handlers in an enclosed cab, stored in a sealed container to prevent contamination.
- Handlers must wear the applicator PPE specified by the labeling if they exit the cab within a treated area during application or when a REI is in effect.
- Once PPE has been worn in a treated area, the handler must remove it before reentering the cab to prevent contaminating the cab.

Figure 9. In some situations, PPE requirements may be reduced when a handler is in an enclosed cab. UNL photo.

If the enclosed cab has a properly functioning air ventilation system that is used and maintained according to the manufacturer's written operating instructions, a handler in an enclosed cab does not have to wear a filtering facepiece respirator (NIOSH approval number prefix TC-84A, formerly called dust/mist respirator) if one is required by the labeling. A handler in an enclosed cab must wear any other type of respirator required by the labeling.

PPE regarding aerial application. Wearing chemical-resistant gloves when entering or leaving an aircraft used to apply pesticides is optional, unless those gloves are required on the pesticide product labeling. Gloves that have been used to apply pesticides must be kept in an enclosed container if brought into the cockpit, to prevent contaminating the inside of the cockpit.

Open cockpit. Handlers applying pesticides from an open cockpit aircraft must use the PPE specified in the pesticide product labeling for use during application, except that chemical-resistant footwear need not be worn. A helmet may be substituted for chemical-resistant headgear, and a helmet with a face shield lowered to cover the face may be substituted for protective eyewear.

Enclosed cockpit. A person in an enclosed cockpit may substitute a long-sleeved shirt, long pants, shoes, and socks for labeling-specified PPE.

Heat illness. Employers must take necessary steps to help employees prevent heat illness, especially while wearing PPE. Train handlers to recognize, prevent, and treat heat illness. A number of key elements to keep in mind are listed.

- Make sure that employees drink enough water to replace fluids lost through sweating. Thirst is not a good indicator of how much water a person needs to drink; usually a person needs water more often.
- Monitor temperature and humidity, and workers' responses at least hourly in hot temperatures.
- Schedule heavy work and tasks that require PPE for the cooler hours of the day.
- Help workers gradually adjust to hot temperatures.
- Shorten the length of work periods and increase the length of rest periods.
- Give workers shade or cooling during breaks.
- Stop work altogether under extreme conditions.

OSHA has relevant resources at https://www.osha.gov/SLTC/heatstress/ .

Information Exchange between Employer and Commercial Applicator

To ensure the agricultural owner/operator has the information to protect employees and comply with WPS, a commercial applicator must inform an agricultural owner/operator before a pesticide is applied on the agricultural establishment. The commercial applicator must provide the owner/operator with the following information:

- location and description of area to be treated;
- date, and start and estimated end times of the application;
- product name, EPA registration number, active ingredients, and REI;
- whether postings at the treated area and/or oral warnings are required; and
- any restrictions or use directions on the pesticide product labeling that must be followed to protect workers, handlers, or other persons during or after application.

In addition, the agricultural employer must obtain and display the SDS for any WPS-covered pesticides used on the establishment if the agricultural establishment employs workers or handlers. Although the commercial applicator isn't required to provide a copy of the SDS to the agricultural employer, the EPA encourages this since the commercial applicator should have received copies of the SDS from the distributor.

If the owner of an agricultural establishment hires people to perform handler activities, such as commercial applicators, the agricultural owner/operator must inform the employer of the commercial handler of any treated areas under an REI if they will be at or walk within a quarter mile of that area. The employer of the commercial handler must pass that information along to the commercial handler. The agricultural owner/operator is responsible for providing all WPS protections for his/her employees. If the operator of an agricultural establishment hires a commercial handler, that commercial handler employer is responsible for providing all WPS protections to his/her employees.

Exemptions for Agricultural Owners and Immediate Family

On any agricultural establishment where a majority of the establishment is owned by one or more members of the same immediate family, the owner(s) of the establishment are not required to provide some of the WPS requirements to themselves or members of their immediate family while performing handling activities and tasks related to the production of agricultural plants on their own establishment. The following WPS requirements do not need to be met by owners or members of their immediate family, but must be provided to any worker or handler they hire.

- Minimum age of 18 years for handlers and early-entry workers
- Information at a central location and certain decontamination sites
- Pesticide safety training for workers and handlers
- Decontamination and eyeflush supplies
- Emergency medical assistance
- Notification of pesticide applications
- Monitoring of handler's actions and health
- Specific handling instructions
- Duties related to early entry: training and instructions and decontamination sites
- Inspecting, cleaning, and maintaining PPE

Owners of agricultural establishments and their immediate family members are required to comply with all of the following WPS requirements when using WPS-labeled products:

- Wear the PPE and any other work attire required by the pesticide labeling
- Keep out of the treated area until the REI expires
- Ensure the pesticide is applied so it does not contact any persons, including members of the immediate family
- Ensure that all persons, including immediate family members, are kept out of the treated area and the AEZ during the application of the pesticide

- Ensure that the pesticide applied is used in a manner consistent with the product's labeling
- Provide a medical evaluation, fit test, and respirator training to any handler, including an immediate family member, before the handler uses a pesticide whose labeling requires a respirator
- Beginning January 2, 2018, a handler must suspend a pesticide application if a worker or other person is in the AEZ during the application.

Exemptions for Crop Advisors

Certified crop advisors are exempt from some WPS provisions in Nebraska if they have met pesticide safety training requirements. To meet the training requirement, the crop advisor must be certified or licensed as a crop advisor by a program acknowledged as appropriate in writing by EPA, the NDA, or Tribal agency responsible for pesticide enforcement.

When performing crop advisor tasks in a treated area during the REI, certified crop advisors who meet this description may determine the appropriate PPE to wear and do not have to comply with the requirements for emergency assistance, understanding the label, and decontamination for themselves. However, certified crop advisors must provide these protections for their employees.

As pesticide handlers under the WPS, a crop advisor (i.e., anyone who does a crop advisor task) other than a certified crop advisor may enter treated areas during the REI if the application has been complete for at least four hours, they only perform crop-advising tasks, and they:

- wear the PPE required for handling activities as required by the label, OR
- follow the PPE requirements on the product label for early-entry activities, OR
- wear a standard set of PPE (coveralls, shoes, socks, waterproof gloves, and eye protection if the product labeling requires protective eyewear for handlers).

Resources

Nebraska Department of Agriculture. For WPS regulatory interpretation and compliance guidance, call 402-471-2351 or 877-800-4080 (toll free).

Ogg, C.L., Bauer, E.C., Hygnstrom, J.R., Hansen, P.J. (2012) *Protective Clothing and Equipment for Pesticide Applicators*, NebGuide G758.

U.S. Code of Federal Regulations. 2016. Title 40, Chapter I, Subchapter E Part 170 Worker Protection Standard available online at http://www.ecfr.gov/cgi-bin/text-idx?SID=e3b0693d1b8ccd5e04ed42ced2a268c8&mc=true&tpl=/ecfrbrowse/Title40/40cfr170_main_02.tpl

U.S. Environmental Protection Agency. 2016. *How to Comply with the Worker Protection Standard for Agricultural Pesticides−What Employers Need to Know*, at https://www.epa.gov/pesticide-worker-safety.

U.S. Occupational Health and Safety Administration information on heat and outdoor work at https://www.osha.gov/SLTC/heatstress/

This publication was peer reviewed. We gratefully acknowledge Trevor Johnson, Nebraska Department of Agriculture, and Nancy Fitz, US EPA, for extensive reviews.
UNL Extension publications are available online at http://extensionpubs.unl.edu .

Index: Pesticides, General Regulations

October 2016.

G2033 Index: Pesticides, Pesticides General
Issued October 2016

Nebraska Pesticide Container and Secondary Containment Rules

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This NebGuide examines the rules and regulations required in Nebraska for pesticide containers and secondary containment of liquid pesticides and fertilizers.

The Environmental Protection Agency (EPA) Pesticide Container and Containment (PCC) Rule is intended to ensure that containers are strong and durable and that cross-contamination or other problems do not occur. The PCC Rule's purpose is to minimize human pesticide exposure while handling containers, facilitate pesticide container disposal and recycling, and protect the environment from pesticide spills, leaks, or other accidents at bulk storage sites during the pesticide refilling or dispensing process. The PCC Rule may apply to you if you are a pesticide registrant, distributor, retailer, commercial applicator, custom blender, or end user.

Pesticide Containers

EPA pesticide container rules apply to nonrefillable containers, refillable containers, and the reuse of refillable containers (repackaging). The PCC Rule also addresses labeling on pesticide containers, including requirements for cleaning and disposing of empty containers.

Nonrefillable Containers

Registrants, formulators, distributors, and dealers are responsible for ensuring that their nonrefillables meet standards. EPA's publication *A Snapshot of the EPA Container and Containment Rule* (2009) explains that for products that are not restricted use and are in Toxicity Categories III and IV, containers must:

- Meet basic Department of Transportation (DOT) requirements in the Code of Federal Regulations (49 CFR 173.24).

Packaging for all other products (Restricted Use Products (RUP) and/or toxicity categories I or II) must meet the nonrefillable container requirements. Nonrefillables must:

- Meet certain requirements for DOT construction, design, and marking (for example, five-gallon or smaller containers should be capable of 99.99 percent residue removal; three-gallon or smaller containers require special lids).
- Be vented so product does not surge and pours in a continuous stream (for example, not "glug"); dripping outside the container should be minimal.

Labels for nonrefillables identify them as nonrefillable containers with a "Do not use" statement. The label also contains cleaning/rinsing and disposal instructions, recycling instructions *(Figure 1)*, and a lot number identifying the batch.

> **Container Disposal**
>
> ***Nonrefillable Container. DO NOT*** reuse or refill this container. Triple rinse or pressure rinse container (or equivalent) promptly after emptying; then offer for recycling, if available, or reconditioning, if appropriate, or puncture and dispose of in a sanitary llandfill, or by incineration, or by other procedures approved by state and local authorities.

Figure 1. Example of label language on a nonrefillable container.

Refillable Containers

Both registrants and independent refillers (those who repackage but do not register the product) must comply with requirements for stationary tanks, repackaging, and portable refillable containers *(Figure 2)*.

> **STORAGE AND DISPOSAL**
>
> **Container Disposal**
>
> ***Refillable Container.*** Refill this container with pesticide only. DO NOT reuse this container for any other purpose. Triple rinsing the container before final disposal is the responsibility of the person disposing of the container. Cleaning before refilling is the responsibility of the refiller.

Figure 2. Example of label language on a refillable container.

Requirements for refillable containers are discussed below.

1) *Stationary tanks* are containers that are fixed in place for 30 or more days at the facilities of independent refillers and hold 500 gallons (liquid) or 4,000 pounds (dry) pesticides. The tanks require:
    - A serial number or other identifying code
    - Sufficient strength and durability
    - Vents that limit evaporation
    - No external sight gauges
    - A lockable inlet/outlet valve
    - Secondary containment if holding an agricultural pesticide
    - Anchorage or elevation to prevent flotation if holding an agricultural pesticide
2) Registrants are responsible for making sure *portable refillable containers (mini bulks, shuttles, totes, etc.)* meet DOT standards and bear a DOT transport marking and serial number. They also must be tamper resistant or have one-way valves. These changes will result in many older containers being recycled. Tri-Rinse, Inc. and many other agro chemical manufacturers or distributors offer programs to properly collect and destroy old mini-bulk containers that can no longer be used under the PCC Rule. Many of these programs will continue for years as old containers are being taken out of circulation and replaced by new, compliant containers. In Nebraska, Tri-Rinse will collect containers annually, biannually, or as requested. For more information, see www.tri-rinse.com/.
3) *Repackaging* requirements for any refiller or registrant include:
    - A written contract between the independent refiller and the registrant
    - Responsibility for product integrity
    - No regulatory limits on size of refillable containers, although in their contract, registrants might establish a specific size limitation
    - Acquiring from the registrant 1) procedures to clean refillables; 2) descriptions of acceptable containers that meet stationary tank and portable refillable requirements. Refillers must have these documents on file.
4) Important requirements that refillers need to implement during the repackaging process include:
    - Identifying the previous pesticide that was in the refillable container and visually inspecting the container to ensure it is safe and has the required marks and openings
    - Cleaning containers unless the tamper-resistant or one-way valve is intact and the container is being refilled with the same product (or if a new product meets other limited circumstances)
    - Ensuring that the container is included in the registrant's description of acceptable containers

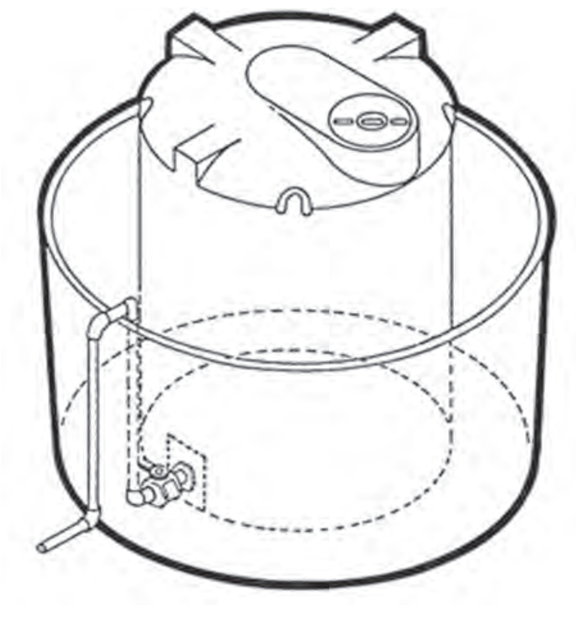

Figure 3. Secondary containment.

- Properly labeling the product, including the EPA establishment number and net contents
- Recording product repackaging information, such as date of repackaging and container serial number
- Examples of label language for refillables include a "refillable container" statement and instructions for cleaning the container before recycling or disposal (not before being refilled).

Secondary Containment/Load-out Facilities

Large containers of bulk liquid fertilizers or pesticides pose some unique challenges, such as the potential for spillage or leakage into groundwater or surface water. To address these issues, there are secondary containment and load-out facility standards covered by the EPA containment rules and Nebraska Title 198, *Rules and Regulations Pertaining to Agricultural Chemical Containment.* According to Title 198, secondary containment is "a device or structure designed, constructed, and maintained to hold or confine a release of a liquid pesticide or liquid fertilizer from a storage facility." Simply stated, this means using a larger container to hold a smaller container in order to prevent leakage *(Figure 3)*.

Also, a load-out facility *(Figure 4)* is defined as "a location, other than the field of application, used for the loading, unloading, handling, or mixing of pesticides or fertilizers or a location used for the rinsing or washing of delivery or application equipment which is designed, constructed, and maintained to hold or confine a release of a liquid pesticide or liquid fertilizer." For more detailed information about rules pertaining to size, capacity, enclosed or not enclosed, and other aspects of secondary containment and load-out facilities, see the full Title 198 rule at http://deq.ne.gov/RuleAndR.nsf/Title_198.xsp.

The Nebraska Department of Environmental Quality (NDEQ) administers Title 198. According to the NDEQ,

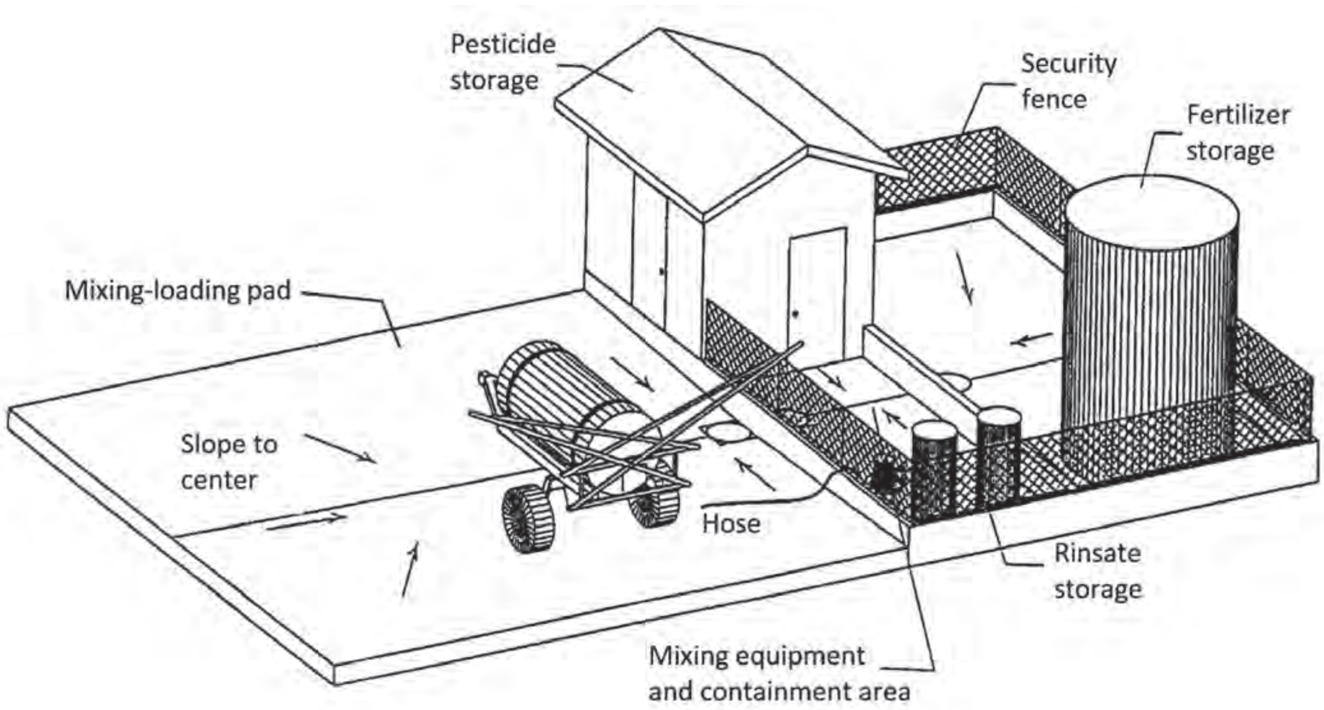

Figure 4. A load-out pad.

secondary containment and/or load-out facilities are required if the storage capacity of a liquid pesticide exceeds 500 gallons. Also, custom applicators must be aware that load-out facilities are required if using liquid pesticides in original containers greater than 3 gallons or if using mixtures of liquid fertilizers or pesticides in containers greater than 100 gallons.

Liquid fertilizer storage requirements differ from liquid pesticide storage requirements in that liquid fertilizers require secondary containment if:

- One container exceeds 2,000 gallons
- Two or more containers have a combined capacity greater than 3,000 gallons, or
- Liquid fertilizers are stored anytime between November 1 and March 15 in quantities that occupy over 25 percent of the container capacity for containers larger than 500 gallons.

Secondary containment is not required if the contents of one or more containers (up to 6,000 gallons total) are stored at the application site between March 15 and October 1 for no more than 21 consecutive days. Note that this exception is specific to application sites, and some containers, such as those used in chemigation, do not qualify for this exemption. Containers must also follow other rules, including maintaining a minimum distance from wells and surface water. For more information about containment rules and/or exceptions, consult the NDEQ publications *Are Environmental Regulations becoming a Pest?* or *Fertilizer and Pesticide Containment in Nebraska (see Resources)*.

While Title 198 does not require either registration or a permit, you must have a construction plan and management program for secondary containment and load-out facilities. The construction plans must be certified by a Nebraska registered professional engineer. These plans remain with the owner and must be made available to NDEQ upon request.

Containment standards follow existing NDEQ regulations. For guidance contact the NDEQ at (402) 471–2186 or visit them at http://deq.ne.gov/.

Resources

Are Environmental Regulations becoming a Pest? Nebraska Department of Environmental Quality. http://www.nda.nebraska.gov/pesticide/ndeq_title198.pdf.

Fertilizer and Pesticide Containment in Nebraska, 2004, Nebraska Department of Environmental Quality. http://www.deq.state.ne.us/. Search for publication title.

Title 198: Rules And Regulations Pertaining To Agricultural Chemical Containment, Nebraska Department of Environmental Quality. http://deq.ne.gov/RuleAndR.nsf/Title_198.xsp.

A snapshot of the EPA Pesticide Container and Containment Rule, Environmental Protection Agency, 2009. https://www.epa.gov/pesticide-worker-safety/snapshot-epa-pesticide-container-and-containment-rule.

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Brand, Trade, or Product Name

Brand, trade, or product name is used to identify and market the product (e.g., Pest No More in *Figure 1*). Different companies use different brand names to market products even when the same active ingredient is used.

Ingredient Statement

Every pesticide label must include the product's active and inert ingredients with the percentage of each by weight. Only the active ingredients must be listed out by name (chemical and/or common name). Inert ingredients, also referred to as "other ingredients" on consumer pesticide labels, don't have to be listed out by name but must show the percentage by weight. *Net contents* are listed on the front of the product and indicate the total amount of product in the container (flui ounces, pints, quarts, ounces, pounds, etc.).

Use Classification Statemen

Each pesticide is categorized as either a General Use Pesticide (GUP) or a Restricted Use Pesticide (RUP). In general, GUPs are less toxic than RUPs. Thus, to purchase, apply, or supervise the use of RUPs, the applicator must be trained and certifie *(Figure 2)*.

RESTRICTED USE PESTICIDE
May injure (Phytotoxic) susceptible, non-target plants. For retail sale to and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification. Commercial certified applicators must also ensure that all persons involved in these activities are informed of the precautionary statements.

Figure 2. An example of a Restricted Use Pesticide statement.

Type of Pesticide

Most labels state the type of pesticide on the front. For example, the label may say *Herbicide,* indicating it controls weeds or *Insecticide,* indicating it will control insects.

Manufacturer

The name and address of the manufacturer, formulator, or registrant (e.g., Pesticide Company, Inc. in *Figure 1*) of the product is required to be on the label. If the registrant is not the manufacturer, then contact information will be preceded by statements like "packed for," "distributed by," or "sold by."

Emergency Telephone Number

Often the label will show a telephone number to use in case of emergencies (poisoning, spill, fire etc.). This is especially common on consumer labels.

Registration and Establishment Numbers

The *Registration Number* (EPA Reg. No.) is proof that the product and the label was approved by the EPA. The *Establishment Number* (EPA Est. No.) identifie the specifi facility that manufactured the product. This allows an individual product to be traced back to the manufacturing facility.

Signal Words

Pesticide labels must include a signal word prominently displayed on the front unless they have a Class IV toxicity level. Signal words identify the relative toxicity of a particular product. The signal words, in order of increasing toxicity, are Caution, Warning, Danger, and Danger-Poison. *(Table I)*.

Table I. Signal words that may appear on the label.

Signal Word	*Category*	*Toxicity**
Danger or Danger-Poison	Class I — highly toxic	Corrosive or irritant properties, a few drops to 1 teaspoon
Warning	Class II — moderately toxic	1 teaspoon to 1 ounce
Caution	Class III — slightly toxic	1 ounce to 1 pint/ 1 pound
Caution or none	Class IV — very slight hazard	Over 1 pint or 1 pound
*The lethal dose is less than those listed for a child or person under 150 lbs. and more for a person over 150 lbs.		

Precautionary Statements

These statements guide the applicator to take proper precautions to protect humans or animals that could be exposed. Sometimes these statements are listed under the heading *Hazards to Humans and Domestic Animals*. Every pesticide label must include the statement: "Keep Out of Reach of Children." Some example *Precautionary Statements* include: "Harmful if inhaled," and "Remove contaminated clothing and wash before reuse."

Often the *Route of Entry* and *Personal Protective Equipment (PPE) Statements* are located under the *Precautionary Statement* on a label. The *Route of Entry Statement* identifie the way(s) in which a particular pesticide may enter the body and gives specifi actions to prevent exposure. The main routes of exposure are dermal (skin and eyes), oral, and respiratory.

The *Personal Protective Equipment Statement* outlines the equipment requirements that protect the applicator from exposure to the pesticide (see NebGuide G758, *Protective Clothing and Equipment for Applicators*). Nebraska Extension recommends applicators wear at a minimum long-sleeved shirt, long pants, chemical-resistant shoes plus socks, and chemical-resistant gloves in order to be adequately protected, other necessary protective clothing and equipment will be provided on the label.

Statement of Practical Treatment

Also called *First Aid* on many consumer labels, the *Statement of Practical Treatment* tells what to do in case of exposure to the product. This information should be read before using the product, again in the event of an emergency, and be available for all emergencies in order to reference specifi information. Statements like "move individual to fresh air" and "seek medical attention" are two examples of information found in the *Statement of Practical Treatment* section.

Environmental Hazard Statement

Environmental Hazard Statement details possible hazards to the environment including soil, water, air, wildlife, fish and nontarget plants. There may be special warning statements like "this product is highly toxic to bees," "do not contaminate water when disposing of equipment washwaters," and "do not allow drift to contact nontarget plants or trees."

Physical or Chemical Hazards

The *Physical or Chemical Hazards* section of the label describes any possible fire chemical, or explosion hazards specifi to the product. For example, "spray solutions of this product should be mixed, stored, and applied, using only stainless steel, aluminum, fibe glass, plastic, or plastic-lined steel containers" and "this gas mixture could flas or explode causing serious personal injury if ignited by open flame spark, welder's torch, lighted cigarette, or other ignition source" are both statements that can be found under this section of the label.

Agricultural Use Requirements

Information about use in agricultural settings *(Figure 3)* will only be on pesticide labels where the *Worker Protection Standard* (WPS) must be followed. The WPS includes specifi safety measures for agriculture workers and handlers of agricultural pesticides.

Agricultural Use Requirements

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE), and restricted entry interval. The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard.

Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 4 hours.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water is:

- Coveralls
- Chemical resistant gloves made of any waterproof material
- Shoes plus socks

Figure 3. An example of an *Agricultural Use* label section.

The *Re-entry Statement* or *Restricted Entry Interval* (REI) is often contained in the information pertaining to WPS. The REI indicates how much time must pass after the application before workers are allowed back in to the treated area with no personal protective equipment (PPE). (See NebGuide G1219, *Worker Protection Standard for Agricultural Pesticides*.)

Some pesticide applications fall under *Non-agricultural Use Requirements* (lawns, golf courses, aquatic areas, rights-of-way, etc.) and no specifi re-entry time is indicated. Often the label on these products advises people and pets to not enter the area until the application has dried or dust has settled.

Storage and Disposal Statement

Each pesticide label has general storage and disposal instructions. Keep pesticides stored in a secure location, away from food and feed supplies, and in the original containers. When disposing of pesticide containers, **triple- or pressure-rinse and puncture containers to avoid re-use**. State and local laws may include additional requirements, especially for proper pesticide disposal procedures (see Exension Circular EC2507, *Safe Transport, Storage, and Disposal of Pesticides*). Two very common statements found on the label under this section are: "do not contaminate water, food, or feed by storage or disposal," and "store in original containers only."

Directions for Use

Directions For Use instruct the applicator how to properly apply the pesticide and achieve the best results. This section provides information such as the rate of application, the sites the product is intended to protect (e.g., aquatic, non-crop sites, wildlife habitat areas, crop sites, greenhouses, etc.), which pests it controls, mixing directions, and other specifi directions related to applying the pesticide.

In cases where the product is intended for use on crops or vegetables, the *Pre-harvest Interval* (PHI) will be listed, which indicates how much time must pass between the application and harvest to avoid pesticide residues so that the crop will not exceed the maximum tolerance level for pesticide residues. The consequences of not following the PHI can vary, but toxicity to livestock or inability to sell harvested grain are two possible results. On some labels, the *Re-entry Statement* may also be listed under this section.

A product with the potential to harm pollinators will have restrictions to the application, indicated by a *Bee Hazard Icon* (Bee Box) on the label *(Figure 4)* in the directions for use section.

PROTECTION OF POLLINATORS

APPLICATION RESTRICTIONS EXIST FOR THIS PRODUCT BECAUSE OF RISK TO BEES AND OTHER INSECT POLLINATORS. FOLLOW APPLICATION RESTRICTIONS FOUND IN THE DIRECTIONS FOR USE TO PROTECT POLLINATORS.

Look for the bee hazard icon in the Directions for Use for each application site for specific use restrictions and instructions to protect bees and other insect pollinators.

This product can kill bees and other insect pollinators.

Bees and other insect pollinators will forage on plants when they flower, shed pollen, or produce nectar.

Bees and other insect pollinators can be exposed to this pesticide from:

- Direct contact during foliar applications, or contact with residues on plant surfaces after foliar applications
- Ingestion of residues in nectar and pollen when the pesticide is applied as a seed treatment, soil, tree injection, as well as foliar applications.

When Using This Product Take Steps To:

- Minimize exposure of this product to bees and other insect pollinators when they are foraging on pollinator attractive plants around the application site.
- Minimize drift of this product on to beehives or to off-site pollinator attractive habitat. Drift of this product onto beehives or off-site to pollinator attractive habitat can result in bee kills.

Information on protecting bees and other insect pollinators may be found at the Pesticide Environmental Stewardship website at http://pesticidestewardship.org/PollinatorProtection/Pages/default.aspx.

Pesticide incidents (for example, bee kills) should immediately be reported to the state/tribal lead agency. For contact information for your state, go to www.aapco.org/officials.html. Pesticide incidents should also be reported to the National Pesticide Information Center at www.npic.orst.edu or directly to EPA at beekill@epa.gov

Figure 4. Explanation of the bee hazard icon.

Read and follow all label directions for effective, safe, and legal use of pesticides. Reading the pesticide label will help ensure proper and legal pesticide use.

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Index: Pesticides
General Safety
2009, Revised May 2015

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

NebGuide

University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

Know how. Know now.

G1773
(Revised November 2013)

Spray Drift of Pesticides

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This NebGuide discusses conditions that cause particle drift, and methods private and commercial applicators can adopt to reduce drift potential from pesticide spray applications.

Spray drift of pesticides away from the target is an important and costly problem facing both commercial and private applicators. Drift causes many problems, including

1) damage to susceptible off-target sites;
2) a lower rate than intended on target, which can reduce the effectiveness of the pesticide and waste pesticide and money; and
3) environmental contamination, such as water pollution and illegal pesticide residues.

Drift occurs by two methods: vapor drift and particle drift. This NebGuide focuses on conditions that cause particle drift, and methods to reduce the drift potential when spraying pesticides. The potential for off-target movement needs to be a primary consideration for all pesticide applications.

Drift Dynamics

A solution sprayed through a nozzle atomizes into droplets that are spherical or nearly spherical in shape. Particle drift is the actual movement of spray particles away from the target area. Many factors affect this type of drift, but the most important is the initial droplet size. Small droplets fall through the air slowly and are carried farther by air movement.

The size of a droplet is measured in microns. Droplets with diameters smaller than 100 microns, about the diameter of a human hair, are considered highly driftable and are so small they cannot be readily seen unless in high concentrations, such as fog. As a result of the small size, drift is more dependent on the irregular movement of turbulent air than on gravity.

Table I shows the effect of droplet size on the rate of fall. The longer the droplet is airborne, the greater the potential for drift.

When leaving the nozzle, the solution may have a velocity of 60 feet per second (41 mph) or more. Unless the spray particles are electrostatically charged, there are two forces acting upon the emerging droplets. These forces, gravity and air resistance, greatly influence the deceleration and movement of spray droplets. Droplet speed is reduced by air resistance, which can also break up the droplets. After their initial speed slows, the droplets are more influenced by gravitational pull

Table I. Effect of droplet size on drift potential (Grisso, et al., 2013).

Droplet Diameter (microns)	*Droplet Size **	*Time Required to Fall 10 Feet*	*Lateral Movement in a 3-mph Wind*
5	Fog (VF)	66 minutes	3 miles
20	Very fine (VF	4.2 minutes	1,100 feet
100	Very fine (VF	10 seconds	44 feet
240	Medium (M)	6 seconds	28 feet
400	Coarse (C)	2 seconds	8.5 feet
1,000	Extremely coarse (XC)	1 second	4.7 feet

*Droplet size categories in parentheses are based on the British Crop Protection Council (BCPC) and American Society of Agricultural and Biological Engineers (ASABE) droplet size classification now in use

With lower boom heights, the initial speed may be great enough that the droplet reaches the target before drift occurs. Large droplets maintain a downward velocity longer than smaller ones, and are more likely to be deposited on the intended target. Small droplets evaporate quicker than large droplets, leaving minute quantities of the pesticide in the air *(Figure 1)*. In addition to realizing that spray droplet size is an important factor in reducing drift, an applicator should be aware that a nozzle will produce many different sizes of droplets.

Droplet Size Categories

A nozzle that produces only one size droplet is not available, despite many efforts to develop one. Volume median diameter (VMD) is a term used to describe the various droplet sizes

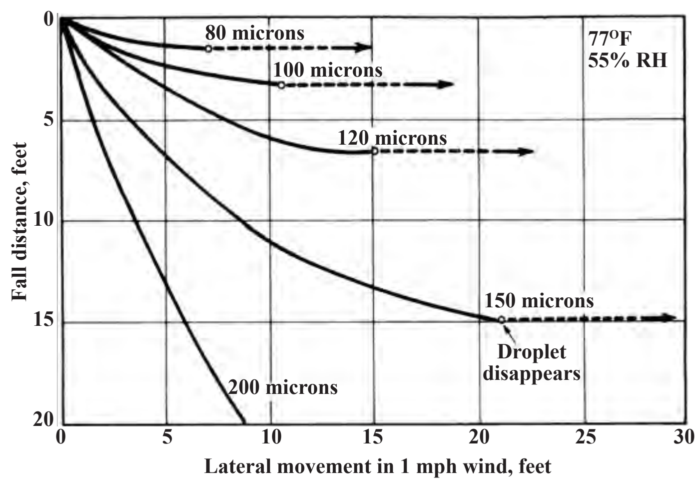


Figure 1. Lateral movement of water droplets. (Hofman and Solseg, 2004)

produced from a nozzle tip. VMD is the droplet size at which one-half the spray volume consists of droplets larger than the given value and one-half consists of droplets smaller than the given value. Since it takes many more small droplets to make up one-half the spray volume, there always will be more small droplets present in a typical spray pattern. Ideally, most of the volume should be contained in larger droplets, which is shown by a larger VMD.

The British Crop Protection Council (BCPC) and the American Society of Agricultural and Biological Engineers (ASABE) developed a droplet size classification system with categories ranging from extra fine to ultra coarse, based on VMD values measured in microns (*Table II*). Nozzle catalogs and guides often refer to these droplet size categories and color code descriptions to reduce confusion. An applicator can select the nozzle and pressure based on the droplet size category charts. In addition, the pesticide label may list the recommended droplet size category to use with a particular product. For example, the label statement might read: "Apply with 12 or more gallons per acre using a nozzle producing a coarse droplet." The label includes these spray category recommendations to make sure that the droplet size is suitable for pesticide efficac , yet as large as possible to reduce the potential for drift. Typically, low-drift nozzles produce spray droplets in the medium (M) to extremely coarse (XC) range, while reducing the amount of fine droplets that would be likely to drift.

Table II. Droplet size classifications with color codes, based on BCPC specifications in accordance with ASABE Standards.

Category	*Symbol*	*Color Code*	*Approximate VMD Range (microns)*
Extremely Fine	XF	**Purple**	~50
Very Fine	VF	**Red**	<136
Fine	F	**Orange**	136-177
Medium	M	**Yellow**	177-218
Coarse	C	**Blue**	218-349
Very Coarse	VC	**Green**	349-428
Extremely Coarse	EC	**White**	428-622
Ultra Coarse	UC	**Black**	>622

Altering Droplet Size

Some sprayer components can be adjusted to alter droplet size. Nozzle type selection is one of the most influential means *(Table III)*. For more information on droplet sizes created under various conditions, download the University of Nebraska–Lincoln Extension smartphone app "Ground Spray" from the Apple App Store or the Google Play Store.

The following section covers ways to alter droplet size.

Nozzle Type

Spray droplets are produced from nozzles in different ways.

- A *flat-fan nozzle* forces the liquid under pressure through an elliptical orifice and the liquid spreads out into a thin sheet that breaks up into different-sized droplets. This type includes the venturi-type that relies on a pressure-against-orifice effect to atomize the spray.
- A *flood nozzle* deflects a liquid stream off a plate that causes droplets to form.
- A *whirl chamber nozzle* swirls the liquid out an orific with a circular motion and aids the droplet formation with a spinning force.
- An *air inclusion nozzle* has one orifice to meter liquid flo and another larger orifice to form the pattern. Between these two orifices is a venturi or jet that draws air into the nozzle body. There, air mixes with the liquid and forms a spray pattern at a lower pressure. The coarse spray contains large, air-filled droplets and few drift-susceptible droplets.

Droplet sizes are influenced by various nozzle types and spray pressures. In *Table III*, of the three nozzles being compared, the Turbo TeeJet® produces the largest droplet, which results in the lowest drift potential. For many herbicide applications a large droplet gives good results, but for good plant coverage (i.e. postemergence application), large droplets may not give good pest control.

Table III. Effect of nozzle type on droplet size at 40 PSI and 0.5 GPM (*adapted from Spraying Systems Co., 2007).

Nozzle Type	*Volume Median Diameter, microns*
Hollow Cone	330 (*Coarse*)
Drift Guard	440 (*Extremely Coarse*)
Turbo TeeJet®	500 (*Extremely Coarse*)

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use

Spray Pressure

Spray pressure influences the formation of the droplets as well as droplet size. When boom or nozzle pressure is increased, a higher percentage of droplets are small. With a greater proportion of the total spray volume in smaller droplets, the potential drift to off-target sites increases. The spray solution emerges from the nozzle in a thin sheet, and droplets form at the edge of the sheet. Higher pressures cause the sheet to be thinner and break up into smaller droplets. Small droplets are carried farther downwind than larger droplets formed at lower pressures *(Figure 1)*. *Table IV* shows the mean droplet size for nozzles when spraying at three pressures. Higher pressures decrease the droplet size.

Orifice Size and Carrie Volume

Large orifice nozzles with higher carrier volumes produce larger drops. The relationship between flow rate (gallons per minute or GPM) and pressure (pounds per square inch or PSI) is not linear. For example, to double the flow rate would require the pressure to be increased by four times. This action would contribute to the drift potential and is not an acceptable method to increase carrier volume. If the carrier volume needs to be changed, select a different nozzle tip that meets the spraying requirements. Consult the pesticide label and *NebGuide G955, Nozzles — Selection and Sizing,* for proper selection.

Nozzle Spray Angle

The spray angle of a nozzle is the distance between the outer edges of the spray pattern, expressed as a number of arc degrees. (A full circle is 360°.) Wider angles cover a wider spray path and produce a thinner sheet of spray solution and smaller droplets at the same pressure *(Table IV)*. However, wide angle nozzles can be placed closer to the target, and the benefits of lower nozzle placement may outweigh the disadvantage of slightly smaller droplets. Lower pressures can be used to reduce the amount of fine droplets. For lower pressures with fl t-fan nozzles, low pressure or extended range nozzles must be used.

Table IV. Effect of spray angle and pressure on droplet size (*adapted from Spraying Systems Co., 1990).

Nozzle Spray Angle Degrees	*Volume Median Diameter, microns*		
	15 PSI	*40 PSI*	*60 PSI*
40	900 (*UC*)	810 (*UC*)	780 (*UC*)
65	600 (*EC*)	550 (*EC*)	530 (*EC*)
80	540 (*EC*)	470 (*EC*)	450 (*EC*)
110	410 (*VC*)	380 (*VC*)	360 (*VC*)

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use

Spray Volume

The size or capacity of the nozzle also influ nces droplet size. A larger orifice increases the droplet size at a common pressure. Since a larger orifice uses more spray volume, it also increases the number of refills; however, the increased volume of carrier solution improves coverage, and in some cases increases pesticide effectiveness. *Table V* shows the influence of increasing flow rate on droplet size at a constant pressure. With some pesticides, such as glyphosate, performance is better at lower carrier volumes.

Table V. Effect of flow rate on droplet size at 40 PSI (*adapted from Spraying Systems Co., 2007).

Nozzle Type	*Volume Median Diameter, microns*		
	0.3 GPM	*0.4 GPM*	*0.5 GPM*
Extended Range Flat Fan	270 (*C*)	300 (*C*)	330 (*C*)
Drift Guard	400 (*VC*)	425 (*EC*)	450 (*EC*)
Turbo TeeJet	450 (*EC*)	480 (*EC*)	510 (*EC*)

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use

Other Drift Factors

Boom Height

Operating the boom as close to the sprayed surface as possible while staying within the manufacturer's recommendation will reduce the potential for drift. A wider spray angle allows the boom to be placed closer to the target *(Table VI)*. Booms that bounce cause uneven coverage and drift. Wheel-carried booms stabilize boom height, which reduces the drift hazard, provides more uniform coverage, and permits lower boom height. Boom height controllers are now optional on many sprayers.

Table VI. Suggested minimum spray heights above spray contact surface.

Spray Angle Degrees	*Spray Height, inches*			
	20-inch Nozzle Spacing		*30-inch Nozzle Spacing*	
	30% overlap	*100% overlap*	*30% overlap*	*100% overlap*
65	22-24	-NR-	-NR-	-NR-
73	20-22	-NR-	29-31	-NR-
80	17-19	26-28	26-28	-NR-
110	10-12	15-17	14-18	25-27

NR — Not recommended if height is above 30 inches

Nozzle Spacing

This is the distance between nozzles on a spray boom. Nozzle spacing is critical to achieving adequate spray coverage. Spray angle and boom height also are key factors in coverage. Nozzle spacing for a given spray volume requires an increase in orifice size as the spacing increases. This typically means increasing the boom height to get the proper overlap. However, enlarging the droplet size is more important than increasing boom height.

Follow the equipment and nozzle manufacturer's recommendations for appropriate nozzle configuration. As a general guideline, do not exceed a 30-inch nozzle spacing because the spray pattern will not be as uniform. A configuration of nozzle spacing, height, and direction that gives 100 percent overlap is preferred. The best nozzle spacing for most sprayers is 15 inches. Specificall , for high volumes use a 15-inch nozzle spacing and for low volumes, cap off every other nozzle and use a 30-inch nozzle spacing.

Wind Speed

Both the amount of pesticide lost from the target area and the distance it moves increase as wind velocity increases *(Table VII)*. However, severe drift injury can occur with low wind velocities, especially under temperature inversion situations. Most recommendations are to stop spraying if wind speeds are less than 3 mph or exceed 10 mph. Some product labels have application restrictions when winds are higher than 8 mph. The wind effect can be minimized by using shielded booms and a lower boom height.

Table VII. Effect of wind speed on drift in a 10-foot fall (*adapted from Ross and Lembi, 1985)

Droplet Diameter	*Drift*	
	1 mph Winds	*5 mph Winds*
Microns	*feet*	
100 (Mist) (*VF*)	15	77
400 (Coarse Spray) (*VC*)	3	15

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use

Wind Direction

Pesticides should not be applied when the wind is blowing toward a nearby susceptible crop or a crop in a vulnerable stage of growth. Select a time when there is little wind or the wind blows gently away from susceptible crops. If these conditions do not exist, consider another method of control or time of application.

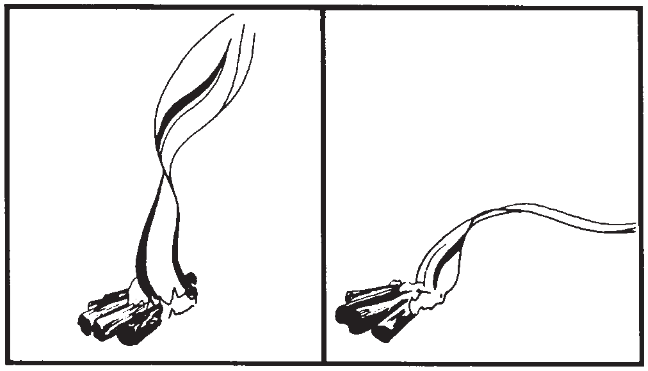
Air Stability

Air movement largely determines the distribution of spray droplets. Often wind is recognized as an important factor, but vertical air movement is overlooked. Temperature inversion occurs when cool air near the soil surface is trapped under a layer of warmer air. A strong inversion potential occurs when ground air is 2°F to 5°F cooler than the air above it and there is no wind.

Under inversion conditions there is little vertical mixing of air, even with a breeze. Spray drift can be severe. Small spray droplets may fall slowly or be suspended and move several miles to susceptible areas, carried by a gentle breeze. Do not apply pesticides near susceptible crops during temperature inversion conditions. Identify an inversion by observing smoke from a smoke bomb or a fir *(Figure 2)*. Smoke moving horizontally close to the ground indicates a temperature inversion.

Relative Humidity and Temperature

Low relative humidity and/or high temperature conditions cause faster evaporation of spray droplets and a higher potential for drift. During evaporation, the spray solution loses more water than pesticide, creating smaller droplets with a greater concentration of pesticide. The quantity of spray that evaporates from the target surface is related to the quantity of spray deposited on that surface. Smaller droplets, being more prone to drift and evaporation, have less chance of actually being deposited on the target surface than do large droplets. Therefore, hot and dry weather conditions lead to less spray deposition and more drift, due to evaporation of the spray carrier solution.



Proper application condition

Temperature inversion — do not apply

Figure 2. Smoke rising with wind velocity below 5 mph.

Evaporation increases the potential for drift so spray during lower temperature and higher humidity conditions. Pesticides differ in their evaporation rate. Use formulations and adjuvants that reduce evaporation. Some pesticide labels specify relative humidity and temperature conditions for product use. Generally, if the relative humidity is above 70 percent, conditions are ideal for spraying. A relative humidity below 50 percent is critical enough to warrant special attention.

Spray Thickeners

Some spray adjuvants act as spray thickeners or drift retardants when added to a spray tank. These materials increase the number of larger droplets and decrease the number of fine droplets. They tend to give water-based sprays a "stringy" quality and reduce drift potential. Droplets formed from an oil carrier tend to drift farther than those formed from a water carrier. Oil droplets are usually smaller, lighter, and remain airborne for longer periods, but don't evaporate quickly.

Best Management Practices to Avoid Pesticide Drift

All nozzles produce a range of droplet sizes. The small, drift-prone particles cannot be eliminated but can be reduced and kept within reasonable limits. Here are some tips:

1. Select low or nonvolatile pesticides.
2. Read and follow the pesticide label. Instructions on the pesticide label are given to ensure the safe and effective use of pesticides with minimal risk to the environment. Each pesticide is registered for use on specific sites or locations. Many drift complaints involve application procedures in violation of the label.
3. Use spray additives within label guidelines. This will result in better pesticide effectiveness and less potential for drift.
4. Use nozzles with larger orifice sizes. This will produce larger droplets and increase the number of tank refills, but may improve coverage and effectiveness while reducing the potential for drift.
5. Avoid high spray boom pressures; high spray pressure creates finer droplets. Consider 45 PSI the maximum for conventional broadcast ground spraying.
6. Use drift-reduction nozzles that produce larger droplets when operated at low pressures. When using venturi nozzles, higher pressures will be required to maintain an effective pattern. As the pressure is increased with these nozzles, the drift potential will increase, but not as much as with other types of nozzles.
7. Use wide-angle nozzles, low boom heights, and keep the boom stable. Drive perpendicular to terraces rather than parallel to avoid moving the boom ends high above the target surface or digging into the ground.
8. Drift is minimal when wind velocity is between 3 mph and 10 mph. Do not spray when temperature inversions are likely or when wind is high or blowing toward sensitive crops, gardens, dwellings, livestock, or water sources.
9. Use shielded booms. When banding, use shroud covers.
10. When possible, use lower application speeds. As application speed increases, there are often unintended effects on other application parameters that may increase drift.

References

Elliot, J.G. and B.J. Wilson, editors. 1983. The influence of weather on the efficiency and safety of pesticide application. The drift of herbicides. Occasional Publ. No. 3. BCPC Publs., Croydon, England.

Grisso, R., P. Hipkins, S. Askew, L. Hipkins, and D. McCall. 2013. Nozzles: Selection and Sizing. Virginia Cooperative Extension, Publication 442-032.

Hansen, G., F.E. Oliver, and N.E. Otto. 1983. Herbicide manual, a water resources technical publication. U.S. Government Printing Office, Denve , Colo.

Hartley, G.S. and I.J. Graham-Bryce. 1980. Physical principles of pesticide behavior. Vol. 1 Academic Press Inc., New York, N.Y.

Haskel, P.T., editor. 1985. Pesticide application: principles and practice. Oxford University Press, New York, N.Y.

Hofman, V. and E. Solseg. 2004. Spray equipment and calibration. North Dakota State University Extension AE-73. North Dakota State University, Fargo, ND.

Matthews, G.A. 1979. Pesticide Application Methods. Longman, Inc., New York, N.Y.

Pearson, S. 1989. Don't get my drift. In: Grounds Maintenance 25(1): 32, 36, 38.

Ross, Merrill A. and Carole A. Lembi. 1985. Applied Weed Science. Burgess Publishing Company, Minneapolis, Minn.

Spraying Systems Company. 1990. TeeJet Catalog 42, Agricultural Spray Products. Wheaton, Ill.

Spraying Systems Company. 2007. TeeJet Catalog 50, Agricultural Spray Products. Wheaton, Ill.

This publication has been peer reviewed.

Index: Pesticides, General Equipment

2007, Revised November 2013

F I E L D W A T C H

To promote communications between producers of specialty crops and pesticide applicators in support of ongoing stewardship activities.

July 2014

What is DriftWatch?

The DriftWatch® Specialty Crop Site Registry is a voluntary online tool that is intended to help pesticide applicators and specialty crop growers in Member States communicate more effectively and to promote awareness and stewardship activities to help prevent and/or manage drift appropriately.

DriftWatch was originally designed by staff from the Purdue University Agricultural and Biological Engineering and Agricultural Communications departments with input and support from Purdue University Cooperative Extension Specialists. It is now a national registry platform operated by FieldWatch, Inc, a non-profit company created by Purdue in collaboration with and sponsored by interested agricultural stakeholder groups.

DriftWatch is not intended to be a registry for non-commercial gardens or sites less than half an acre.

For more information, visit www.fieldwatch.com.

For crop producers and beekeepers:

Register and map sites so applicators know about your specialty areas and can plan their stewardship activities accordingly.

For applicators:

You can easily locate registered sites on DriftWatch before you spray and register to receive automated e-mails alerting you when a new commercial specialty crop or apiary site has been registered in the state or local area you designate.

How does DriftWatch work?

Producers of high-value specialty crops, such as tomatoes, fruit trees, grapes and vegetables, map their sites online with an easy-to-use mapping tool and provide contact information about their operation. Likewise, commercial beekeepers register and map their hives the same way. Pesticide applicators access the website to help determine the scope and location of specialty crops and beehives in their trade areas. DriftWatch provides the platform to facilitate better awareness, communication and interaction between all parties as one part of ongoing stewardship activities.

Who can use DriftWatch?

DriftWatch is free and the site locations are viewable by the public; but, not just anyone can register crop sites or fields. The tool is for specialty crop producers, beekeepers and pesticide applicators. Only managers and owners of specialty crop fields that are used for commercial production and are of at least a half-acre will have fields approved. It is not intended for homeowner gardens.

The DriftWatch Specialty Crop Site Registry has a new look and updated functionality.

Who checks the validity of sites submitted?

Each DriftWatch state has data stewards who are employed through the state's Department of Agriculture. These data stewards provide a key leadership role in implementing and administering the DriftWatch stewardship communication tool. Each site submission is reviewed by the data steward and will either be approved or denied based on the established criteria before being placed on the public map.

What is FieldWatch?

FieldWatch, Inc is a non-profit company that was created in December 2012 to develop and expand the operation of the DriftWatch Specialty Crop Site Registry. The new company is located off-campus at the Purdue Research Park in West Lafayette, IN.

Voluntary Membership

As a non-profit company, FieldWatch relies on donations and sponsors to keep DriftWatch operational, up- to-date and a useful tool for producers and applicators. While keeping DriftWatch free to use, the company has established a Voluntary Membership for generating revenue from companies, organizations and individuals that want to get involved and demonstrate their support of the DriftWatch registry.
For a list of supporting Members and more information, please visit the website www.fieldwatch.com

NEBRASKA
DEPARTMENT OF AGRICULTURE

Nebraska DriftWatch – Crop Eligibility

DriftWatch is an online map system for displaying locations of specialty and pesticide sensitive crops for pesticide applicators. The Nebraska Department of Agriculture (NDA) is the data steward for this web site. Basic eligibility for crops to be approved for DriftWatch in Nebraska is as follows:

- Crops must be commercial in nature - that is, sold in some way and not solely for personal use.
- Crop categories in Nebraska are:
  - Grapes
  - Fruits
  - Vegetables
  - Beehives
  - Greenhouse – high tunnel
  - Nursery crops
  - Orchards
  - Fish Farms
  - Non-specialty Certified Organic
  - Other (plants grown for seed, cut flowers, flowers for scented products, woody florals, hops, and certain non-herbicide resistant crops)
- Certified Organic crops, including alfalfa, pasture, and native prairie, are considered eligible, if they are a part of a commercial operation. Growers, who are certified organic or transitioning, have invested in the certification and verification process to increase their crops' value. Similar classifications, such as naturally grown, organically grown, natural, etc., are not considered eligible, unless they also fit into one of the other categories of crops as listed above.
- Conventionally grown pasture and native prairie are not considered specialty crops or pesticide-sensitive crops at this time. While any plant may be sensitive to herbicides, drift or misuse complaints concerning these crops happen infrequently.

More information on DriftWatch can be found at fieldwatch.com. More information about NDA's Pesticide Program can be found at bit.ly/NDAPP.

NebGuide
Published by University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
Know how. Know now.

G758
(Revised August 2012)

Protective Clothing and Equipment for Pesticide Applicators

Clyde L. Ogg, Extension Educator; Erin C. Bauer, Extension Associate; Jan R. Hygnstrom, Project Coordinator; and Pierce J. Hansen, Extension Assistant, all in the Pesticide Safety Education Program

This NebGuide explains how to choose and properly use personal protective equipment (PPE) when mixing, loading, and applying pesticides to help reduce exposure to pesticides and protect human health.

Pesticides are valuable pest management tools and, like any tool, must be used carefully and responsibly. Dressing appropriately and using personal protective equipment (PPE) can help minimize pesticide exposure and reduce the risk of pesticide poisoning. These steps also are important signals of appropriate and legal pesticide use.

Use all pesticides safely. Read the pesticide product label and comply with all directions. Failure to do so may subject you to state and/or federal penalties, and place you, your family, and the environment at a greater risk of pesticide exposure.

Manage Your Risk

Wearing protective clothing and equipment when handling or applying pesticides can reduce your risk of exposure, and thus your risk of pesticide poisoning. Understanding the toxicity of a product and the potential for personal exposure allows you to lower your risk. This idea is expressed by the Risk Formula: Risk = Toxicity x Exposure

No matter how toxic a substance is, if the amount of exposure is kept low, risk can be held to an acceptably low level. The toxicity of a substance can't be changed, but risk can be managed, and the applicator is the manager.

What is Toxicity?

All pesticides are toxic, differing only in the degree of toxicity, and are potentially dangerous to people if exposure is high. Pesticide product labels have signal words that clearly indicate the degree of toxicity associated with a given product *(Table I)*. The signal words — "Danger," "Warning," and "Caution" — indicate the degree of potential risk to a user, not the expected level of pest control.

Pesticides can enter the human body in three ways:

1) through the mouth (orally),
2) by breathing into the lungs (inhalation), and, most commonly,
3) by absorption through the skin or eyes (dermally).

Along with the signal words, pesticide product labels also include route of entry statements and specific actions a user must take to avoid exposure.

Table I. Pesticide product label signal words and relative toxicities.

Group	*Signal Word*	*Toxicity Rating*	*Lethal Dose for a 150 lb Human*[a]
I	Danger[b]	Highly toxic	Few drops to 1 teaspoon
II	Warning	Moderately toxic	1 teaspoon to 1 tablespoon
III	Caution	Slightly toxic	1 tablespoon to 1 pint
IV	Caution (signal word not always required)	Relatively non-toxic	More than a pint

[a]The lethal dose is less than those listed for a child, or a person under 150 lb and more for a person over 150 lb.
[b]The skull and crossbones symbol and the word "Poison" are sometimes printed with the "Danger" signal word.

Read the Pesticide Product Label

Route of entry statements on the pesticide product label indicate the outcome that can be expected from different kinds of exposure. For example, a pesticide label might read, "Poisonous if swallowed, inhaled, or absorbed through the skin. Rapidly absorbed through the skin and eyes." This tells the user that this pesticide is a potential hazard through all three routes of entry, and that skin and eye contact are particularly hazardous. The specific action statements normally follow the route of entry statements and indicate what must be done to prevent accidental poisoning. Using the previous example, the specific action statement might read, "Do not get in eyes, on skin, or on clothing. Do not breathe spray mist."

Before handling, mixing, loading, or applying any pesticide, read the product label directions completely. If the label calls for the use of personal protective equipment, comply fully with those directions. The label will define the minimal protective equipment required for various tasks. Note that the PPE required for mixing and loading may be more extensive than the PPE required during application because of the potential for contact with a concentrated pesticide product.

Use Personal Protective Equipment

The type of PPE needed depends both on the toxicity of the pesticide being used and the formulation (liquid, granular, wettable powder, etc.). Some labels, especially for agricultural pesticides, are affected by the Worker Protection Standard and specifically state that certain items of clothing, equipment, eyewear, footgear, and gloves must be used. Others do not include such a statement. Some of the PPE required are specific to early entry while others are specific to handling and applying. In general, the more toxic the pesticide, the greater the need for PPE.

Choose the Right PPE

If a pesticide label does not have specific PPE requirements, always take reasonable precautions and use common sense. Use the route of entry and specific action statements from the product label to determine the type and degree of protection needed to handle the pesticide safely. For example, if you'll be handling pesticides or pesticide equipment, consider wearing chemical-resistant gloves even if the label doesn't specifically call for them

Liquid pesticides often are more hazardous to use than dry formulations, and extra protection is warranted while mixing and/or loading pesticides. Recognize that in cases where there will be prolonged exposure to the spray or where the application is being made in an enclosed area, you must use extra protection.

Use Protective Clothing

Whenever you are using pesticides, at the very least you should wear a long-sleeved shirt, long pants, shoes, socks, and chemical resistant gloves (*Figure 1*). Many labels will require you to wear more than this, depending on the product's toxicity and use. Select garments made of tightly woven fabrics to reduce pesticide penetration. Disposable coveralls, such as those made of Tyvek®, provide adequate protection to a pesticide applicator under most conditions. Protective suits made of or coated with butyl rubber, neoprene, PVC, or one of the newer coated and laminated polyethylene fabrics may be needed for certain applications.

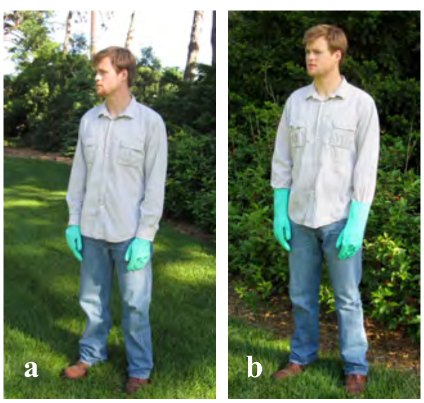


Figure 1. Wear a long-sleeved shirt, long pants, shoes plus socks, and chemical resistant gloves when applying pesticides. We recommend wearing gloves inside sleeves (1a), but wearing gloves outside sleeves may work equally well (1b).

Shoes and socks also should be worn. Avoid sandals, flip flops, and cloth or canvas shoes to minimize exposing your feet to liquid pesticides. Leather shoes are suitable while using most pesticides; however, leather will absorb liquids. Therefore, wear chemical-resistant boots while working with highly toxic liquid pesticides (signal word: DANGER) and when there may be prolonged exposure to any pesticide spray. Applicators who mix and load liquid concentrates, especially highly toxic ones, also should wear chemical-resistant aprons.

Protect Your Head, Eyes, and Hands

Protection for your head also is advisable and in some cases is specifically required. In general, a wide-brimmed, easily cleaned hat that will keep pesticides away from the neck, eyes, mouth, and face is adequate (*Figure 2*). Avoid hats with cloth or leather sweatbands as these will absorb pesticides. Baseball-style caps have headbands that readily absorb and retain pesticides. Labels that specify the use of headgear are generally found on highly toxic liquid concentrates. When working with these pesticides, wear a chemical-resistant hood or a plastic hard hat with a plastic sweatband and a rain-trough edge to keep drips off your neck and back.

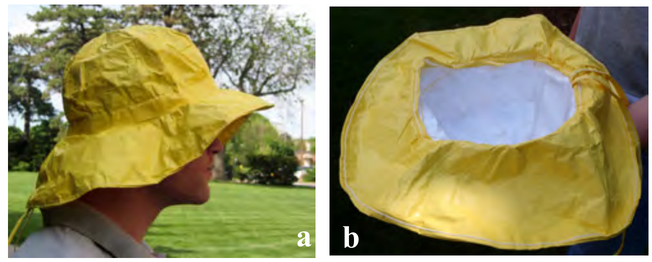


Figure 2. Example of protective hat that can be worn when applying pesticides.

Pesticides are readily absorbed through the eyes and can cause eye injury. When the labels for liquid pesticides include precautionary statements with the signal words "Warning" or "Danger," it generally indicates the need for eye protection. Use goggles or safety glasses when the label requires it. (See *Figure 3* for examples.) Some goggles have a wider bridge over the nose to be compatible with respirators. Goggles will provide adequate protection if they have the right type of venting. Safety goggles have three types of venting:

Figure 3. Different types of safety goggles and glasses.

- open vents for impact protection only; not recommended for use with pesticides;
- indirect vents for protection from pesticide and other chemical splashes; and
- non-vented for protection from gases, mists, and fumes.

Other labels may require a full face shield.

Figure 4. Chemical resistant gloves (top row, left to right): natural rubber, disposable nitrile, reusable nitrile and (bottom row, left to right) neoprene, butyl rubber, Viton, and barrier laminate.

Chemical-resistant gloves (*Figure 4*) often are needed for mixing, loading, and applying pesticides. Unlined, liquid-proof neoprene, butyl, PVC, Viton®, barrier laminate, or nitrile gloves with tops that extend well up on the forearm are best. Most of these gloves are available in reusable pairs that can be cleaned after each

Figure 5. Disposable nitrile gloves in 4, 8, and 12 mil weights.

Use and Care of a Respirator

Always read and follow the label guidelines to see what type of respiratory protection is required for the pesticide you'll be using. OSHA (Occupational Safety and Health Administration) requires that when using a respirator, you must have a medical evaluation prior to fit testing. In addition, you will need to be properly trained in respirator use

- Use respirators approved by the National Institute of Occupational Safety and Health (NIOSH).
- Read and follow the manufacturer's instructions for use and care of the respirator. Filters, cartridges, and canisters must be designed for the type of contaminant expected. For example, a particulate filter is appropriate for dusts and mists. An organic vapor cartridge is necessary for protection against organic vapors, such as pesticides. Other examples include mercury vapor cartridges or acid gas cartridges. Manufacturers also offer combination cartridges when protection against multiple types of contaminants is needed.
- Cartridges and canisters have a limited useful life and must be replaced at proper intervals.
- Inspect and fit test respirators before use to ensure a snug seal against the face. Users with facial hair may not be able to obtain an adequate seal; a clean shave along the seal line is usually necessary.
- Exposed respirator parts must be cleaned after each use, and cartridges should be stored in an airtight container in a clean location. For more information about fit testing and cleaning respirators, see NebGuide 2083, *Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications* at *http://www.ianrpubs.unl.edu/live/g2083/build/g2083.pdf*.

mixing/loading task or pesticide application. Others, such as nitrile gloves, are available in single-use disposable versions in a variety of mil weights (*Figure 5*).

Avoid lined gloves because the lining can absorb the pesticides and is hard to clean. Latex gloves, commonly used by medical personnel, do not provide adequate dermal protection because they are not chemical-resistant. Never wear cotton, leather, or canvas gloves unless the label specifically requires them, as with certain fumigants. Some fumigants penetrate rubber, neoprene, and leather, and if trapped inside a glove can cause severe skin irritation or be absorbed through the skin.

In most cases, we recommend wearing gloves under your sleeves to keep the pesticide from running down the sleeves and into the gloves. When working with your hands above your head, roll glove tops into cuffs to prevent the pesticide from running down the gloves to your forearms. As an extra safety measure, you can duct tape around where the glove and sleeve meet. Remember, the most important thing is to wear gloves! For more information about types of gloves, see NebGuide 1961, *Pesticide Safety: Choosing the Right Gloves,* at *http://www.ianrpubs.unl.edu/sendIt/g1961.pdf*.

Protect Your Lungs

Your lungs and the lining of your respiratory system readily absorb pesticide dusts and vapors from the air. Respiratory protection, therefore, is essential whenever the label calls for it and is recommended during mixing and loading, even if not required by the label. Respiratory protection also is recommended whenever an applicator will be exposed to intensive concentrations of pesticide dusts, fumes, or vapors. The type of respirator an applicator uses will be determined by the type and toxicity of the pesticide, application site, and other factors.

Particulate respirators (dust masks) are acceptable when applying pesticide dusts and granules, and for protection against large droplets suspended in air. They are not recommended for protection against vapors. Always read the pesticide label for product-specific recommendations. In all cases, the selected respirator should bear a mark indicating it is "NIOSH approved." (NIOSH refers to the National Institute of Occupational Safety and Health.) One-strap dust masks typically available at hardware stores generally are not NIOSH approved and will not provide adequate respiratory protection. Discard particulate respirators after each use and do not attempt to reuse a disposable respirator.

Most air purifying respirators consist of a tight-fitting mask with disposable cartridges or canisters (*Figures 6* and *7*). The respirator design may be a half-mask (covers the nose, mouth, and chin) or full-face (covers the entire face). An air-purifying respirator equipped with suitable cartridges/canisters is needed for protection against vapors. An air-purifying respirator also can provide protection against dusts/mists if the appropriate cartridge/canister is selected. Canisters typically have a longer use life than cartridges because they have more absorption capacity. A full-face respirator provides greater protection than a half-mask and also protects the eyes.

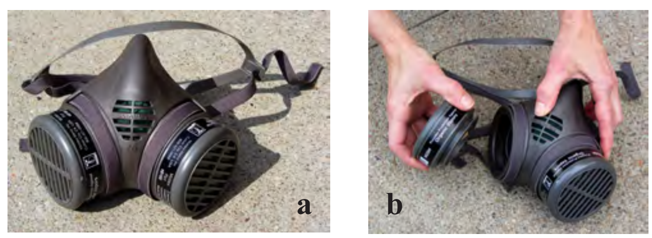


Figure 6. Half-face cartridge respirator with cartridges attached (6a) and cartridge detached (6b).

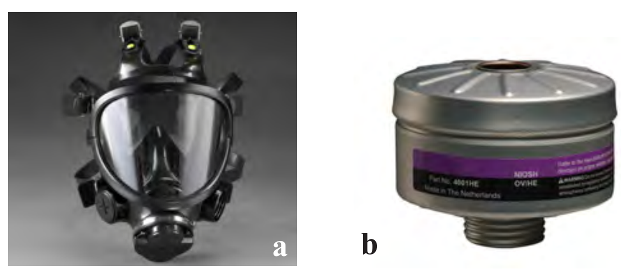


Figure 7a. Full-face canister respirator (no canister) (Photo courtesy of 3M); 7b. Close-up of canister. (Photo courtesy of North by Honeywell)

If the oxygen supply is likely to be low or the application will result in heavy concentrations of highly toxic pesticides, such as fumigants, a self-contained breathing apparatus (SCBA) (*Figure 8*) or supplied-air respirator (*Figure 9*) will be needed. The air pack is an SCBA commonly used for

Figure 8. Self-contained breathing apparatus. (Photo courtesy of MSA.)

fumigation. Air packs typically supply 25-30 minutes of air and consist of a full-face mask attached to a tank of air carried on the applicator's back. The supply time may be considerably shorter if the respiration rate increases due to overexertion. A warning bell can be set to signal depletion of the air supply.

Figure 9. Supplied air respirator. (Photo courtesy of MSA.)

Air-supplied respirators provide air from an outside source that is pumped to the applicator through an airline. A major advantage of an airline is that the air supply does not expire in a short time. However, the airline must be towed throughout the facility being treated; air pump failure or a constriction of the airline can shut off the air supply. Also, the air pump must be located in a fumigant-free area. In combination with an SCBA, an air-supplied respirator offers an unlimited work period with backup respiratory protection provided by the SCBA if the outside air supply is cut off for any reason.

Caring for Protective Clothing

Applicators who routinely work with pesticides should wear clean clothing daily, and reserve at least one set of clothing for pesticide work if possible. Launder pesticide-contaminated clothing and store work clothing separately.

Clothing that has become wet from pesticides should be removed immediately. Fast action will reduce your exposure to the pesticide. Discard clothing (including shoes and boots) saturated with any concentrate or any diluted spray of highly toxic pesticides (signal word: "Danger"). Waterproof and chemical-resistant hats, gloves, boots, and goggles should be washed daily and hung to dry. Test reusable gloves for leaks by filling them with water and gently squeezing the top. If water comes out, replace the gloves.

Laundering Clothing Soiled With Pesticide

- Wear uncontaminated clothes during pesticide applications. Remove these clothes upon finishing the job and change into clean clothes before going home for the day. Or wear chemically resistant, disposable (non-reusable) coveralls over your clothing.
- At the end of the job or application, remove your contaminated clothing and wash immediately. If this is not possible, wash separately from family laundry.
- Dispose of clothing heavily soiled with pesticide according to label instructions. This includes pesticide saturated shoes and boots.
- Wear chemical-resistant gloves when handling pesticide contaminated clothing.
- Wash pesticide contaminated clothing daily.
- Wash only a few items at a time. Do not mix with regular laundry.
- Use liquid detergent, highest water level, and hot water.
- Use wash cycle for heavily soiled clothes.
- After washing, remove clothing from the machine and run the washer through another cycle with hot water and detergent before laundering other clothing.
- Line dry if possible, or use regular dryer setting.

Emergency Phone Numbers

The Poison Control Center
For aid in human poisoning cases
(800) 222-1222
Nebraska Department of Environmental Quality
To report chemical spills 8 a.m. to 5 p.m. M-F
(402) 471-2186; (877) 253-2603
Nebraska State Patrol (after hours)
To report chemicals spills after hours
(800) 525-5555; (402) 471-4545

Washing Up

Good personal hygiene is essential to keeping yourself pesticide-free. Soap and water are cheap insurance against pesticide contamination.

- Wash your hands and face often and keep soap and water nearby when working.
- If you've handled pesticides, always wash your hands with soap before smoking, eating, drinking, or using the toilet.
- Shower immediately after using pesticides and before changing into clean clothes.
- Remove and leave shoes at the door so you don't track pesticides into the house.

Be Prepared for an Emergency

Take the pesticide label with you when seeking medical care. Have emergency telephone numbers handy (see above box) and keep them posted where pesticides are stored, mixed, or applied. If you experience any pesticide poisoning symptoms (nausea, skin rashes, headaches, coughing, diarrhea, chest pain, twitching, or seizures), see a physician immediately. For more information, see Extension Circular 2505, *Signs and Symptoms of Pesticide Poisoning*.

This publication has been peer reviewed.

Disclaimer

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

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Index: Pesticides, General Safety
1985, 2002, 2006, Revised August 2012

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

G1961

Pesticide Safety: Choosing the Right Gloves

Erin C. Bauer, Extension Associate; Clyde L. Ogg, Extension Educator; Jan R. Hygnstrom, Project Coordinator; Emilee A. Dorn, Extension Assistant; and Ben W. Beckman, Extension Assistant

This NebGuide explains how to choose and properly use gloves when mixing, loading, or applying pesticides; how to maintain such gloves; and how these procedures can help reduce exposure to chemicals and protect human health.

Properly protecting yourself when using pesticides can decrease the risk a pesticide has on your health and safety. Handling pesticides can include mixing, loading, or applying pesticides, all of which could expose your hands to chemicals. Using the right gloves is essential, since the highest percentage of pesticide exposure occurs through the skin. Chemical-resistant gloves are one of the most important pieces of personal protective equipment (PPE). Most pesticide labels have minimum requirements for personal protective clothing and equipment. Even when the label does not require chemical-resistant gloves, we recommend that you wear them when handling any pesticide.

Types of Gloves

Choosing gloves depends on the type of pesticide and the application. In general, unlined, liquid-proof neoprene, butyl, or nitrile gloves (*Figure 1*) with tops that extend well up on the forearm are best. These materials provide good protection under most conditions, are durable, and are reasonably priced. Most of these gloves are available in reusable pairs that can be cleaned after each mixing/loading task or pesticide application. Others, such as nitrile gloves, are available as single-use disposables.

The barrier laminate glove (*Figure 2*) offers the most protection. It consists of two or more different materials that are laminated or blended together. Viton® is another good choice, but is more expensive than most other chemical-resistant gloves. When making decisions about which gloves to purchase, you must consider your risk—the length of time you will be exposed to the pesticide along with the type of pesticide you'll be using (Risk = Exposure X Toxicity)—and weigh this against the cost of gloves.

Figure 1. Examples of recommended gloves: nitrile (reusable and disposable), neoprene, and butyl rubber. Photo: University of Nebraska–Lincoln.

Figure 2. Example of EPA's highest rated protective glove material, barrier laminate. Photo: University of Nebraska–Lincoln.

Table I. Types and Characteristics of Personal Protective Material.
(for use when PPE section on pesticide label lists a chemical resistance category)

Selection Category Listed on Pesticide Label	***Types of Personal Protective Material***							
	Barrier Laminate	*Butyl Rubber ≥ 14 mils*	*Nitrile Rubber ≥ 14 mils*	*Neoprene Rubber ≥ 14 mils*	*Natural Rubber* ≥ 14 mils*	*Polyethylene*	*Polyvinyl Chloride (PVC) ≥ 14 mils*	*Viton ≥ 14 mils*
A (dry and water- based formulation)	NA	NA	NA	NA	high	NA	NA	NA
B (acetate)	high	high	slight	slight	none	slight	slight	slight
C (alcohol)	high	high	high	high	moderate	moderate	high	high
D (halogenated hydrocarbons)	high	high	moderate	moderate	none	none	none	slight
E (ketones, such as acetone)	high	slight	high	high	slight	none	moderate	high
F (ketone and aromatic petroleum distillates mixture)	high	high	high	moderate	slight	none	slight	high
G (aliphatic petroleum distillates, such as kerosene, petroleum oil, or mineral oil)	high	slight	slight	slight	none	none	none	high
H (aromatic petroleum distillates, such as xylene)	high	slight	slight	slight	none	none	none	high

*includes natural rubber blends and laminates

High: Highly chemical resistant. Clean or replace PPE at end of each day's work period. Rinse off pesticides at rest breaks.
Moderate: Moderately chemical resistant. Clean or replace PPE within an hour or two of contact.
Slight: Slightly chemical resistant. Clean or replace PPE within ten minutes of contact.
None: No chemical resistance. Do not wear this type of material as PPE when contact is possible.
NA: Not Applicable. Provides high resistance but exceeds level of protection required for these formulations.
Reference: Environmental Protection Agency, "Labeling Review Manual-Chapter 10: Worker Protection Labeling, EPA Chemical Resistance Category Selection Chart," http://www.epa.gov/oppfead1/labeling/lrm/chap-10.htm#VIA

Waterproof gloves will not provide adequate protection from pesticides, so be sure your gloves are rated as chemical-resistant. You should avoid latex gloves, as they do not provide adequate skin protection; they disintegrate rapidly; and they are not recommended by the Environmental Protection Agency (EPA). Canvas (such as gardening) or leather gloves, gloves worn by medical personnel, or household cleaning gloves are all inadequate for working with pesticides.

You may wear lightweight, single-use cotton liners inside chemical-resistant gloves. These liners improve the comfort and ease of putting on and taking off your gloves. Never reuse these liners, however; they must be discarded after each use to avoid potential exposure to pesticides that may have been absorbed by the cotton material. In addition, you should avoid gloves with integrated linings or gloves made entirely of cotton. These materials absorb pesticides, are hard to clean, and increase your chance of pesticide exposure.

The EPA developed a rating chart defining chemical resistance of various materials used for gloves. These ratings range from no chemical resistance—materials that should never be used during pesticide applications—to highly chemical-resistant materials that, with proper care and cleaning, can be reused and still provide good protection. A chemical resistance category (designated with letters A-H) may be listed on the pesticide label and is based on the solvents used in pesticides rather than the pesticides themselves. These categories refer to how long you can safely wear gloves of a certain material and thickness while handling a specific pesticide. This also depends on the formulation of a pesticide. For example, the amount of time you can wear a certain glove material when using a dry formulation may be different from the same pesticide in a liquid formulation.

Table I, a reproduction of the EPA's rating chart, gives the types of personal protective material and their characteristics to help determine the appropriate type of gloves to use when mixing and loading or applying a pesticide. The first column of *Table I* has the selection categories (A through H) that may be found on some pesticide labels, as well as the solvents (listed in parentheses) that are associated with pesticides in those categories.

The guidelines in this chart provide basic information about protective materials used in gloves. Glove longevity is determined by whether you are using a concentrated pesticide, such as when mixing and loading, or a diluted pesticide, used during application. Glove lifespan is much longer when using a diluted pesticide than when using a concentrated one. Regardless of whether you are mixing and loading or applying pesticides, the amount of contact time you have with pesticides also will be a factor. For example, someone mixing and loading a concentrated pesticide all day will need to change gloves that are labeled as having "slight" or "moderate" chemical resistance more often than someone who mixes and loads for one hour or someone who spends half a day applying diluted pesticide. Always follow label instructions about which gloves to wear for the activity you will be doing.

Disposable vs. Reusable

The majority of information in this guide addresses gloves that have 14-mil (mil = 0.001 inch) or greater thickness (often referred to as reusable). These gloves are available in a variety of sizes, cuff lengths, and thicknesses. Like any other protective equipment, however, the number of times you can reuse these gloves is determined by the hours of use. For example, gloves would have to be replaced after eight hours of continuous use, but if used for shorter intervals they could be reused several times Other factors include the age and condition of the material. After enough use or lengthy storage, glove material can become brittle and less impervious to chemicals. Also, any glove, no matter its thickness, should be discarded if it becomes torn or damaged. Do not reuse gloves from one season to the next.

Gloves with less than 14-mil thickness (often referred to as disposable) have a shorter usable life than those gloves indicated in the EPA chart. These disposable gloves are available in a variety of thicknesses (e.g., 4, 8, or 12 mil), sizes, and cuff lengths.

Cost often varies with thickness; thicker gloves usually are more expensive. Keep in mind, however, that thicker gloves offer better protection than thinner ones.

In general, disposable gloves may be preferable over reusable because they can be discarded after one use and thus do not require as much maintenance as reusable gloves. However, because reusable gloves are thicker, always consider the type of pesticide being used and the length of time needed to make the application. Thicknesses of 14 mil or greater may be a better choice in some circumstances.

Reusable gloves must be washed and carefully removed after use to prevent contaminating your skin or other areas, such as the interior of tractor cabs. In addition, reusable gloves must be stored properly and checked for leaks before using again; you can throw away disposable gloves according to directions on the label upon completion of your pesticide application.

Glove Size

Depending upon the manufacturer and material, disposable and reusable gloves are available in standard or long-cuff lengths. Determine the best glove size for you by measuring the circumference around the palm of your hand. For example, if it measures 8 inches, a medium would probably be the best choice.

Table II lists available glove sizes:

Proper glove fit is essential. Poorly fitting gloves can complicate your ability to apply pesticides correctly. A glove that is too tight will be uncomfortable and may split, allowing the pesticide to penetrate your skin. Gloves that are too large can slide on your hands and allow the pesticide to run down into the gloves and onto your skin. Handling equipment also becomes more difficult when you can't grip it sufficientl , increasing the chance for mistakes. Always try on your gloves and ensure they fit properly before handling pesticides

Table II. Glove size in relation to circumference of the hand at the palm.

Glove size	*Circumference of palm (in inches)*
Extra small	6-7
Small	7-8
Medium	8-9
Large	9-10
Extra large	10-11
2XL	11-12
Jumbo	12-13

Glove Thickness

The thickness of the material used in chemical-resistant gloves can affect their lifespan and their susceptibility to tears, abrasions, and general wear. Both disposables and reusables are available in various thicknesses. Manufacturers sell gloves with thickness ranges falling between 4-22 mils (*Figure 3*). Other thicknesses also may be available. Note that breakthrough time (the length of time for the pesticide to permeate the glove) is generally greater the thicker the material.

As mentioned earlier, the lifespan of a pair of gloves also depends on whether you are using concentrated or diluted pesticides. Concentrated pesticide will wear out gloves much faster and decrease lifespan much more quickly than diluted pesticides. Keep this in mind when choosing a glove thickness.

Proper Use

In most cases, we recommend wearing gloves under your sleeves to keep pesticide from running down the sleeves and into the gloves (*Figure 4*). When working with your hands above your head, roll glove tops into cuffs over your sleeves to prevent the pesticide from running down the gloves to your forearms. As an extra safety measure, you can apply duct tape where the glove and sleeve meet. Remember, the most important thing is to wear gloves!

Figure 3. Disposable nitrile gloves in 4-, 8- and 12-mil weights. Photo: University of Nebraska–Lincoln.

Figure 4. Wear gloves under long sleeves to protect yourself from pesticide exposure. Photo: University of Nebraska–Lincoln.

If applying fumigants, be especially careful to follow label directions regarding gloves. Some fumigants can penetrate materials such as rubber and neoprene, and may cause severe skin irritation if trapped and absorbed by the skin. Many labels for pelletized fumigants, such as aluminum phosphide, may require dry cotton gloves. These gloves allow airflow so that fumigant gasses won't be trapped against and burn skin.

Proper Cleaning and Removal

After fin shing a pesticide application, remove and discard disposable gloves and then wash your hands with soap and warm water. It is especially important to do so before eating, smoking, or using the toilet. Wash reusable gloves with soap and warm water while still wearing them, and then remove them.

If you are using a concentrated pesticide for mixing and loading and it gets on your gloves, you should rinse them immediately before continuing the activity. Then, after finishing the job, thoroughly wash and remove the gloves, as outlined below. By following these guidelines, you can prolong the life of your gloves as well as protect yourself from exposure.

To remove disposable gloves properly:

1. Grasp the outside cuff of one glove with the other gloved hand and pull it inside out and off the hand. Be careful not to touch your skin. Then, ball up the removed glove in your gloved hand as you take off the remaining glove by grasping the inside of the cuff and pulling it off. You can pull it so the first glove ends up inside the glove you just removed.
2. Finally, dispose of gloves according to label directions, being careful at all times not to contaminate clothes and skin.

To remove reusable gloves properly:

1. Wash the outsides of your gloves with soap and warm water. Use a sink if one is available nearby, otherwise bring a bucket and water onsite with you.
2. Next, with one gloved hand, grasp the fingers of the other glove and slowly work back and forth alternately between the gloves until you have pulled off both gloves.
3. Finally, hang the reusable gloves out to dry. Do not put gloves in the washing machine!

After removal of either disposable or reusable gloves, always wash your hands with warm water and soap before going about daily activities. This will ensure that you do not transfer pesticide residue from your hands into your home, vehicle, or other areas where it could expose you, your family, or other nontargets to pesticides.

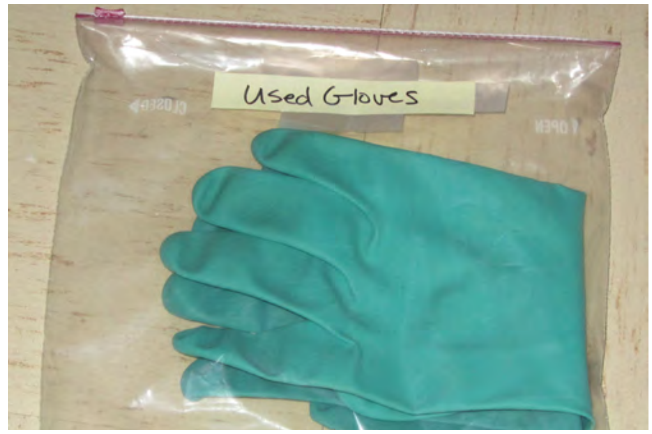

Figure 5. Properly store used gloves in a plastic bag or bucket labeled as such. Photo: University of Nebraska–Lincoln.

Storage and Disposal

Proper maintenance of chemical-resistant gloves includes not only cleaning and removal, but also safe storage and disposal practices.

1. Store unused disposable or reusable gloves in their original bag or other container with a lid, such as a plastic bucket. Mark the container with the name of its contents.
2. After using disposable gloves, discard them according to label directions.
3. Store reusable gloves in a bucket or plastic bag marked as such once they are dry (*Figure 5*). Never place contaminated gloves directly onto the seat of your vehicle or other surfaces you may come in contact with.
4. Check reusable gloves before each pesticide application for leaks or wear. A good practice is to fill the gloves with water and look for any holes or tears, or put the gloves on and put your hands in a bucket or sink of clean water. Dispose of any glove according to the pesticide label if it is defective or has significant wear and replace with a new one.
5. Store gloves in a different location from pesticides to prevent them from accidental contamination during storage. Gloves should be stored in a clean environment, away from direct sunlight or temperature extremes. Do not store used gloves in your home where they might be accessible to children or pets.

By following the label, using recommended chemical-resistant gloves when applying pesticides, and properly maintaining gloves when not in use, you will reduce your risk of pesticide exposure.

This publication has been peer reviewed.

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Index: Pesticides
General Safety
2009, Revised April 2015

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

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University of Nebraska–Lincoln
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Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications

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Pierce J. Hansen, Extension Assistant; and Jan R. Hygnstrom, Project Coordinator**

This NebGuide examines the proper way to fit test a cartridge respirator before beginning a pesticide application and how to maintain a respirator after use.

When working with any pesticide, you must follow all personal protective equipment (PPE) requirements listed on the label. This is for your safety, and also is a legal requirement for using pesticides. Some pesticides carry a risk of inhalation exposure and require the use of a respirator, such as a dust respirator, full or half face cartridge (air purifying) respirator, or self-contained breathing apparatus (SCBA). This NebGuide will focus on the half face cartridge respirator, which is one of the most common respirators used when applying pesticides.

Like other PPE, it is vital to properly maintain your respirator to ensure that it offers adequate protection when you apply pesticides. This includes testing the respirator before each use to make sure that it has a tight seal, as well as proper cleaning and storage of the respirator after each use.

Your New Respirator

Some pesticide labels clearly state specific types of respirators/cartridges/filters that are required. Be sure to follow these directions carefully; purchase and use the appropriate type for the product you will be applying.

When you buy a new respirator, it will come in a package with several components. These include an instruction manual, faceplate with straps, two cartridges, and extra accessories to attach for dust or particulate protection *(Figure 1)*. Check the labels on the cartridges to ensure they provide the protection you need, whether it is against organic vapors or other particulates.

It is important to read the instruction manual thoroughly before using the respirator. The manual explains how to properly assemble, fit, maintain, and store the respirator. The most important thing to remember when using a respirator is to get a good seal. Without a good seal, the respirator will not effectively protect you from pesticide inhalation exposure.

Fit Testing

Fit testing is mandatory under Occupational Safety and Health Administration (OSHA) regulations. Fit testing must be done to determine the size of the respirator for a particular user. Pesticide applicators need to meet certain health requirements before conducting a fit test or doing work that requires a respirator. OSHA requires that an employee who will be using a respirator have a medical evaluation prior to fit testing. The employee also needs to be properly trained in respirator use. For more information about OSHA's medical evaluation questionnaire, mandatory fit test procedures, and

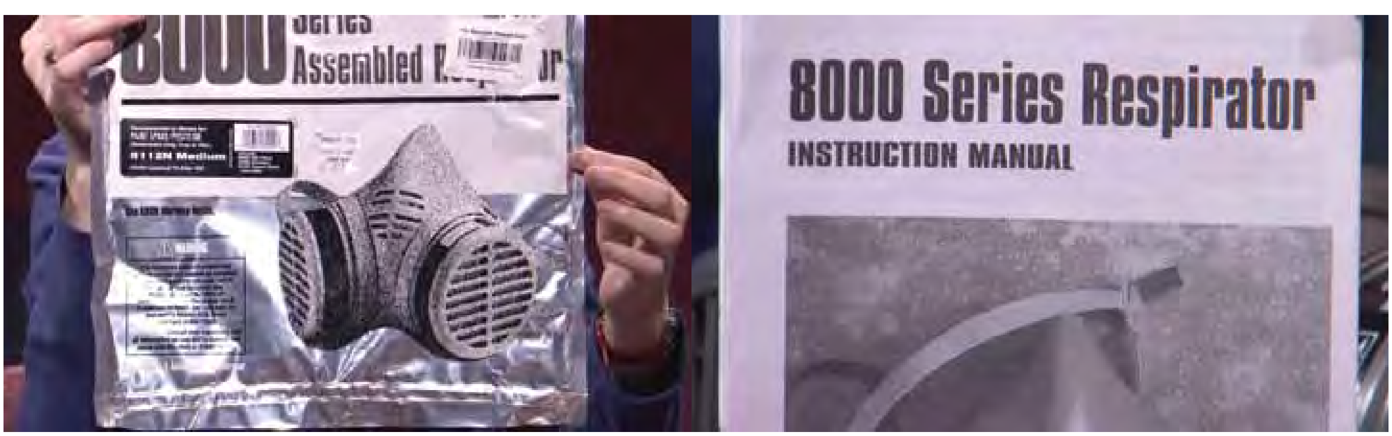

Figure 1. Examples of respirator packaging and instruction manual.

Figure 2. Adjusting a respirator step-by-step: 1. Place on face. 2. Adjust halo. 3. Adjust neck straps.

other respirator requirements, visit OSHA's website at *http://www.osha.gov* and search for regulation 1910.134.

OSHA lists minimum requirements for respirator fit testing and initial use. For example, a new fit test may be required if there is a change in size, make, or model of the respirator you are using, or a change in user characteristics such as dental work, body weight, etc. You should always follow these guidelines.

The most important part of a fit test is obtaining a good seal. It is good common practice to test the seal on your respirator **every time** you put it on. Between removal, cleaning, and storage, the respirator may not fit the same, so you'll have to readjust it before using it again. Prior to each use, check the face seal for cracks and abrasions. Check respirator assembly (components, valves, O-rings) to ensure they are intact, present, and appropriate.

To accomplish a seal check, the faceplate has to fit tightly against your face. Facial hair may prevent you from being able to get a tight seal, so you may need to shave before using a half face respirator, or choose an alternative pesticide that does not require a respirator.

There are three common ways to test the seal. Before testing, adjust the respirator so you think you have a good fit. To begin, place the respirator on your face, then pull the top (halo-shaped in some models) plastic strap and adjust it over and on top of your head. Next, connect the straps that go behind your neck, and pull the loose ends of the straps to adjust for comfort and fit. When you feel you have a tight seal, test to ensure your respirator is fitted properl *(Figure 2).*

Positive Seal Check

To perform the positive seal check *(Figure 3)*, cover the exhalation valve in front of the respirator and gently exhale. If you can do this without feeling a rush of air around the faceplate, you have a good seal.

Negative Seal Check

To perform the negative seal check *(Figure 4)*, cover the intake portion of each of the two cartridges with your hands and inhale gently. Note that you also can do this test without

Figure 3. Positive seal.

Figure 4. Negative seal.

Figure 5. Ampule test.

Prior to Fit Testing

1. Remove respirator and cartridges from their packaging.

2. Place the mask in front of you with the cartridge holes facing toward you.

3. Attach each cartridge by lining it up with one of the holes, inserting it, and turning it counterclockwise until it locks firmly in place

4. Perform the fit test and seal check

the cartridges by simply covering the inlet holes and testing the seal. If you have a good seal, you should not be able to pull any air through the seal against your face. If you can pull air, check carefully around the seal for damages or obstructions. If you find breaks or damaged portions of the seal, replace the respirator. If you are able to clear obstructions and make additional adjustments to strengthen the seal, simply retest the unit. In some cases, if you can't find a solution, you will need to replace the respirator seal or the entire unit.

Ampule Test

An ampule is a small, sealed vial that can be purchased from many online suppliers. Ampule testing for respirator fit is one example of several procedures that may be required by OSHA. In the ampule test *(Figure 5)*, you break an ampule designed for this purpose and see if you can detect an odor (often smelling like concentrated banana) through the respirator. If you detect an odor, you know that your seal isn't adequate and you'll have to make additional adjustments. Make sure to test the ampule across all portions of the respirator seal. You also should consider simulating common working motions such as moving your head up and down and side to side to test field operabilit .

Maintaining Your Respirator

When finished with your respirator, clean and store it properly after each use so that it's in good condition for the next use.

After removing your respirator, remove the cartridges. They generally unthread, bend, or snap out of the faceplate. If the cartridge seating is damaged during removal, do not attempt to repair or bend it back in place — simply replace the cartridge. Store cartridges in either the original respirator packaging or a resealable zipper storage bag when not in use. The best type of storage container is one with an airtight seal. Cartridges absorb pesticides and other organic vapors when exposed to air. You can extend their life span by storing them properly whenever they are not in use. The respirator package or resealable zipper storage bag provides ideal storage because it offers an airtight seal that will help preserve the cartridges by keeping organic vapors out. It is also a good idea to mark the storage container with the purchase date of the cartridges and a running tally of the total number of hours used *(Figure 6)*.

After removing and storing the cartridges, wash the faceplate with soapy water and either air or towel dry before storing it in a clean, dry container with a good seal such as a resealable zipper storage bag or a tight-sealing plastic storage container until the next use. Store the respirator in a way that preserves the shape and integrity of the respirator, protecting it from distortion, contamination, and extreme temperatures.

Figure 6. Store your respirator in its original packaging or a resealable zipper storage bag or plastic storage container.

Figure 7. After each use and before storing your respirator, the faceplate should be washed with soapy water, hung to dry, and checked for wear or damage.

Also, be sure to inspect the respirator for any holes, damage, or wear, and replace it if necessary *(Figure 7)*.

Replacing Your Cartridges

A respirator cartridge has a limited life span, which is greatly affected by the conditions of use, such as the temperature, humidity, work efforts of the user, and the chemical concentration and type of chemicals for which the cartridge is used. Many respirator manufacturers have online calculators in which you can enter this information to determine cartridge life. Consult the manufacturer's website for such software. Keep a log of respirator usage to know how long the cartridges have been used. For more information and a sample log, see the UNL Safe Operating Procedure "Respiratory Protection — Air Purifying Respirators: Cartridge Change Schedules" at *http://ehs.unl.edu/sop/RPP_SOP_Cartridge_Change_Log.pdf*.

Proper storage will help preserve cartridges for as long as possible, but eventually you will need to replace them.

Figure 8. Cartridges are color coded according to the particulates they filte .

Pay attention to when a cartridge's life is spent and be sure to replace as necessary. Cartridge life may be reduced if exposure to organic vapors is extensive and occurs over a short time span. Always replace cartridges immediately if you can smell pesticide odors when using the respirator. If you are unsure of the last time a cartridge was used or if the total hours of use have not been recorded, replace it; when in doubt, replace.

Your new cartridges should be the same type as those you are replacing. Cartridges are color coded depending on what particulates they filte . For example, organic vapor cartridges are black and have "organic vapors" written on the label *(Figure 8)*. A cartridge that filters organic vapors as well as pesticide dusts, mists, and fine particles (using a P100 filter) will be magenta and black.

To learn more about maintenance and fit testing of your respirator, refer to the user's manual that came with your respirator, or view the University of Nebraska–Lincoln Extension video, "Cartridge Respirator Use" at *http://www.youtube.com/user/UNLExtensionPSEP*.

This publication has been peer reviewed.

Disclaimer

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Index: Pesticides, General Safety

Issued June 2011

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

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NebGuide
Published by University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
University of Nebraska Lincoln

G1893
(Revised October 2014)

Pesticides and the Endangered Species Protection Program

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This NebGuide discusses the Endangered Species Protection Program and its role in the use of pesticides.

Background

The Endangered Species Act (ESA) is designed to protect animal and plant species in danger of becoming extinct, as well as the ecosystems in which they live. According to the ESA, federal agencies are required to "use their legal authorities to promote the conservation purposes of the ESA and to consult with the U.S. Fish and Wildlife Service and National Marine Fisheries Service, as appropriate, to ensure that effects of actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of listed species" (U.S. Fish & Wildlife Service, 2013). The overall goal of the ESA is to help populations of species recover so they no longer are threatened or endangered. An endangered species is one in danger of becoming extinct in all or most of its range. Threatened species have a high probability of becoming endangered in the near future if assistance is not given.

The U.S. Environmental Protection Agency (EPA) requires and is responsible for registration of pesticides. The EPA reviews information and data and determines whether a pesticide product may be registered for a particular use. Because some pesticides may harm certain threatened or endangered species, the EPA requires a review of potential impacts.

The Endangered Species Protection Program (ESPP) is one of the ways that the EPA meets the requirements of the ESA. A primary goal of the ESPP is to manage federally registered pesticides to avoid jeopardizing protected species while avoiding any unnecessary limitations on the use of many pesticides important to American agriculture for the production of food, fibe , wood, and other commodities.

Pesticide Labeling

A key component of the ESPP is directing pesticide users, through labeling on applicable pesticide products, to follow use limitations found in Endangered Species Protection Bulletins. When referenced on a pesticide label, the limitations on pesticide use given in the bulletins are mandatory and enforceable.

Bulletins are available through EPA's "Bulletins Live!" (*Figure 1*) database program at *http://www.epa.gov/espp/bulletins.htm*, which is searchable by state and county. Click the "Bulletins Live!" link and select the state and county where the pesticide application will take place. You also may click

Figure 1. Bulletins Live! map on U.S. EPA website.

"NE" on the map, and choose the county where the application will take place from the pull-down menu. Next, select the month of the pesticide application and follow the steps given in the bulletin. Bulletins also are available by calling the toll-free Endangered Species Hotline at 1-800-447-3813. Those applying pesticides can check for information in a bulletin up to six months prior to making a pesticide application.

Bulletins contain a description of the endangered or threatened species to be protected, the name of the pesticide's active ingredient that could cause harm, use limitations of the pesticide that ensure the species' protection, county maps where the bulletin applies, and the valid month(s) in which the bulletin is applicable.

Species-Based Approach

A pesticide is included in the ESPP if it poses a potential threat to a federally listed plant or animal species. The EPA consults with the U.S. Fish and Wildlife Service to make this determination. Discussed here are examples of Endangered and Threatened (E&T) animal or plant species that may appear in Endangered Species Protection Bulletins for Nebraska. While all E&T species require special attention, this publication covers only 10 of Nebraska's species, to explain how pesticides may affect plants, insects, fis , and birds. For a complete listing of all Nebraska E&T species, visit the Nebraska Game and Parks Commission's (NGPC) Rare Species website at *http://rarespecies.nebraska.gov*.

Endangered and Threatened Plants

Herbicide applications, drift, and overspray may weaken or kill fragile populations of plants. In addition, pollinators such as bees, butterflies, moths, and flies are important to the survival of many plants. Be careful when applying pesticides that could affect pollinators.

Hayden's (blowout) penstemon (*Penstemon haydenii, Figure 2,* federal and state endangered) is unique to the Sandhills region of Nebraska and Carbon County, Wyoming. Blowout penstemon is a "pioneer" plant that begins growth in a sand blowout site before most other plant species, anchoring the sandy soil and reducing wind erosion. In 1968, about 7,000 plants grew on less than 25 total acres scattered throughout the Sandhills. Since then, seeds have been collected and raised in greenhouses, with seedlings introduced to blowouts. About 20,000 plants existed in 2008 due to recovery efforts, primarily in Box Butte, Cherry, Garden, Hooker, and Thomas counties, with populations in Grant and Morrill counties, as well. In 2013, 32 blowout penstemon populations were found in the Sandhills region of Nebraska (10 native sites and 22 introduced populations). Most of the known plants are on private land. To sustain the populations, continual transplanting and maintenance of blowout sites may be necessary.

Figure 2. Blowout penstemon (photo credit: James Stubbendieck, UNL.

Western prairie fringed orchid (*Platanthera praeclara, Figure 3*, federal and state threatened) requires a relatively high and constant level of soil moisture, maintained by groundwater that is near the surface. Known populations are in 64 sites in wet prairies and meadows in the eastern two-thirds of Nebraska. According to the Nebraska Natural Legacy Project, the western prairie fringed orchid is one of Nebraska's rarest plants, with estimates of 2,000 to 5,000 plants in the state. It relies on the sphinx moth for pollination and seed production, so insecticides and other threats to these insects threaten the orchid as well. Loss of these native pollinators may be impacting pollination and genetic diversity in the western prairie fringed orchid. Other threats include invasive species, annual mid-summer haying, loss of habitat, and herbicide sprays.

Figure 3. Western prairie fringed orchid (photo credit: NGPC).

Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*, *Figure 4*, federal and state threatened) is found in moist areas of floodplains within a small area of southeastern Wyoming, north-central Colorado, and western Nebraska. The only known populations in Nebraska are located in the floodplain of Lodgepole Creek in Kimball County and the Oliver Reservoir State Recreation Area. The U.S. Fish and Wildlife Service estimates fewer than 50,000 reproducing individuals in its entire range, with only 10 of the 14 current populations considered stable or increasing in numbers. In 2008, Nebraska populations were estimated at less than 200 plants; a field survey of the two areas of Nebraska counted 12 plants. Threats to this species include invasion of habitat by Canada thistle and herbicide spraying.

Figure 4. Colorado butterfly plant (photo credit: NGPC).

Ute ladies'-tresses (*Spiranthes diluvialis, Figure 5*, federal threatened, state endangered) is a perennial terrestrial orchid. It grows in scattered sites in Colorado, Wyoming, Utah, Montana, Washington, Idaho, and Nevada. Nebraska is at the eastern edge of the species' known range. In Nebraska, they have been found only in Sioux County on private land in a two-mile stretch of the Niobrara River Valley, in subirrigated wet meadows. Ute ladies'-tresses could occur in other river and stream valleys in far western Nebraska, but have not been found during surveys. Only about 60,000 individual plants remain in the U.S. A 2010 survey in Nebraska found 831 flowering plants

Figure 5. Ute ladies'-tresses (photo credit: Bekee Hotze, U.S. Fish and Wildlife Service).

Small white lady's slipper (*Cypripedium candidum, Figure 6*, state threatened) is a perennial orchid of the northeastern U.S. Historically, the orchid probably was found throughout eastern Nebraska and much of central Nebraska. Historic collection records account for the orchid in 17 Nebraska counties. The present range consists of the eastern Sandhills and the Loup River Valley. All known Nebraska populations have less than 200 plants each, with total population estimates of 1,000 to 2,000 plants in the state. Nebraska's known populations occur primarily in native, subirrigated wet meadows, which are commonly hayed. Populations of orchids also can occur in road ditches adjacent to native wet meadows. Threats include invasive species, annual mid-summer haying, loss of habitat, and herbicide sprays.

Figure 6. Small white lady's slipper (photo credit: Tom Barnes, University of Kentucky).

Endangered and Threatened Insects

Applications of insecticides in areas occupied by E&T insects could result in the loss of local populations. Direct contact with the spray or insecticide carried by particle drift, vapor drift, or runoff could affect these insects.

Figure 7. Salt Creek tiger beetle (photo credit: UNL Department of Entomology Image Library).

Salt Creek tiger beetle (*Cicindela nevadica lincolniana, Figure 7*, federal and state endangered) is a predatory insect, about ½ inch long, that captures smaller or similar-sized insects by grasping prey with its mouthparts. The beetle spends two years as a larva in an underground burrow, capturing insects that wander by the opening. The adult beetle lives on the surface for only about six weeks, from mid-June through July.

Found only in Lancaster and Saunders counties of Nebraska, Salt Creek tiger beetles live in the moist, muddy areas of saline wetlands and stream edges associated with Salt Creek, Little Salt Creek, and Rock Creek. In 2012, researchers counted 374 beetles during an intensive field surve .

Applications of insecticides in areas occupied by Salt Creek tiger beetle could result in the loss of local populations or the entire subspecies. Both the adult and larvae are susceptible to insecticides. They may be killed through direct contact with insecticides, or they could die from secondary poisoning — eating insects that had been sprayed with an insecticide. Insecticides may reduce the numbers of insects that serve as food for this beetle, as well.

Figure 8. American burying beetle (photo credit: NGPC).

American burying beetle (*Nicrophorus americanus, Figure 8*, federal and state endangered) feeds on carrion — dead birds, fis , mammals, and other organisms. It now is found only in six states, including Nebraska. This beetle is the largest North American carrion beetle and may reach up to 2 inches in length. This species is nocturnal, seeking out and burying carrion to feed its young.

Availability of carrion and soil moisture, rather than vegetation type, appears to determine the habitat of the American burying beetle. This insect seems to require a soil type that allows for burial of carrion. The species occurs in areas least disturbed by human influence, including the Sandhills and an area southeast of North Platte. Locations include grassland prairie, forest edges, and wet meadows.

Perhaps fewer than 1,000 American burying beetles live east of the Mississippi River. In Nebraska, an estimated 3,000 beetles live in Lincoln County, with the population extending into Gosper, Frontier, and Dawson counties. A northern population of perhaps 30,000 is in the Sandhills of Nebraska, extending into South Dakota. Factors that may play a role in the population decline include habitat fragmentation that lowers the availability of preferred carrion, competition for carrion by other predators, and artificial lighting that decreases the populations of nocturnal insects. Contact with insecticides can cause direct mortality or lower reproduction rates. Applications of pesticides to control grasshoppers may affect populations.

Endangered and Threatened Fish

Pesticide applications or runoff could enter streams, ponds, or rivers and harm fish populations. Fish are particularly susceptible to pesticides during their larval development. In addition, most small native fish depend on aquatic insects for survival. Applications of insecticides could affect the fish populations indirectly due to the loss of insects as a food source. Reduce the risk of having pesticides enter surface water by establishing adequate buffer strips and using sound agricultural practices to reduce erosion and runoff.

Figure 9. Topeka shiner (photo credit: Konrad Schmidt, Minnesota Department of Natural Resources).

Topeka shiner (*Notropis topeka, Figure 9*, federal and state endangered) is a small minnow, less than 3 inches long. Food consists of insects, algae and other plant material, and fish eggs. The Topeka shiner is known to occur in portions of South Dakota, Minnesota, Kansas, Iowa, Missouri, and Nebraska. It is found in small prairie (or former prairie) streams in pools containing clear, clean water in areas of Cherry County, and the North Loup River. It also is found in Taylor Creek and its tributaries in Madison County. Most streams with Topeka shiner flow year-round, but some are small enough to stop flowing during dry summer months. When this happens, water levels must be maintained by groundwater seepage for the fish to survive. The estimated population in Nebraska is less than 200 fish

Endangered and Threatened Birds

Pesticides in stormwater runoff could enter streams, ponds, or rivers and harm or kill fish and invertebrates such as aquatic insects, crustaceans, and mollusks upon which some shorebirds feed. Fish and invertebrates can accumulate toxins in their bodies; a bird that eats them may have a buildup of toxins as well.

Figure 10. Interior least tern (photo credit: NGPC).

Interior least tern (*Sternula antillarum athalassos, Figure 10*, federal and state endangered) is 8 to 9 inches long with a 20-inch wingspread. Males and females are similar in appearance. Immature birds also look similar but have considerably browner upperparts and the black on the head is more diffuse.

Interior least terns leave their wintering grounds in Central and South America and arrive in Nebraska from mid-May to early June. This tern nests on midstream river sandbars, sand and gravel mines, and lakeshore housing developments across the state (primarily along the Platte, Missouri, Elkhorn, Loup, and Niobrara River drainages). Nests are inconspicuous, consisting of a small depression on sand or similar substrate.

NebGuide

IANR

University of Nebraska–Lincoln

University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

G1955
Revised May 2015

Understanding the Pesticide Label

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This NebGuide describes the parts of a pesticide label to aid understanding and promote safe and effective use of pesticide products.

The pesticide label is more than just a piece of paper, it is a legal document recognized by courts of law. Pesticide applicators assume certain responsibilities when they purchase and use a product. (For more information see NebGuide G479, *Pesticide Laws and Regulations*).

The format of labels differs between manufacturers, as well as between consumer and commercial product labels. The U.S. Environmental Protection Agency's (EPA) *Consumer Labeling Initiative* (CLI) details the main differences between consumer and commercial product labels. (See more on CLI at *http://www.epa.gov/pesticides/regulating/labels/consumer-labeling.htm*.)

Pesticide products are further differentiated based on type and registration, and have different label types. There are many different types of pesticides but some examples include herbicides, insecticides, fungicides, termiticides and rodenticides. All pesticide products must be registered with the EPA. The four main pesticide registrations are:

- **Section 3** — product has standard registration;
- **Section 25(b)** — minimal risk, product has been exempted from registration;
- **Section 24(c)** — pesticide has been registered based on a special local need; and
- **Section 18** — product has been given an emergency exemption.

Pesticide manufacturers are required by law to provide certain information on the label. The information includes:

- brand name or trade name of the product;
- ingredient statement;
- percentage or amount of active ingredient(s) by weight;
- net contents of the container; and
- name and address of the manufacturer.

Other required parts of the label are:

- the registration and establishment numbers;
- statement of practical treatment;
- environmental hazard statement;
- classificatio statement;
- directions for use;
- re-entry statement, if necessary;
- harvesting and/or grazing restrictions; and
- storage and disposal statements.

Figure 1. An example of pesticide label.

Interior least terns typically lay two or three brown spotted eggs.

Adult interior least terns eat small fish. Water quality must be high enough to support a reproducing fish population. During the breeding season, least terns may feed within a few hundred yards of, to miles from the nesting area. Typically, all interior least terns have migrated out of Nebraska by the end of August.

The decline of interior least terns is principally attributed to habitat loss, but human disturbance at nesting sites, pollution, and disease also negatively affect this species in Nebraska and elsewhere.

Piping plover (*Charadrius melodus, Figure 11*, federal and state threatened) is a robin-sized shorebird. A common relative, the killdeer, is larger, more darkly colored, and has two dark breast bands.

Figure 11. Piping Plover (photo credit: NGPC).

Piping plovers breed in Nebraska from early April through August. Nesting habitat includes extensive, sparsely vegetated areas of sand adjacent to water, including sandbars, sand and gravel beaches, reservoir shorelines, and sand and gravel mines along rivers. Nests are shallow, typically lined with small pebbles, shells, or other material. Females lay a clutch of four eggs. Piping plovers feed on small insects, worms, and other invertebrates they collect from the surface of wet sand along the shoreline of rivers, ponds, and lakes. Reduced availability of food due to pollution or other variables can affect survival and reproductive success. The piping plover commonly is found in the same breeding areas as the interior least tern, and has been negatively affected by many of the same variables as the interior least tern.

National Pollutant Discharge Elimination System Permits

When making pesticide applications to, over, or near waters of the state for nonagricultural uses (rights-of-way, mosquito control, algae control, etc.), a National Pollutant Discharge Elimination System (NPDES) permit may be required. In these cases, you must consider if state-listed E&T species could be adversely affected. The NGPC has developed a document with standard procedures to follow, *E&T Species Standard Procedures for NPDES Pesticide Permit.* If you cannot follow these procedures, you must consult with the NGPC Planning and Programming Division prior to the pesticide application. Paperwork must be submitted, and at least 30 days are required for the review. Information on a consultation with NGPC is available at *http://outdoornebraska.ne.gov/wildlife/programs/nongame/consultation.asp*.

Summary

Endangered and threatened species require special attention due to their vulnerability. Always read pesticide labels carefully. If directed to do so by the label, follow use limitations found in Endangered Species Protection Bulletins, accessed either online or through the toll-free telephone number. When applying nonagricultural pesticides to, over, or near waters of the state, a National Pollutant Discharge Elimination System may be required. If so, Nebraska Game and Parks Commission has additional standards that must be followed.

Resources

Contact the following individuals, offices, or websites for additional information.

Nebraska Department of Agriculture

Craig Romary, Nebraska Department of Agriculture, Lincoln, NE (402) 471-2394

Nebraska Department of Agriculture List of Threatened and Endangered Species *http://www.nda.nebraska.gov/pesticide/endangered.html*

Nebraska Department of Environmental Quality

NPDES Press Release *http://www.deq.state.ne.us/Press.nsf/pages/PR111011* or *http://pested.unl.edu/NPDES*

Nebraska Game and Parks Commission

Nebraska Game and Parks Commission, Lincoln, NE (402) 471-0641 *http://rarespecies.nebraska.gov/*

NGPC Endangered and Threatened Species Consultation Information *http://outdoornebraska.ne.gov/wildlife/programs/nongame/consultation.asp.*

NGPC Environmental Analyst Supervisor, Michelle Koch, Lincoln, NE (402) 471-5438

NGPC E&T Species Standard Procedures for NPDES Pesticide Permit *http://outdoornebraska.ne.gov/wildlife/programs/nongame/pdf/E&T%20Species%20Standard%20Procedures%20for%20Pesticide%20Permit_04112012.pdf*

USDA Natural Resource Conservation Service (NRCS)

Field Office Technical Guide listing of Nebraska Endangered and Threatened Species with descriptions and locations (2011). *http://efotg.sc.egov.usda.gov//references/public/NE/Subsection_II_TOC_ENDANGERED_AND_THREATENED_SPECIES_LISTS.pdf*

U.S. Environmental Protection Agency

Dick Wiechman, Environmental Protection Agency Region 7, Nebraska Field Office, Lincoln, NE (402) 437-508

EPA endangered species hotline (800) 447-3813

Endangered Species Protection Program, U.S. Environmental Protection Agency *http://www.epa.gov/espp*

U.S. Fish & Wildlife Service

U.S. Fish & Wildlife Service, Grand Island, NE (308) 382-6468

U.S. Fish & Wildlife Service. 2013. ESA Basics at *http://www.fws.gov/endangered/esa-library/pdf/ESA_basics.pdf*

This publication has been peer reviewed.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.

Index: Environmental & Natural Resources Conservation

2008, Revised October 2014

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

NebGuide

University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

Know how. Know now.

G2179

Protecting Pesticide Sensitive Crops

Clyde L. Ogg, Extension Pesticide Education Coordinator; Erin C. Bauer, Extension Associate; Greg R. Kruger, Extension Cropping Systems Specialist; Pierce J. Hansen, Extension Assistant; Janet R. Hygnstrom, Project Coordinator; and Craig L. Romary, Environmental Programs Specialist, Nebraska Department of Agriculture

This NebGuide examines how to protect sensitive crops, such as those found on organic and traditional commercial farms or in vineyards, from pesticide injury.

Pesticide sensitive crops, such as grapes in vineyards or fruit, vegetable, and ornamental crops grown on organic or traditional commercial farms, are becoming more common in the landscape. Consumer demand has created markets for these products, and sales of these crops have contributed to the state's agricultural economic diversity. Even though any agricultural crop can be damaged by pesticide drift, these crops are especially sensitive to injury by pesticides; the potential for economic loss is significant For example, grapes have an annual fruit value of $4,000 to $5,000 per acre and the processed value can be up to 10 times higher *(Figure 1)*.

Figure 1. Fruit crops such as grapes contribute to Nebraska's agricultural economic diversity *(Jeanne Fox, Kansas Department of Agriculture).*

Use Pesticides Carefully

Pesticides include herbicides, insecticides, and fungicides. When applying pesticides, take extra precautions to avoid damaging sensitive crops. Many plants and animals are sensitive to pesticides and may be harmed by particle spray drift, vapor drift, or pesticides that run off the target area. This NebGuide focuses on herbicides that are especially prone to drift, and have high risk of causing damage when they move off-target. Reducing the potential for off-site movement onto sensitive sites is particularly important when applying these herbicides.

Since the introduction of Roundup Ready® crops in 1996, glyphosate has been used extensively for weed management in the Midwest. Glyphosate drift can damage many different crops. Plants including grapes, tomatoes, potatoes, soybeans, and fruit and nut trees, are very sensitive to spray drift from hormonal-type herbicides such as dicamba, picloram, MCPA, triclopyr, fluroxypy , mecoprop, and 2,4-D. These herbicides can affect plants, especially sensitive crops, near the application site.

Be Proactive

The Nebraska Department of Agriculture (NDA) and Purdue University have arranged for a Web-based locater for sensitive commercial crops and bee hives called Driftwatch™ *(Figure 2)*. Commercial growers of sensitive crops and bee keepers

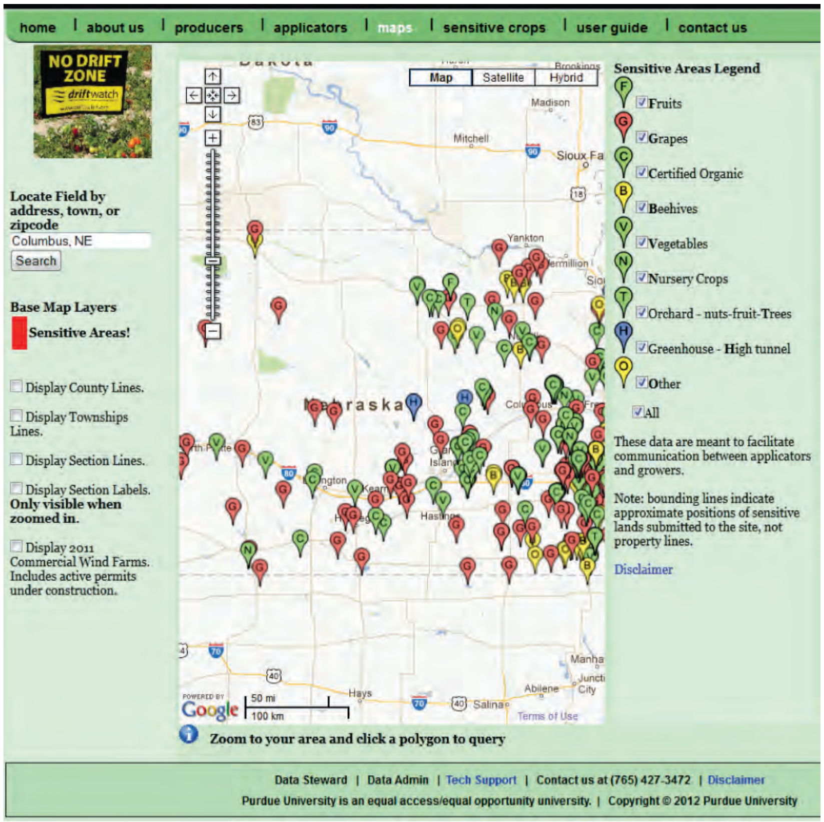

Figure 2. Nebraska Driftwatch encourages commercial producers to register locations of sensitive crops and bee hives.

are encouraged to register locations of their crops and hives. Pesticide applicators are encouraged to use this website to determine if any sensitive crops are near a planned pesticide application site. If a sensitive crop site is identified applicators should adjust pesticide application procedures, including timing and/or application methods, accordingly.

Applicators are encouraged to use Driftwatch and document known locations in application records, or print a map from the website and incorporate it into application records. It is also good practice to scout the area before the planned pesticide application to become familiar with the landscape. Because listings on Driftwatch are voluntary, not all sensitive crop locations may be included. Pesticide applicators and dealers should visit with neighbors who may have sensitive crops or bee hives to let them know of intended pesticide applications, and assure them that all applications will be made so as to avoid injury.

Driftwatch allows applicators the ability to sign up for email notification when new locations are entered in their "business area." Simply register for this service then choose a business area by selecting statewide or individual counties, or use the online mapping tool to draw a geographic area.

Driftwatch is only as effective as the information provided by growers and the action taken by applicators. New or updated information should be submitted as soon as possible. In addition, those with sensitive crops should contact their neighbors and/or local pesticide dealers, co-ops, and other pesticide applicators in the area to alert them to the potential for pesticide damage. Good communication is the key to avoiding pesticide injury problems.

The Nebraska Driftwatch can be found at *http://nebraska.agriculture.purdue.edu/.*

Strategies to Protect Sensitive Crops

Use Integrated Pest Management (IPM). Before each application, review and consider using a variety of IPM methods, including pest prevention, scouting to monitor pest populations, economic threshold levels, and pesticide alternatives such as mechanical controls, sanitation, crop rotation, biological controls, and selection of resistant varieties.

Select an appropriate pesticide product. If using a chemical control, read product labels to find one suitable for the pest you want to control. Consider the toxicity and potential hazard of the product, and select one with the lowest risk of harming sensitive crops. Make sure the target site or crop is listed on the label.

Read the label. Follow all label directions. It is illegal to apply more than the label allows. For more details about the pesticide label see *Understanding the Pesticide Label* (NebGuide G1955).

- Remember that the pesticide label is the law. Read and follow all directions and precautions. Only apply pesticides on sites (crops, pastures, or other areas) that are listed on the label. Application of a pesticide to a site that is not listed on the label is illegal. Do not exceed the rate specified on the pesticide label; the use of a rate higher than that given on the label is illegal. The risk of off-target injury to people, livestock, pets, wildlife, and plants will be greatly reduced by following label instructions.
- Many labels, especially new ones, have instructions on avoiding drift. Some new labels include set-back zones to protect sensitive areas. Additionally, there could be information ranging from droplet size, nozzle selection, and maximum wind speeds in which applications can be made to avoid drift.

Follow all precautions and plan your application. The pesticide label will list environmental hazards and restrictions on the use of the product. Become familiar with the application site and ask yourself these questions:

- Are there any sensitive or desirable plants nearby?
- Is there a stream, pond, ditch, drainage area, or other open-water site close by?
- Does the weather forecast predict suitable conditions for application?
- Could the wind carry the pesticide to a neighboring property?
- Is my chosen pesticide product likely to volatilize due to high temperatures either on the day of application or the next day?
- Are there any children, pets, or other animals in the area?
- Do I know the amount of pesticide needed to complete the job so I don't mix more than necessary?

Watch for drift or runoff during the pesticide application. It's good practice to adjust pesticide applications for conditions that may increase drift or runoff. One factor to consider is wind speed and direction. Stop applying if the weather becomes too windy or if the product starts to run off the target area. You can also reduce injury by reducing your field speed when navigating difficult areas and if near sensitive crops. This will prevent uneven treatment patterns and wind eddies that can form behind a fast-moving tractor, and decrease unwanted movement of the boom.

Wind and boom height are two of the biggest problems when it comes to drift. By using a rate controller that changes output pressure, and lowering boom height, you can effectively help reduce drift. For more details about pesticide drift and how to prevent it, see *Spray Drift of Pesticides* (NebGuide G1773).

Clean equipment thoroughly after applying any herbicide. Herbicide residues in spray equipment can damage crops during future pesticide applications. Always clean tanks, nozzles, and other equipment thoroughly after applying herbicides by adding one-half tank of water, then flushing all parts of the tank for five minutes through both agitation and spraying. Always spray rinsate on an appropriate site.

If several pieces of spray application equipment are available, dedicate one to phenoxy herbicides or one to the specific crop to be treated. If not, extra careful cleaning following each application of a phenoxy herbicide is necessary to avoid subsequent crop damage. Mixing two quarts of ammonia and letting it stand in the sprayer overnight is especially effective for cleaning residue from growth regulator herbicides such as 2,4-D (phenoxy) or dicamba. Certain herbicides, such as glyphosate, if left in the tank, will absorb growth regulator herbicides that are added later and result in crop injury when applied. For more details about cleaning pesticide application equipment see *Cleaning Pesticide Equipment* (NebGuide G1770).

Follow directions for storing and disposing of unused pesticides and empty containers. Off-site movement of rinse water or unused pesticides can harm sensitive sites, including sensitive crops. Plan your application carefully so that only the amount of pesticides needed will be mixed, and no extra mixed product will be left over. However, if extra product remains after an application is completed, dispose of the remainder by applying to a site mentioned on the label. Nebraska does not have a statewide pesticide disposal program. There are companies that can help you dispose of unused or outdated pesticide for a fee, but it is better to plan ahead and avoid having leftover pesticide.

Empty containers should be triple or pressure rinsed and either disposed of at a landfill according to label directions, or recycled. See the resources listed under "Additional Information" in this publication for more information about disposal and recycling programs.

Always store pesticides in a cool, dry, locked storage facility away from food, feed, and other supplies. Be sure the structure where you store pesticides is not located near water resources or sensitive sites. Store liquid pesticides on lower shelves in case of spills, and always have a spill kit available. Keep pesticides in their original containers, and when ready to do an application, use the oldest pesticides first.

For more details about storage and disposal of pesticides see *Safe Transport, Storage, and Disposal of Pesticides* (EC2507).

Pesticides Can Move Off the Application Site

Particle Drift. Small spray droplets are susceptible to drift during a pesticide application and may potentially travel long distances to damage nontarget plants or animals. To help prevent drift, use larger spray droplets and lower pressures; select nozzles designed to reduce drift, and apply the pesticides using the appropriate boom height. Make sure the wind speed is low and blowing away from sensitive areas.

Vapor Drift. After a pesticide is applied, the product may volatilize off the application site and move in an unpredictable manner, affecting off-site plants. The volatility of some pesticide products increases as the temperature rises into the upper 80s and 90s. The product label will warn you not to apply the product if a certain temperature is expected in the next few days. *Ester* formulations of phenoxy herbicides, for example, are more likely to volatilize and damage sensitive crops than *amine* formulations.

Spray drift can be reduced by doing the following:

- Spray when wind speeds are less than 10 mph.
- Avoid applying pesticides when there is a temperature inversion. An inversion occurs when there is cool, calm air near the surface with warmer air above. The inversion reduces air circulation and results in spray particles concentrating at the cool/warm air boundary and then moving off-site in an unpredictable manner.
- Select a nozzle that produces coarser (larger) spray droplets.
- Use the lower end of the suggested pressure range for a given spray nozzle.
- Adjust the height of the boom so it is at the appropriate application height.
- Use an additive to control drift on windy days.

Volatilization can be reduced by doing the following:

- Switch to a less volatile formulation. For example, switch from the ester form of 2,4-D to the less volatile amine form.
  - The companies that manufacture growth regulator herbicides are currently working to design, manufacture and market low drift and low volatility compounds. These new formulations in combination with practices such as low drift nozzles, drift reducing adjuvants, and reduction in pressure will reduce both drift and volatility.
    - DowAgroSciences has a low volatile 2,4-D choline salt
    - BASF has a low volatile dicamba BAPMA
- Spray only when temperatures will remain less than 90°F for several days.

Runoff. A pesticide product applied to a steep slope, bare ground, or even level ground immediately before a rain can run off and enter streams, rivers, and lakes, or severely damage other plants. Runoff can kill fish or aquatic invertebrates and/or make the water unsuitable for recreation or human consumption. Select a chemical weed control and application method that will not violate the label or cause damage. For more details about pesticide runoff and runoff prevention see *Protecting Surface Water Quality* (EC730).

Growth Regulator Herbicides

Growth regulator herbicides, despite being the oldest herbicide mode-of-action on the market, are not completely known. Growth regulator herbicides are known to mimic indole acetic acid in plants. The mimicry of auxin in the plant leads to malformed growth and epinasty (downward bending of plant parts such as leaves due to increased growth of upper leaf tissue) in broadleaf plants when exposed to growth regulator herbicides. While growth regulators are not any more prone to drift than other herbicides, they are often thought to be because injury from growth regulator herbicides are distinct and are caused by much lower doses than many of the other herbicides currently on the market.

Figure 3. A young grape shoot injured by 2,4-D ***(Bruce Bordelon, Purdue University).***

Figure 4. Grape leaf injured by 2,4-D ***(Bruce Bordelon, Purdue University).***

Symptoms of Phenoxy (2,4-D) Injury

Phenoxy (phenoxyacetic acid) herbicides, such as 2,4-D, are a subset of growth regulator herbicides that cause abnormal plant growth by disrupting the hormone balance within the plant. Broadleaf plants are more susceptible to this type of injury. Sensitive plants that receive small amounts of a phenoxy herbicide may develop abnormal leaves and multiple or enlarged lower plant parts *(Figure 3)*. Higher concentrations of the herbicide can cause stunting and cupping of leaves, twisted growth of soft shoots, clearing and enlargement of major leaf veins *(Figure 4),*-and-severe-distortion-of-flowerin - or fruiting plant parts.

When phenoxy injury is present, the youngest growth is most severely affected. Plant growth may stop after exposure to a phenoxy herbicide and may be restricted for several weeks. Vines (i.e. grapes) showing symptoms of 2,4-D injury usually do not produce new growth with normal features for the rest of the season. Severely injured vines may not recover for two or more years.

Other Growth Regulators

In addition to the phenoxy herbicides, other examples of growth regulators that can injure sensitive crops include dicamba (benzoic acid picloram) and triclopyr (pyridine carboxylic acid). Like phenoxys, these herbicides are prone to particle drift, but unlike phenoxys, they are less prone to vapor drift.

Other Herbicide Injury

While much of this publication is focused on growth regulator herbicides, it should be noted that any herbicide that moves into an unintended area through physical particle drift or volatility has the potential to cause injury. Because many of the compounds used in production agriculture have low risk of volatility, injury observed from physical particle drift is much more common. Products such as glyphosate, glufosinate, 4-HPPD inhibitors, and ALS inhibitors can all cause injury when they move away from the intended application area. The amount and type of injury will be dependent on the amount of drift that occurs as well as the type of species in the drift area.

Summary

Making pesticide applications having low drift potential and-that-are-highly-efficaciou -is-a-judicious-task.-It-is-absolutely necessary when it comes to protecting sensitive crops and bee hives. Reading pesticide labels, checking application equipment, and being cognizant of environmental conditions are critical to making sure the products go where they are intended,-as-well-as-maximizing-the-efficac -of-the-products.

Additional Information

University of Nebraska Extension Publications
http://www.ianrpubs.unl.edu/epublic/pages/index.jsp

- *Spray Drift of Pesticides*, G1773
- *Nozzles - Selection and Sizing*, G955
- *How to Spray a Field to Prevent Overlap and Reduce Drift Injury*, G1570
- *Cleaning Pesticide Equipment*, G1770
- *Guide for Weed Management*, EC130
- *Protecting Surface Water Quality,* EC730
- *Safe Transport, Storage, and Disposal of Pesticides,* EC2507
- *Understanding the Pesticide Label,* G1955

University of Nebraska–Lincoln Extension Pesticide Safety Education Program

- Pesticide-Container-Recycling:- *http://pested.unl.edu/recycling*
- Pesticide-Disposal:-*http://pested.unl.edu/Hazardous*

NDA's Pesticide Program: *http://www.agr.ne.gov/pesticide/*

- Nebraska-Driftwatch
- Integrated-Pest-Management
- Applicator-Certificatio -and-Training
- Nebraska-Pesticide-Act-and-Enforcement

National Pesticide Information Center, for objective, science-based information about pesticides and pesticide-related topics: (800) 858-7378, *www.npic.orst.edu*

The U.S. Environmental Protection Agency Offic of Pesticide Programs *www.epa.gov/pesticides/*

This publication has been peer reviewed.

Index: Pesticides, General
Herbicides

Issued October 2012

Bee Aware: Protecting Pollinators from Pesticides

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Honey bees (*Apis mellifera*) and other bee species such as bumblebees, orchard mason bees, and leafcutter bees are very important to the pollination of flowers and crops, and can be found foraging on numerous plants in the spring through late summer and early fall. In addition to bees, butterflies, moths, flies, hummingbirds, and some bats can be important pollinators.

Approximately 3,500 species of bees live in North America. Bees are valuable pollinators of 95 crops grown in the United States. Crops pollinated by bees have a farm value of well over $10 billion annually in the U.S. Honey bee colonies also contribute to our agricultural economy by producing over $200 million of honey annually.

Figure 1. Honey bee

This Extension Circular focuses on the honey bee, the most important pollinator in the Midwest, because it can:

- be managed by beekeepers,
- be transported,
- be managed for income from both honey production and pollination,
- be maintained in large populations throughout the growing season, and
- visit and pollinate many plant species.

Honey bees (*Figure 1*) are hairy, yellow, and black or brown banded social insects that are about ½-inch long on average and live in hives. Each individual has distinct duties, either

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

as a worker (serving as a nursemaid, housekeeper, or forager) or a reproductive bee (drone or queen).

Maintenance of the hive relies on the distributed work within the colony. For example, foragers (usually older worker bees) search for food resources (pollen and nectar) and communicate this to the colony. Because the health of the hive and successful crop pollination relies on the foraging activities of worker honey bees, it is essential to protect these important insects from potentially harmful pesticide exposure.

Protecting pollinators is an important consideration when applying pesticides to control crop pests. Pesticides such as insecticides, fungicides, and miticides may be toxic to bees. Insecticides are formulated to kill insects, fungicides kill fungi that cause some plant diseases, and miticides kill mites. Pesticide labels may carry specific statements to protect bees and should be read carefully prior to pesticide application. The loss of native pollinators due to habitat reduction, and the decline in honey bee colonies due to parasitic bee mites and other factors, reinforces the need to protect these insects through good pesticide stewardship. While this Extension Circular focuses on protecting honey bees, many of the recommendations serve to protect other bee and pollinator species as well.

Considerations for Pollinator Protection

Plant Growth Stage

Most honey bee poisonings happen when pesticides are applied to flowering crops (e.g., apples, melons, soybeans) or are allowed to drift onto flowering plants (e.g., weeds and wildflowers) during periods when the bees are actively foraging. If applications are permitted by the label, growers and applicators need to communicate with beekeepers and exercise all reasonable measures to minimize the risks to bees.

Relative Toxicity of the Chemical

Pesticides vary in their toxicity to honey bees. Most fungicides and herbicides (pesticides that kill weeds) have relatively low toxicities to honey bees and can be used without endangering them. In addition, certain insecticides and miticides are not hazardous to bees and can be applied with little risk of bee injury. For example, *Bacillus thuringiensis* (*Bt*), a biological insecticide derived from a soil-dwelling bacterium, is not toxic to bees. However, insecticides such as pyrethroids that are more toxic to bees can only be applied when bees are not actively foraging because bees that are exposed during the application may be killed. Pesticides that are highly toxic to honey bees cannot be applied to flowering crops when bees are present without causing serious injury or death. Bee toxicity data for selected pesticides are listed in *Table I*. Lethal dose (LD_{50}) and relative toxicity ratings are provided for each active ingredient (AI) included. Use the table to compare toxicities within and between broad pesticide types (i.e. fungicides, insecticides, herbicides, miticides), but understand that these pesticide types can vary in their toxicity to bees. Also, recognize that toxicity does not indicate the exposure a bee is likely to receive, but rather how much of an AI it takes to kill a bee. Realize that toxicity is only one factor when considering hazards to bees. Exposure time and dosage, application rate, and formulation all contribute toward overall risk or hazard of using an active ingredient. A good way to think about risk is with the risk formula:

RISK = TOXICITY X EXPOSURE

Always read and follow the label for the product you are using. It will provide guidance about toxicity to bees and how you can reduce the risk of exposure during application.

Choice of Formulation

Different formulations of the same pesticide often vary considerably in their toxicity to bees. Granular (G) pesticides are generally less hazardous to honey bees than other formulations. Dust (D) formulations, though uncommon, are usually more hazardous than emulsifiable concentrates (EC) because they adhere to the bee's body hairs and are carried back to the beehive. Wettable powder (WP) and flowable (F) formulations dry after application to a dust-like material that can be transferred to foraging pollinators. Likewise, microencapsulated (M) formulations also can be transferred to bees along with pollen and brought back to the colony. Since bees are highly social and hives can be crowded, substances picked up in the field can be spread within a hive. Exposure to pesticide formulations can cause significant losses of both foraging bees and bees in the hive. In severe cases, pesticides may remain active in the hive for several months and prevent colonies from recovering.

Using Treated Seed

Pesticides added as a protective coating to seeds can become dislodged during handling and/or planting. Graphite and talc used to lubricate seeds during planting can carry these residues to non-target locations. Before handling or planting treated seed, take precautions to reduce the risk of pesticide residues or planter talcs drifting or moving offsite onto flowering plants where bees may be foraging. For example, if you intend to plant treated corn seed with a pneumatic planter, a burndown herbicide should be used to eliminate henbit from the site prior to planting. This will prevent planter talc from settling on the henbit, which is usually blooming at corn planting time and may be visited by bees.

Table I. Selected representative trade names, pesticide AIs, bee toxicities, toxicity ratings, and pesticide types.[1]

Representative Trade Names	*Pesticide Active Ingredient (AI)*	*Bee Toxicity (LD_{50} as µg/bee)*	*Toxicity Rating*	*Pesticide type*
Gaucho	Imidacloprid	0.0039	Highly toxic	I
Cruiser Platinum	Thiamethoxam	0.005	Highly toxic	F
Lorsban Vulcan Nufos 4E	Chlorpyrifos	0.01	Highly toxic	I
Brigade Capture	Bifenthrin	0.0146	Highly toxic	I
Ambush Pounce	Permethrin	0.024	Highly toxic	I
Aztec	Cyfluthrin	0.037	Highly toxic	I
Dimethoate	Dimethoate	0.056	Highly toxic	I
Methyl	Methyl parathion	0.111	Highly toxic	I
Avid Zoro	Abamectin	0.41	Highly toxic	M
Carbaryl Sevin	Carbaryl	1	Highly toxic	I
Acramite	Bifenazate	7.8	Moderately toxic	M
Captan	Captan	10	Moderately toxic	F
Javelin Dipel	*Bacillus thuringiensis*[2]	23.2	Relatively nontoxic	I
Tilt Bumper Fitness	Propiconazole	25	Relatively nontoxic	F
Quilt	Propiconazole + Azoxystrobin	25 200	Relatively nontoxic	F
Atrazine AAtrex	Atrazine	97	Relatively nontoxic	H
Headline	Pyraclostrobin	100	Relatively nontoxic	F
Kanemite Shuttle	Acequinocyl	100	Relatively nontoxic	M
2,4-D Ester	2,4-D 2-EHE	100	Relatively nontoxic	H
Roundup	Glyphosate	100	Relatively nontoxic	H
Parallel Stalwart	Metolachlor	110	Relatively nontoxic	H
Stratego	Trifloxystrobin + Propiconazole	200 25	Relatively nontoxic	F
Quadris Dynasty	Azoxystrobin	200	Relatively nontoxic	F

[1]The USDA Windows Pesticide Screening Tool (Win-PST) is an environmental risk screening tool that includes bee toxicity data available for each active ingredient in the database. The tool is available for download from *http://go.usa.gov/Kok*.

[2] *Bacillus thuringiensis* (*Bt*) Reregistration Eligibility Decision (RED), U.S. EPA. Data can be found at *http://www.epa.gov/oppsrrd1/REDs/0247.pdf*

Residual Action

Residual activity of a pesticide is an important factor in determining its safety to pollinators. Pesticides that degrade within a few hours usually can be applied with minimal risk during times when bees are not actively foraging. Applying pesticides with extended residual activity (more than eight hours), even when bees are not actively foraging, may still result in bee injury if bees visit the crop during the period of residual activity. Pesticides with extended residual activity require extra precaution to prevent bee exposure. Look for clues about the residual activity of an individual pesticide on the pesticide label. For example, restricted entry intervals greater than 12 hours indicate extended residual activity.

Drift

Bees may forage in areas adjacent to the target crop. Pesticides that drift from the target crop onto nearby flowering plants can cause significant bee poisoning. In general, sprays should not be applied if wind speed exceeds 10 mph or is blowing toward adjacent flowering plants. While pesticides should never be applied near beehives, drift alone rarely causes extensive bee poisoning. When evaluating potential drift hazards, focus on reducing the risk of drift moving to nearby flowering plants.

Temperature

Because temperature plays such an important role in the activity of cold-blooded animals, such as bees, as well as having an effect on pesticides, it can affect when or how bees are exposed to pesticides. Bees are most actively foraging during periods of high temperature and sunlight. Also realize that some pesticides vaporize during these times, thereby increasing potential for bee injury. Making pesticide applications during periods of cooler temperatures and low light or overcast conditions will minimize exposure to bees. Always be aware of temperature fluctuations and use common sense before applying pesticides that are toxic to bees.

Distance from Treated Areas

Honey bee mortality due to pesticides usually decreases the farther away colonies are from treated areas (i.e., crops, turf, etc.). Most foraging activity occurs within one to two miles of the hive. However, during periods of nectar or pollen shortage, honey bees forage at greater distances, and colonies up to five miles from the treated area can be injured.

Time of Application

Application timing is related to all the previously mentioned factors, but the most critical one is to control pests either prior to crop flowering or after flowering is complete. This will greatly reduce the risk of pollinators being exposed to pesticides. If pesticides must be applied to flowering plants, use pesticides with short residuals in the evening when the temperatures are below 60 degrees. This can greatly reduce the potential for honey bee injury.

Communication and Cooperation

Reducing pesticide injury to honey bees requires communication and cooperation among beekeepers, growers, and pesticide applicators. Beekeepers should understand the cropping and pest management practices used by growers near their apiaries. Likewise, pesticide applicators should be aware of apiary locations, have a basic understanding of honey bee behavior, and know which materials and application practices are the most hazardous to bees. It is unlikely that all bee poisonings can be avoided, but in most cases, bee losses can be reduced by understanding the hazards and maintaining effective communication.

How Growers and Applicators Can Reduce Risks of Honey Bee Injury

Understand the risks. Many crop pests can be controlled without endangering bees. Attend crop pest management training sessions to learn the latest about crop pests and control measures used by growers and applicators.

Do not treat flowering plants. Be especially careful when treating crops such as alfalfa, sunflowers, and canola, which are highly attractive to bees. Pesticide labels carry warning statements and sometimes prohibit application during bloom. Always read and follow the label.

Examine fields before spraying to determine if bees are foraging on flowering weeds. Milkweed, smartweed, henbit, and dandelion are examples of weeds that are highly attractive to honey bees. Where feasible, eliminate these flowering weeds in fields by mowing or cultivating prior to pesticide application or planting. While bright and colorful flowers are highly attractive to bees, some plants with inconspicuous blossoms such as dock, lambsquarter, and ragweed are also visited. Therefore, when you examine areas for flowering plants, consider all plants that have flowers. Be aware that many plants only produce pollen and nectar for a few hours each day. Fields should be scouted for honey bees at the same time of day as the anticipated pesticide application.

Maintain forage areas for bees. Intensive agriculture often increases bee dependence on cultivated crops for forage. Establishing plants in wild or uncultivated areas for honey bees to forage will reduce bee dependence on crop plants that may require pesticide treatments. Plants recommended for uncultivated areas include sweet clover, white Dutch clover, alfalfa, purple vetch, birdsfoot trefoil, and partridge

Figure 2. Partridge pea planted in an uncultivated area serves as bee forage.

pea (*Figure 2*). Many trees and shrubs are beneficial to bees as well. The most attractive species include linden, black locust, honey locust, Russian olive, wild plums, elderberries, red maples, willows, and honeysuckle. However, when establishing foraging areas with trees and shrubs, avoid planting honey locust, Russian olive, or honeysuckle. Although attractive to honey bees, these species can become invasive and outcompete native plant species. Soil conservation, natural resource, and game managers usually are eager to help establish plantings that benefit honey bees because these areas also conserve soil and provide valuable habitat for plant and wildlife conservation programs. These individuals can be a good resource for selecting trees that are both attractive to bees and healthy for the environment.

Avoid spray drift. Give careful attention to the location of flowering crops and weeds relative to wind speed and direction. Changing spray nozzles or reducing pressure as allowed by the label can increase droplet size and reduce spray drift.

Apply pesticides when bees are not foraging. In general, bees are foraging more actively during the sunniest and warmest times of the day. Therefore, some pesticides can be applied in late evening or early morning (i.e. from 8 p.m. to 6 a.m.) with relative safety. For example, with the partridge pea plant, bees work heavily on it in the morning, but by early afternoon the field will go quiet because the nectar stops flowing about that time of day.

Although bees don't prefer corn pollen and it has limited nutritive value, they may collect pollen from tassels in the early morning but are not present in the afternoon or evening. Short-residual materials applied from late afternoon until midnight pose less bee hazard in corn fields if flowering weeds are not present.

Adjust spray programs in relation to weather conditions. Reconsider the timing of a pesticide application if unusually low temperatures are expected. Cool temperatures can delay pesticide degradation and cause residues to remain toxic to bees the following day. Stop applications when temperatures rise and when bees re-enter the area in early morning. Similarly, do not apply during evening hours if temperatures are unusually high and bees are still foraging.

Contact local beekeepers and obtain locations of beehives. If colonies are present in an area where you will be applying a product that is toxic to bees, you should contact beekeepers (*Figure 3*) within 48 hours so they have time to protect or move the colonies. Many pesticide applications pose minimal risk to bees, and beekeepers may choose to accept some risk rather than move colonies. Notify beekeepers as far in advance as possible.

Figure 3. Notify beekeepers when you will be applying a product that is toxic to bees.

Figure 4. DriftWatch encourages commercial producers to register locations of beehives.

Use DriftWatch. The Nebraska Department of Agriculture (NDA) and Purdue University have developed a Web-based locator for sensitive commercial crops and beehives called DriftWatch™ *(Figure 4).* This site can be accessed at *http://www.driftwatch.org*. Beekeepers are encouraged to register the locations of their hives, and pesticide applicators are encouraged to use this website to determine if any beehives are located near a planned pesticide application site. Many beekeepers have provided their contact information on DriftWatch, making personal communication much easier. If beehives are present, pesticide application procedures, including timing and/or application methods, should be adjusted accordingly.

Beekeepers, crop producers, and applicators are encouraged to access DriftWatch and document known beehive locations in application records, or print a map from the website and incorporate it into application records. It is also good practice to scout the area prior to a planned pesticide application to become familiar with the landscape. Because listings on DriftWatch are voluntary, not all apiary locations may be included. DriftWatch is only as effective as the information provided by beekeepers and the action taken by applicators. New or updated information should be submitted as soon as possible. Good communication is the key to avoiding pesticide injury to honey bees. To view video segments about DriftWatch and bees/pollinators, visit the UNL Extension PSEP YouTube channel, listed in the Resources section of this Extension Circular.

Read the pesticide label. Carefully follow listed restrictions and/or precautions with regard to bee safety.

Steps Beekeepers Can Take to Protect Their Colonies

Choose low hazard apiary locations. Do not place beehives adjacent to crops likely to be sprayed with a pesticide (*Figure 5*).

Know the risks. Many crop pests can be controlled without endangering bees. Attend crop pest management training sessions to learn the latest about crop pests and control measures used by growers and applicators. These sessions also provide an opportunity to establish communication links with growers and pesticide applicators.

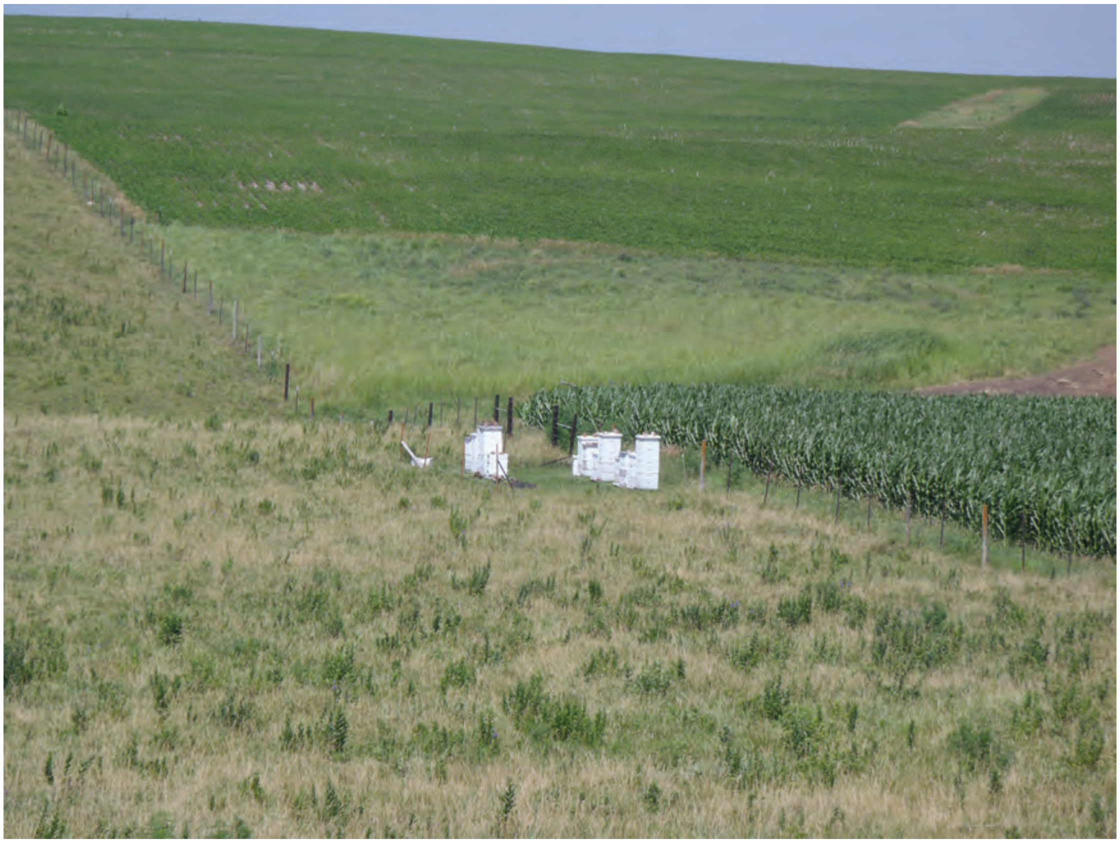

Figure 5. Hives shouldn't be placed near crops likely to be sprayed with pesticides.

Maintain positive working relationships with applicators. Risk management decisions can best be made when both parties understand each other's needs. Establish a communication link prior to the spray season rather than during peak activity periods when all parties are busy.

Use DriftWatch. As mentioned earlier, register the location of your hives on DriftWatch.

Applicators will be able to search for such locations and communicate with you before applying pesticides near your beehives.

Be prepared to protect colonies if necessary. If pest control measures that carry unacceptable risks are necessary, know the options for protecting your colonies and be prepared to implement them. Options for protecting bees include:

1. When products with short residual activity are to be applied, briefly confine bees to their hive with wet burlap. This measure is only feasible if a small number of colonies are involved and if the confinement period is brief and early in the morning. *Caution! This measure can result in the colony overheating and should be used with care.* Fine mesh moving nets are also available and can be purchased by beekeepers if the need arises.

2. Temporarily disrupt foraging activity by removing colony covers and offsetting boxes. This will result in a temporary reduction in foraging. Most honey bees will remain in the hive to protect their stores and to maintain temperature and humidity in the exposed hive. After a few hours to one day, colonies will adjust to the change and resume foraging. This approach is safer than confining colonies but is not recommended if bees are located in or adjacent to areas that will be treated.

3. When highly toxic products with extended residual activity are applied to flowering crops, move honey bees to another location at least four miles from the treated area. Moving populous colonies during hot weather can result in considerable bee mortality and should be avoided if possible. Moves should be made early in the morning or evening when temperatures are cool and the bees are the least active. In general, moving colonies isn't practical for most beekeepers. It requires that hives be kept on pallets and moved using a forklift. Migratory beekeepers may be some of the few with such equipment.

Report colony injury. Beekeepers are often reluctant to report bee injury incidents for a number of reasons, one of which is because they may be relying on the landowner/applicator to provide a place to put their hives. However, EPA is unable to adequately evaluate product use and risk assessment without bee injury incident information. The best way for EPA to collect this necessary information is through an incident reporting form, available at *http://pi.ace.orst.edu/erep/*.

Final Thoughts

There are many ways to reduce bee poisoning. Often, severe losses can be avoided by relatively simple modifications of pest control programs. Talk with other growers and applicators about how to reduce bee injury and consult reference materials, such as this Extension Circular, on protecting honey bees.

With good environmental stewardship, you can help protect the bees that are essential pollinators for Nebraska crops. Applicators and beekeepers should work together to ensure successful pest control while reducing the risks to honey bees. This includes registering beehives on DriftWatch, having a good communication network, using pesticides that are least toxic to bees, and timing applications when bees are not actively foraging. Bees are a valuable agricultural resource that are worthy of our respect and protection.

Resources

DriftWatch:
http://www.driftwatch.org

UNL Extension PSEP YouTube Channel:
http://www.youtube.com/user/UNLExtensionPSEP

This publication has been peer reviewed.

Disclaimer

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

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NebGuide

Published by University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

Know how. Know now.

G1736
(Revised April 2013)

Rinsing Pesticide Containers

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It is estimated that every year 1 million plastic agricultural pesticide containers are used in Nebraska. Effective rinsing of these containers saves money, protects the environment, and meets federal and state regulations for pesticide use.

Proper rinsing of pesticide containers is easy to do, saves money, and contributes to good environmental stewardship. Rinsing containers when preparing spray solutions prevents potential problems with un-rinsed containers, storing rinse solution (rinsate), and generating hazardous waste. Even during a busy season, the few extra minutes it takes to properly rinse empty pesticide containers is time well spent. For example:

- Rinsing pesticide containers efficientl and economically uses all the pesticide that you purchased. When the rinsate is added immediately to the load and sprayed on a labeled site, the need to store and later dispose of it is eliminated.
- Rinsing pesticide containers immediately after emptying easily removes leftover concentrate. If the container is not rinsed immediately, remaining pesticide mixtures may dry inside the container and be difficul to remove.
- Rinsing containers removes potential pesticide exposures to people, wildlife, and the environment.
- Proper rinsing is required by federal regulations and is a sound management and environmental practice.

Rinsing Saves Money

It is very easy to leave 6 ounces or more of pesticide product in a 2.5-gallon container. Six ounces is about 2 percent. If you do not rinse, you either apply 2 percent less product, which can affect performance of the pesticide, or incur 2 percent more cost for the application. Neither option is good.

If you delay rinsing your used pesticide containers, it is more difficul to remove product from the containers. Because it is more difficult more time is required and time is money. Removing pesticide product from containers that were not rinsed immediately may also require additional dilutents. These added chemicals are costly and some may even cause injury if applied to the target site.

Rinsing Helps Protect the Environment

Proper rinsing of pesticide containers reduces a potential source of contamination of soil, surface water, and groundwater. Contamination harms plants and animals and affects water supplies. Preventing environmental contamination is always better and less expensive than cleanup.

Federal laws require the rinsing of liquid pesticide containers. Violation of these laws is punishable by criminal and/or civil penalties. When an empty container is recycled, returned to the supplier, or disposed of according to label directions, **it must be properly rinsed**. Approved pesticide container recyclers and those receiving returned minibulk containers can accept only properly rinsed containers. Some landfill operations may not accept rinsed pesticide containers.

Types of Pesticide Containers

The most common agricultural pesticide containers are the minibulks (from 85 to 300 gallons), plastic drums in 15-, 30- and 55-gallon sizes, and returnable shuttle containers. The 2.5-gallon plastic containers also remain popular. The minibulk containers and shuttles are intended to be returned and reused by the supplier. Granular and dust insecticides are sold in waxed-paper bags or other water-resistant containers. Nearly all pesticide products used on animals and in households are sold in plastic containers.

Plastic drums and 2.5-gallon containers may be recycled after the pesticide materials have been removed by rinsing. Proper rinsing of plastic pesticide drums and containers will remove more than 99 percent of any pesticide residue after they have been emptied. Two commonly used procedures are effective for rinsing pesticide containers: triple-rinsing and pressure-rinsing.

Triple-Rinsing

Triple-rinsing means rinsing the container three times. This method can be used with all plastic containers.

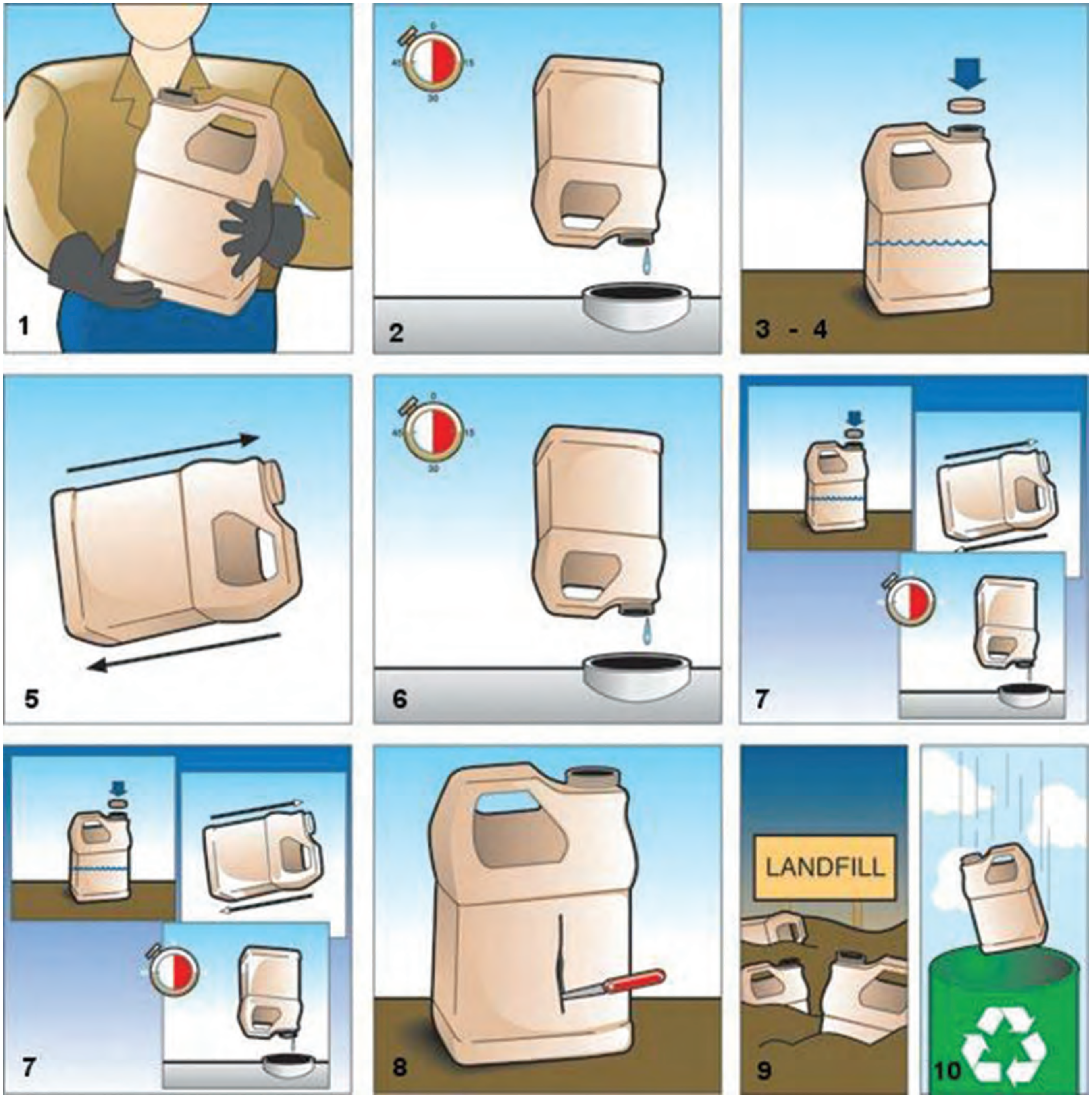

Figure 1. Triple-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.

How to triple-rinse *(Figure 1)*:

1. Wear the same personal protective equipment while rinsing containers as the pesticide label requires for handling and mixing.
2. Remove the cap from the pesticide container. Empty all pesticide into the spray tank, allowing the container to drain for 30 seconds. Begin rinsing immediately or the product may be difficul to remove. If you are unable to rinse the container immediately, replace the cap until you can.
3. Fill the container 10 percent to 20 percent full of water or rinse solution (i.e., fertilizer solution).
4. Replace the cap on the container.
5. Swirl the liquid within the container to rinse all inside surfaces.
6. Remove the cap from the container. Pour the rinsate from the pesticide container to the spray tank and allow it to drain for 30 seconds or more.
7. Repeat steps 3 through 6 **two more times**.
8. Puncture or crush the container so it cannot be reused.

9. Replace the cap and dispose of pesticide container according to label directions.

10. If recycling, remember that caps and containers are made from different materials; therefore, caps cannot be recycled.

How to triple-rinse drums:

First, reread the procedures for triple-rinsing containers because they contain important information not listed here. Using the following procedures for triple-rinsing drums may require two people.

1. Empty the drum as much as possible.
2. Fill the drum with water to 25 percent of capacity. Replace and tighten bungs.
3. Tip the drum on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds.
4. Stand the drum on end and tip it back and forth several times to rinse the corners.
5. Turn the drum over, onto its other end, and repeat this procedure.
6. Carefully empty the rinsate into the spray tank.
7. Repeat steps 2 through 6 **two more times**.
8. Carefully rinse the cap over the spray tank opening and then dispose of as regular solid waste.
9. Puncture the base of the drum with a drill so that it cannot be reused.
10. Store rinsed drums under cover where they will be protected from rain.

Pressure-Rinsing

Use a pressure rinser with an anti-siphon device to flus the remaining pesticide from the container. Attach a special nozzle with a spear-point, which is generally available from your pesticide supplier and other sources, to the end of a water hose and force water under pressure into the pesticide container. Pressure-rinsing is faster and easier than triple-rinsing and can be used most effectively with plastic 2.5 gallon pesticide containers.

How to pressure-rinse 2.5-gallon containers *(Figure 2)***:**

1. Wear the same personal protective equipment while rinsing containers as required on the pesticide label for handling and mixing.
2. Remove the cap from the pesticide container. Empty all pesticide into the spray tank. Turn the container so that any product in the handle flow out. Allow the container

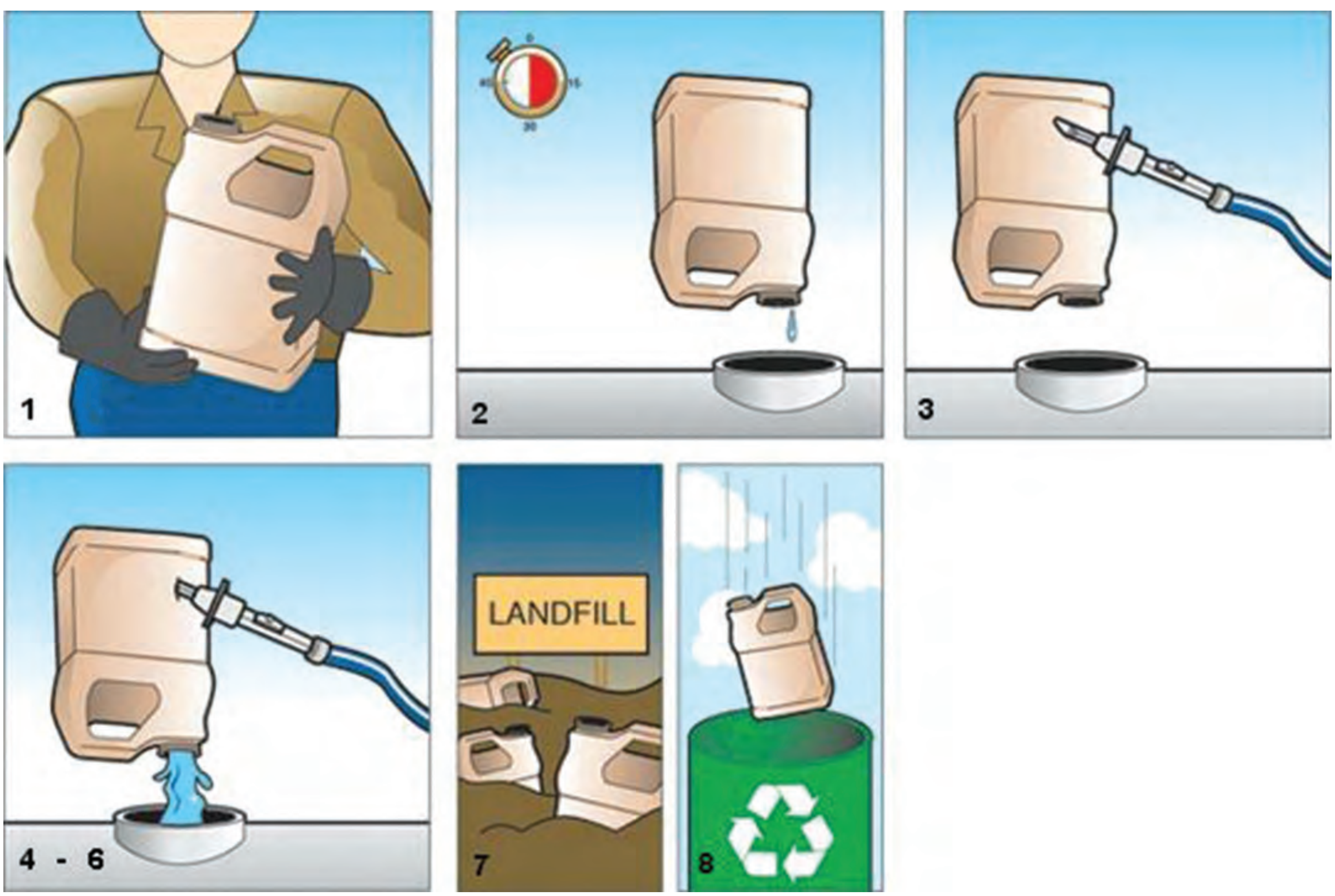

Figure 2. Pressure-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.

to drain for 30 seconds. Begin the rinsing procedure immediately or the product may be difficul to remove. If you are not able to rinse the container immediately, replace the cap until you are able to rinse the container.

3. Insert the pressure-rinsing nozzle, which should be equipped with a flo control, by puncturing a hole through the lower side of the pesticide container.
4. Hold the pesticide container upside down over the spray tank opening, turn on the flo of water, and allow the rinsate to run into the spray tank.
5. Rinse for the length of time recommended by the manufacturer (usually 30 seconds or more). Rotate or rock the nozzle to rinse all inside surfaces.
6. Rinse the cap separately in a bucket of water and pour this rinse water into the spray tank.
7. Replace the cap and dispose of pesticide container according to label directions.
8. If recycling, remember that caps and containers are made from different materials; therefore, caps cannot be recycled.

Storing Empty Pesticide Containers

- Un-rinsed empty pesticide containers should be stored in the same way you store containers with pesticide. Replace the cap and store un-rinsed containers upright in a roofed or covered and secure (locked) structure over an impervious surface.
- Pressure-rinsing creates a hole in the container. Store pressure-rinsed containers indoors to prevent water, rain, or snow from entering the containers. Remove the caps to allow the containers to completely dry out during storage.
- Triple-rinsed containers should be stored outside only if you replace the cap. Triple-rinsed and capped containers do not need to be stored on impervious surfaces.
- When you are ready to offer rinsed, empty pesticide containers for recycling, remove the caps (they cannot be recycled) and any labels, plastic sleeves, or wrappers attached to the container. Dispose of these materials in an approved landfill

Container Recycling

Recycling clean agricultural pesticide containers protects Nebraska's environment. Several locations in Nebraska accept rinsed plastic agricultural pesticide containers for recycling. All containers are thoroughly inspected before acceptance.

Any pesticide container with pesticide residue that can be rubbed off with a neoprene- or nitrile-gloved hand will be rejected. Properly rinsed containers that are stained will be accepted. Do not include pesticide containers in household or curbside recycling programs. Check with your University of Nebraska–Lincoln extension educator, other local officials or the website (*http://pested.unl.edu/recycling*) to determine the locations of plastic pesticide container recycling sites in Nebraska.

Remember

- ✓ Read and follow all pesticide label directions. Federal law requires rinsing of liquid pesticide containers.
- ✓ NEVER dispose of rinsate on a site the pesticide product label doesn't allow. Instead, use the rinsate generated by triple- or pressure-rinsing pesticide containers as part of your spray mixture.
- ✓ Store pesticides only in the original, labeled containers. Never reuse a pesticide container for any purpose.
- ✓ Wear appropriate personal protective equipment as required by the label.
- ✓ Always use an anti-siphon or backflo prevention device when fillin spray tanks or rinsing pesticide containers.
- ✓ Mixing and loading sites should be at least 150 feet away from all wells. Review pesticide labels. Be aware of requirements for specifi setbacks from wells regardless if the well is active or not.

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Index: Pesticides, General Safety

2007, Revised April 2013

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NebGuide

University of Nebraska–Lincoln

University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

Know how. Know now.

G1770
(Revised August 2013)

Cleaning Pesticide Application Equipment

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Important steps in completely and carefully cleaning and rinsing pesticide application equipment are covered in this NebGuide.

Mixing, loading, and application equipment should be cleaned and rinsed as soon as you fi ish a pesticide application. ***Do not leave equipment containing pesticides at the mixing/loading or application site, or wash application equipment repeatedly in the same location, unless you use a containment pad or tray.***

Anyone cleaning pesticide-contaminated equipment must have instruction on proper safety procedures. Equipment cleaning can present as great a risk of exposure to pesticides as many other pesticide handling tasks. When cleaning pesticide-contaminated equipment, wear the same personal protective equipment (PPE) that the labeling requires for making applications, plus a chemical-resistant apron or other appropriate protective equipment. Also wear eye protection, even if not required by the label directions.

Cleaning Procedures

After the equipment is empty, clean both the inside and the outside thoroughly, including nozzles or hopper openings *(Figure 1)*. Certain pesticides use a carrier (e.g., petroleum-based products) that may require special cleaning agents or high water pressure to remove.

Select a location to clean the sprayer where any spilled rinsate will not contaminate water supplies, streams, crops, or other plants and where puddles will not be accessible to children, pets, livestock, or wildlife.

Figure 1. Cleaning a sprayer (Photo credit: USDA).

The area may be the same as the mixing and loading location. It should be impervious to water and have a wash rack or cement apron with a sump to catch contaminated wash water and pesticides. If such a facility is not available, catch or contain the rinsate and spray the rinse water or the cleaning solution on a site and in a manner consistent with the labeled use of the pesticide product.

If concentrated spray material is spilled on the outside of the sprayer during loading or mixing, wash the outside of the sprayer immediately. Screens and strainers also should be cleaned or replaced frequently as they can be a major source of contamination. Self-cleaning strainers do a good job of straining and do not require cleaning. Residues also can accumulate in checked or cracked hoses. Inspect the inside of hoses and replace if necessary. Pay special attention to the following areas as they may be missed or difficult to clean

- spray surfaces or components where buildup of dried pesticides might occur
- sprayer sumps and pumps
- inside the top of the spray tank and around baffle
- irregular surfaces inside tanks caused by baffles, plumbing fixtures, agitation units, etc
- collection points where the hoses connect to the nozzle fittings in dry boom sprayers. Wet booms eliminate this problem.

When transitioning between crops, follow the specific cleanup procedures listed on the pesticide label.

Some cleanups require special cleaning agents. Choose sprayer cleaning agents according to the pesticide and formulation to be removed (for herbicide-specific information see the "Recommended Cleaning Agents for Selected Herbicides" table in the *Guide for Weed Management*, EC130). These agents penetrate and dissolve residues and then are removed in the rinsate. Commercial tank cleaning agents are generally preferred because they do a better job than household detergents and can deactivate some herbicides.

Rinsates

Rinsates from cleaned equipment contain pesticides and can be harmful to people and the environment. Do not allow rinsates to flow into water systems, including sink or floor drains, storm sewers, wells, streams, lakes, or rivers. Collect rinsates and apply them to labeled sites at or below labeled rates. If possible, consider rinsing your equipment at the application site and applying the rinsate to the labeled site.

Equipment rinsate may be also used as a diluent for future mixtures of pesticides if:

- the pesticide in the rinsate is labeled for use on the target site where the new mixture is to be applied.
- the amount of pesticide in the rinsate plus the amount of pesticide product in the new mixture does not exceed the label rate for the target site.
- the rinsate is used to dilute a mixture containing the same or a compatible pesticide.

The rinsate **cannot** be added to a pesticide mixture if:

- the rinsate contains strong cleaning agents, such as bleach or ammonia, which might harm the plant, animal, or surface to which the pesticide will be applied.
- the rinsate would alter the pesticide mixture and make it unusable; for example, if the pesticides are physically or chemically incompatible.

If rinsates cannot be subsequently applied to labeled sites, dispose of them as you would waste pesticides.

Equipment Cleanup

Clean your equipment thoroughly after each use or when changing chemicals. Pesticide residues in a spray tank may corrode metal, plug hoses, or damage pumps and valves unless they are removed immediately after use. Some residues left in the spray tank and components can react with pesticides used later, reducing the effectiveness of the pesticides.

Special tank-cleaning nozzles are available for cleaning the interior walls of spray tanks.

Thoroughly rinse equipment with the recommended cleaning agent and carrier, allowing the cleaning solution to circulate through the system for several minutes. Remove the nozzles and screens, and flush the sprayer system twice with clean water.

Sloppy cleanup practices are a main cause of equipment failure or malfunction. Always clean application equipment immediately after each use. Pesticides allowed to dry in the application equipment are more difficult to remove

Several commercial compounds are available to aid in tank cleaning. These can neutralize and remove pesticide residues, remove mineral deposits and rust, and leave a protective film on tank walls to help prevent corrosion.

As with any procedure involving exposure to pesticides, remove contaminated clothes and take a shower immediately after cleaning equipment. Waiting until the end of the day to clean up can allow additional absorption of the pesticide through the skin. Keep contaminated clothing separate from other laundry and tell whoever washes the clothes of the possible hazards. Encourage him/her to wear protective gloves while handling contaminated laundry and, if the same washer is used for family clothing, run the washer through one or more cycles with hot water and detergent but no clothing before doing regular laundry.

Equipment Storage

When preparing to store your sprayer, add one to five gallons of lightweight oil such as diesel fuel or kerosene (how much depends on the size of the tank) before the final flushing. As water is pumped from the sprayer, the oil leaves a protective coating on the inside of the tank, pump, and plumbing. To prevent corrosion, remove nozzle tips and screens and store them in a can of light oil. In addition, add a small amount of oil and rotate the sprayer pump four or five revolutions by hand to coat interior surfaces completely. Sprayer engines, whether air- or water-cooled, require additional servicing following a pesticide application. Follow the directions in the engine's owner's manual.

After thoroughly cleaning and draining the application equipment, store it in a dry, clean building, if possible. Replace worn-out, deteriorated, or broken parts. If you must store the sprayer outside, remove the hoses, wipe oil off exterior surfaces, and store them inside where they will not become damaged by ultraviolet light. When using trailer sprayers, you may want to put blocks under the frame or axle to prevent flat spots on the tires during storage.

Removing Herbicide Residues from the Sprayer

The following is the sprayer cleanout procedure listed in University of Missouri publication G4852, *Cleaning Field Sprayers to Avoid Crop Injury*, available on the website: *muextension.missouri.edu/xplor/agguides/crops/g04852.htm*.

This procedure is recommended for all herbicides unless the label specifies a different cleanout procedure. With sensitive crops, the best method to avoid herbicide injury from residual in the tank is to use a separate sprayer for the crops. When some herbicides, such as glyphosate, are left in the tank for a period of time, they can absorb products such as dicamba (Banvel®/Clarity®/Sterling) from the spray tank, which can result in crop injury.

1. Add one-half tank of fresh water and flush tanks, lines, booms, and nozzles for at least five minutes using a combination of agitation and spraying. Rinsate sprayed through the booms is best sprayed onto cropland for which the pesticide is labeled to avoid accumulation of pesticide-contaminated rinsate. Thoroughly rinse the inside surfaces of the tank, paying particular attention to the surfaces around the tank-fill access, baffles, and tank plumbing fixtures. The use of a 360-degree nozzle, such as the TeeJet Model 27500E-TEF rinsing nozzle, permanently installed to the spray system, can automate the cleaning of tops and sides of the tanks. Several nozzles may need to be carefully positioned to clean tanks with baffles. Pressure sprayers are useful for removing caked-on internal and external residues. Hot water can increase penetration of dried residues, but adding a hot-water rinse may cause unacceptable health hazards due to the vapors produced. Carefully review labeled safety precautions for the agrichemicals and cleaning products used.
2. Fill the tank with fresh water and the recommended cleaning solutions or a commercially available tank cleaner and agitate the solution for 15 minutes. To make a cleaning solution, add one of the following to 50 gallons of water:
   - 2 quarts of household ammonia (let stand in sprayer overnight for growth regulator herbicides such as 2,4-D or Dicamba), or
   - 4 pounds of trisodium phosphate cleaner detergent.

   Operate the spray booms long enough to ensure that all nozzles and boom lines are filled with the cleaning solution. Let the solution stand in the system for several hours, preferably overnight. Agitate and spray the solution onto areas suitable for the rinsate solution.
3. Add more water and rinse the system again by using a combination of agitation and spraying. Remove nozzles, screens, and strainers and clean separately in a bucket of cleaning agent and water.
4. Rinse and flush the system once again with clean water.

This publication was peer reviewed.

Disclaimer

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

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Index: Pesticides, General
Safety

Issued August 2013

NebGuide

Nebraska Extension

Research-Based Information That You Can Use

G2038 Index: Pesticides, General Safety
Issued September 2010
Revised October 2016

Managing Pesticide Spills

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This NebGuide describes the steps to follow after a pesticide spill to promote safe and effective management and to avoid human toxicity or environmental contamination.

No one expects to have a pesticide spill, but being prepared to manage one is part of practicing good pesticide safety. Protecting human health and the environment is essential. Pesticides are toxic to humans and other living organisms as well as to the pests they control. Exposure to pesticides, whether during the mixing and application process or during a spill, poses a risk to human health. Pesticide spills also can be a direct threat to the environment by leaching into groundwater, contaminating surface water, persisting in the soil, or harming nontarget plants and animals.

There are three common ways pesticide spills occur: during storage or transportation, when mixing the spray solution, or during application. Pesticide spills during storage or transportation can be due to damaged containers or a vehicle accident (see *Safe Transport, Storage, and Disposal of Pesticides* [EC2507] for more on safe transport of pesticides). Spills during the mixing process often can be attributed to human error, while spills during application often are caused by equipment malfunction. Pesticide spills can range from very minor, like a single leaking pesticide container, to a major spill, such as a tanker truck accident. No matter the cause or size of the spill, being prepared to manage it is important.

Spill Management

Proper training in handling pesticides is the number one way to prevent spills. It is important that all those involved in the use of pesticides be trained on how to correctly transport, store, mix and apply, and dispose of pesticides, as well as how to properly respond to and manage a pesticide spill. See the Resources at the end of this NebGuide for more information on preventing pesticide spills.

If a spill occurs, protecting the environment and human health is the primary goal. Following guidelines like the Three C's, referring to the pesticide label, and contacting the appropriate agencies to report the spill will help achieve this goal.

The Three C's

The Three C's—Control, Contain, Clean Up—provide guidelines for managing a pesticide spill. The Three C's provide a way to quickly organize after a pesticide spill, whether it occurred during transport, storage, mixing and loading, or application. Also consider where the spill has occurred when preparing to manage it. Managing a pesticide spill on soil may be different than a spill that occurs on a concrete loading pad.

Control: Control is the first step of the Three C's because the goal is to stop the release of the pesticide. For example, if a five-gallon jug leaks liquid pesticide from a crack in the bottom, place the jug inside a larger container to catch the pesticide. If it is a larger container (e.g., 55-gallon drum), try to stop the leak by plugging it. If a hose or spray tip on application equipment is leaking, relieve the pressure and use a container to catch the solution.

Planning ahead will ensure that the necessary emergency materials are on hand to control a larger leak. Make sure to wear the proper protective clothing to prevent chemical exposure when controlling a pesticide spill.

Contain: When controlling the spill, it is also equally important to contain it to keep the pesticide from spreading. When a spill occurs in the field, the pesticide can be prevented from spreading by creating a dam using soil and a shovel. When the spill is on a hard surface, use an absorbent material like cat litter or an absorbent pillow designed to contain the spill. If the spill occurs with a dry pesticide formulation, prevent spreading by lightly misting with water (do not over-apply water or runoff may occur), or covering the spill with a plastic tarp. The important thing is not to let the spilled material get into any body of water, including storm sewers or drains.

Clean Up: After the spill has been contained, the absorbent material and pesticide need to be properly disposed, and the area cleaned. For spills on concrete or similar materials, the absorbent material should be swept up and placed in a fiber or steel drum lined with a heavy-duty plastic bag. The area can then be cleaned using a commercial cleaning product made for this purpose (e.g., ammonia and water, commercial tank cleaner and water, or as recommended on the product label). Use more absorbent material to soak up the cleaning solution and dispose of it in the heavy-duty plastic bag. When the spill occurs on soil, the only effective way to decontaminate the area is to remove the top 2–3 inches of soil. In either of these situations, the next step is to follow state guidelines for disposing of the pesticide waste material, now considered hazardous waste. Contact the Nebraska Department of Environmental Quality, 402–471–2186, for guidance on disposal of cleanup material following a spill. Since each spill will be different, the Nebraska Department of Environmental Quality will determine the proper steps for each situation.

In addition to cleaning the area where the spill occurred, be sure to clean any equipment used in the cleanup process. Be sure that hands, clothing, and any other exposed skin are washed as soon as possible with soap and water. If only water is available, be sure to rinse repeatedly and then wash with soap and water as soon as possible.

Remember the PPE

In the chaos of an emergency, it can be easy to forget personal safety. Personal protective equipment (PPE) is necessary when dealing with a pesticide spill. Wearing chemical-resistant gloves, a long-sleeved shirt, long pants, shoes plus socks, and a chemical-resistant apron or coveralls (if concentrated pesticide is involved) is a must. Even if there is an injury, PPE should be put on before attending to the victim to prevent exposure to toxic chemicals.

Spill Kit

A spill kit is essential when working with pesticides because it contains all the items needed when a spill occurs. With all the items in one place, response to a pesticide spill can occur quickly. The following items should be included in a plastic container labeled “Spill Kit” (*Figure 1*).

- Emergency telephone numbers (see next page)
- Copies of all labels and Safety Data Sheets (SDS) for pesticides in storage, under transport, or being applied
- Chemical-resistant gloves, footwear, apron/coveralls
- Long-sleeved shirt
- Protective eyewear
- Respirator (if working in a confined space or required by the product label)
- Absorbent material (e.g., cat litter, sawdust, spill pillow)
- Shovel, broom, dustpan
- Heavy-duty detergent for cleaning (e.g., commercial cleaner, ammonia, detergent as recommended by pesticide product manufacturer)
- Decontamination kit (used to clean hard surfaces; can include sponges, paper towels, scrub brush, and cleaning solution appropriate for the chemicals being used)
- Fire extinguisher rated for chemical fires
- Other items specified on labels of the products in use
- Heavy-duty plastic bags for disposing of hazardous waste

Figure 1. Example of a spill kit.

Read the Label

Product labels and SDS contain emergency information and procedures that may be specific to each product. Read labels carefully and make sure they are easily accessible for quick reference in an emergency.

Resources

Nebraska Pesticide Applicator Certification Core Manual, 2015.

Pesticide Environmental Stewardship, *Pesticide Spills, http://pesticidestewardship.org.*

Safe Transport, Storage, and Disposal of Pesticides, EC2507, *http://extensionpubs.unl.edu/publication/9000016363802/safe-transport-storage-and-disposal-of-pesticides/*

When and How to Report a Pesticide Spill

Evaluating which spill situations require reporting is the first step in proper response. The following statement helps assess when to report a spill: "Report a spill if there is any potential harm to human health or the environment . . . a spill is not reportable when it does not result in pesticide lost to the environment . . . such as when it occurs on a concrete floor or in an enclosed area."

Follow these steps when a spill occurs:

1. Call First Responders/EMT for human injuries, and medical or fire emergencies **(911),** OR The Poison Center for aid in human poisoning cases, **800–222–1222**.
2. Control the spill.
3. Contain the spill.
4. Call CHEMTREC (Pesticide Accident Hotline) or the local fire department for help involving spills, leaks, fires; be prepared to report the actual amount of concentrated chemical/fertilizer spilled, **800–424–9300.**
5. Call the Nebraska State Patrol to report chemical spills or releases and motor vehicle accidents on state/public roadways, **800–525–5555**; OR the Nebraska Department of Environmental Quality to report all other spills, **402–471–2186**, and receive guidance.
6. Clean up the spill according to recommendations from appropriate agencies, and contact them when a spill occurs. Refer to the following numbers in nonemergency situations.

Nonemergency Telephone Numbers

- National Pesticide Information Center for questions about pesticides and safety, **800–858–7378**.
- Chemical Referral Center (weekdays only) for referrals to manufacturers on health and safety related to chemicals, **800–262–8200**.
- Individual chemical manufacturer numbers on the pesticide label.

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Nebraska Lincoln EXTENSION
Know how. Know **now**.

EC2505
(Revised October 2012)

Managing the Risk of Pesticide Poisoning and Understanding the Signs and Symptoms

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The potential for accidents with pesticides is real. Accidental exposure or overexposure to pesticides can have serious consequences. While most pesticides can be used with relatively little risk when label directions are followed, some are extremely toxic and require special precautions.

In 2010, the Poison Control Centers received 91,940 calls (3.3 percent of all human exposures) related to pesticide exposures. That year, pesticides were responsible for about 3 percent of all accidental exposures to children 5 years and younger and almost 6 percent for adults. In addition, pesticides were the cause of about 4 percent of children's deaths reported to the Poison Control Centers.

Routes of Exposure

Pesticides can enter the human body three ways: 1) ***dermal exposure***, by absorption through the skin or eyes; 2) ***oral exposure***, through the mouth; and 3) through ***inhalation or respiratory exposure***, by breathing into the lungs.

Dermal exposure results in absorption immediately after a pesticide contacts the skin or eyes. Absorption will continue as long as the pesticide remains in contact with the skin or eyes. The rate at which dermal absorption occurs is different for each part of the body (*Figure 1*). The relative absorption rates are determined by comparing each respective absorption rate with the forearm absorption rate, given a rate of 1.

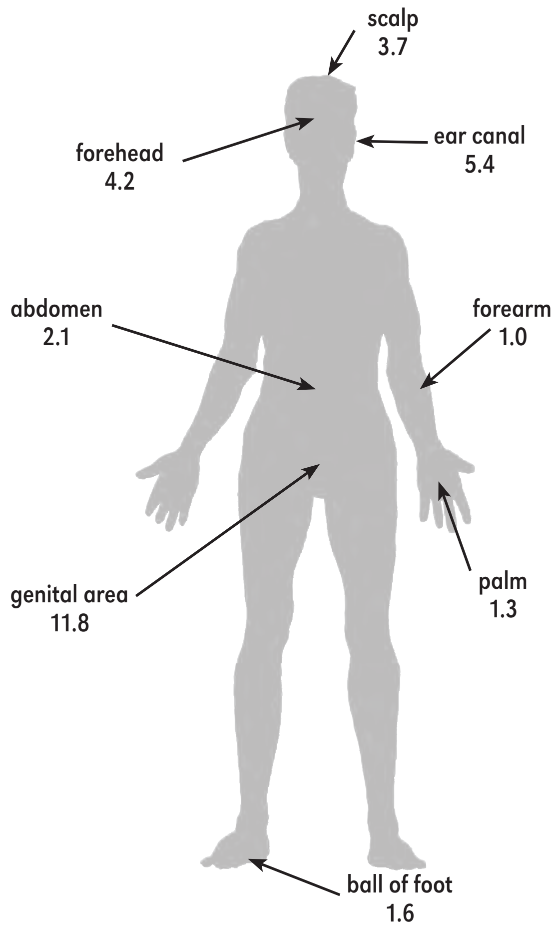

Figure 1. Absorption rates of the different parts of the body based on the absorption rate of the forearm.

It is easy to transfer pesticide residues from one part of the body to another. For example, residues can be inadvertently moved from the palm of a hand that has an absorption rate of 1.3, to a sweaty forehead (4.2) or to the genital area (11.8). When this occurs, the applicator increases the potential for pesticide poisoning.

Oral exposure may result in serious illness, severe injury, or even death. Pesticides can be ingested by accident, through carelessness, or intentionally. The most common accidental oral exposure occurs when a pesticide is taken from its original container and put into an unlabeled bottle, jar, or food container. A pesticide stored in a food container can be especially inviting to a child. When pesticides are managed and stored properly, children should not be able to touch them.

Inhalation or respiratory exposure is particularly hazardous because the lungs can rapidly absorb pesticides into the bloodstream. Some pesticides can cause serious damage to the nose, throat, and lung tissue if inhaled in sufficient amounts. Vapors and very small particles pose the most serious risks.

Lungs can be exposed to pesticides by inhalation of powders, airborne droplets, or vapors. Concentrated wettable powders can pose a hazard if inhaled during mixing. The hazard from inhaling pesticide spray droplets usually is fairly low when dilute sprays are applied with low-pressure application equipment, because most droplets are too large to remain airborne long enough to be inhaled. The potential for respiratory exposure increases, however, when high pressure, ultra low volume (ULV), or fogging equipment is used. Droplets produced during these operations are fog-sized (less than 10 microns) or mist-sized (10 to 100 microns) and can be carried on air currents for a considerable distance.

Follow these guidelines to reduce the risk of pesticide exposure:

- Always store pesticides in their original labeled containers.
- Never use your mouth to clear a spray hose or nozzle, or to begin siphoning a pesticide.
- Always leave the work area and wash thoroughly before eating, drinking, using tobacco, or using the toilet.
- Read the pesticide label and wear appropriate clothing and personal protective equipment (PPE). The label has precautionary statements listing hazards to humans, indicating whether risks are due to oral, dermal, and/or respiratory exposure.

Pesticide Toxicity

The toxicity of a pesticide can be measured several ways. Determining the toxicity of a pesticide to humans is not easy, since humans cannot be used as test subjects. Because of this, other animals, such as rats, are used. If a pesticide is poisonous to rats, however, it is not necessarily poisonous to dogs, cows, wildlife, or people. Toxicity studies are only guidelines: they are used to estimate how poisonous one pesticide is compared with another. Some pesticides are dangerous in one large dose or exposure, which is known as acute toxicity. Others can be dangerous after small, repeated doses, called chronic toxicity.

Measuring toxicity. The LD_{50} (lethal dose, 50 percent) describes the dose of a pesticide that will kill half of a group of test animals (rats, mice, or rabbits) from a single exposure or dose by a dermal, oral, or inhalation route. The LD_{50} is the dose per unit of body weight, such as milligrams per kilogram (mg/kg). A pesticide with a lower LD_{50} is more toxic than a pesticide with a higher number because it takes less of the pesticide to kill half of the test animals. For example, a pesticide with an LD_{50} of 10 mg/kg is much more toxic than a pesticide with an LD_{50} of 1,000 mg/kg.

The toxicity of fumigant pesticides is described in terms of the concentration of the pesticide in the air, LC_{50} (lethal concentration, 50 percent). Researchers use a similar system to test the potential effects of pesticides on aquatic organisms in water.

Acute toxicity of a pesticide refers to the effects from a single exposure or repeated exposures over a short time, such as an accident when mixing or applying pesticides. Various signs and symptoms are associated with acute poisonings. A pesticide with a high acute toxicity can be deadly even if a small amount is absorbed. Acute toxicity can be measured in terms of acute oral, dermal, or inhalation toxicity.

Chronic toxicity refers to the effects of long-term or repeated low-level exposures to a toxic substance. The effects of chronic exposure do not appear immediately after first exposure: years may pass before signs and symptoms develop. Possible effects of long-term exposure to some pesticides include:

- cancer, either alone or by assisting other chemicals;
- genetic changes;
- birth defects in offspring following exposure of the pregnant female;
- tumors, not necessarily cancerous;
- liver damage;
- reproductive disorders;
- nerve damage;
- interfering with the endocrine system (hormones and glands that regulate many body functions); and
- sensitivity or allergic reactions such as irritation of the skin and/or respiratory tract.

The effects of chronic toxicity, as with acute toxicity, are dose-related. Low-level exposure to chemicals that have the potential to cause long-term effects may not cause immediate injury, but repeated exposures through careless handling or misuse can greatly increase the risk of chronic adverse effects.

Table I. Signal words and relative toxicities used on labels of pesticide products.

GROUP	SIGNAL WORD	TOXICITY RATING	ORAL LETHAL DOSE for a 150-pound Human[a]
I	Danger[b]	Highly toxic	Few drops to 1 tsp
II	Warning	Moderately toxic	1 tsp to 1 Tbsp
III	Caution	Slightly toxic	1 Tbsp to a pint
IV	Caution (signal word not always required)	Relatively nontoxic	More than a pint

[a]The lethal dose is less than those listed for a child or for a person under 150 lb, and more for a person over 150 lb.
[b]The skull and crossbones symbol and the word "Poison" sometimes are printed with the signal word "Danger."

Signal Words

Nearly all pesticides are toxic at some dose. They differ only in the *degree* of toxicity. All pesticides are potentially dangerous to people who have had excessive exposure. Every label of a pesticide product will have one of three signal words that clearly indicates the degree of toxicity associated with that product (*Table I*). The signal word indicates the degree of risk to a user, not the effectiveness of the product in controlling the target pest.

Read the Pesticide Label

Pesticide labels also include statements about route of entry and specific actions that must be taken to avoid exposure. Route of entry statements indicate the outcome that can be expected from exposure. For example, a pesticide label might read, "*Poisonous if swallowed, inhaled, or absorbed through the skin. Rapidly absorbed through skin and eyes.*" This indicates that the pesticide is a potential hazard through all three routes of entry, and that skin and eye contact are particularly hazardous. Specific action statements normally follow the route of entry statement and indicate what must be done to prevent poisoning accidents. In the case of the pesticide discussed above, the statement might read, "*Do not get in eyes, on skin, or on clothing. Do not breathe spray mist.*"

The route of entry and specific action statements usually are followed by first aid instructions (see *Table II*). Read this section of the label carefully prior to using the pesticide so you know what to do if an accidental exposure occurs. By following the instructions carefully, you will help limit the amount of exposure you or the victim will receive, even after initial contact with the pesticide.

Table II. Example of a first aid section from a pesticide label.

FIRST AID:	Call a poison control center or doctor for treatment advice.
IF IN EYES:	Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
IF INHALED:	Move the victim to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. Get medical attention.
IF SWALLOWED:	This product will cause gastrointestinal tract irritation. Immediately dilute by having the victim swallow water or milk. Get medical attention. Never give anything by mouth to an unconscious person.

Another important section on a pesticide label provides instructions for pesticide applicators and other handlers on the use of personal protective equipment (PPE) to help them limit pesticide exposure. It lists specific protective clothing and equipment requirements. For example, the label for a moderately toxic pesticide might read, "*Applicators and other handlers must wear long-sleeved shirts and long pants, shoes plus socks, protective eyewear, and chemical-resistant gloves.*"

Manage Your Risk

Wear PPE required by the label when handling or applying pesticides to reduce the risk of exposure to pesticides. If none are listed, wear appropriate clothing, including a long-sleeved shirt, long pants, shoes, socks, and chemical-resistant gloves. Risk of pesticide poisoning is directly related to the toxicity of a pesticide and the level of exposure, which is reflected in the Risk Formula:

Risk = Toxicity *x* Exposure.

Understanding the toxicity of a product and the potential for personal exposure will help you to lower your risk. No matter how toxic a pesticide is, if the amount of exposure is kept low, risk can be held at an acceptably low level. The toxicity of a pesticide can't be changed, but an applicator can manage and reduce risk by selecting less toxic pesticides, carefully following the label instructions, and wearing the required PPE.

Recognizing Signs and Symptoms of Poisoning

Anyone who may be exposed to pesticides or is working with someone who may be exposed should be aware of the signs and symptoms of pesticide poisoning. *Signs* can be seen by others. Vomiting, sweating, and pinpoint pupils are signs of pesticide poisoning. *Symptoms* are any changes in normal condition that can be described by the victim of poisoning, including nausea, headache, weakness, dizziness, and others. Knowledge of these signs and symptoms will allow for prompt treatment and help prevent serious injury. People who are frequently involved with pesticides should become familiar with the following important steps.

1. Recognize the signs and symptoms of pesticide poisoning for those pesticides commonly used or to which people may be exposed. Often, pesticide poisoning resembles flu symptoms.
2. If you suspect poisoning due to a pesticide, get immediate help from a local hospital, physician, or the nearest Poison Control Center (800-222-1222).

3. Identify the pesticide to which the victim was exposed, giving the chemical name and the EPA registration number found on the label, if possible. Provide this information to medical authorities.
4. Have a copy of the pesticide label available when medical attention begins. The label provides information that will be useful to those assisting a victim of pesticide poisoning.
5. Know emergency measures you can undertake until help arrives or the victim can be taken to the hospital. Both first aid and medical treatment procedures are listed on the product label.

Recognizing Common Pesticide Poisonings

All pesticides in a given chemical group generally affect the human body in the same way. Severity of the effects, however, varies depending on the formulation, concentration, toxicity, and route of exposure of the pesticide. Therefore, it is important to know both the type of pesticide being used and the signs and symptoms associated with poisoning from it.

Pesticides that present the greatest potential health risks and those in which the mode of action is better understood are covered in the following sections. Categories of pesticides with similar signs and symptoms are covered together.

The listings of pesticides in *Tables III, IV, and V* are not necessarily complete, nor do they guarantee that the product is currently registered. They do, however, represent products that are or have been used in Nebraska. The Environmental Protection Agency (EPA) and Nebraska Department of Agriculture (NDA) maintain registrations for pesticide products. The EPA attempts to discontinue use of the most toxic products and replace them with less toxic products. Pesticides mentioned in this publication may not currently be registered for use in Nebraska, but still may be found on the shelves of applicators. Therefore, they still present risk, so signs and symptoms are included. Mention of a trade name does not constitute endorsement of a product, nor does omission constitute criticism.

Insecticides

Insecticides have many different modes of action. Some act on the nervous system of the insect. Others slow the production of energy that an insect needs to survive. Another type slows or stops the production of chitin, a major component of an insect exoskeleton, so the insect can't molt. Insect growth regulators, another type, also may prevent an insect from molting or keep it from maturing and reproducing. Some insecticides disrupt the water balance in an insect, causing rapid water loss and eventual death. The modes of action involving the nervous system and energy production may affect not only insects, but other animals as well. Insecticides such as the insect growth regulators typically are specific to insects. The following is a list of insecticides grouped by their chemical makeup.

Organophosphate and Carbamate Insecticides

Most cases of pesticide poisoning involve either organophosphate or carbamate insecticides. Both chemical groups affect humans by inhibiting acetyl cholinesterase, an enzyme essential for proper function of the nervous system. Without acetyl cholinesterase, nerve impulses continue and the victim has uncontrolled twitching. Examples of organophosphate and carbamate insecticides used in Nebraska are listed in *Table III*. Some are being phased out or are not used as much as other insecticides.

Table III. Organophosphate and carbamate insecticides that have been or currently are used in Nebraska. Examples of trade names are in parentheses.

Organophosphates			Carbamates
Acephate (Orthene®)	Dimethoate *(Cygon)* (DeFend)	Phorate (Thimet®)	**Aldicarb (Temik®)*
Azinphos-methyl (Guthion®)	Disulfoton (Di-Syston®)	Phosmet (Imidan®)	Carbaryl (Sevin®)
Chlorpyrifos (Lorsban®)	Ethoprop (Mocap®)	Pirimiphos-methyl (Actellic)	***Carbofuran (Furadan®)*
Coumaphos (Co-Ral®)	Malathion	Terbufos (Counter®)	Methomyl (Lannate®)
Diazinon	Methyl Parathion (Penncap-M®)	Trichlorfon (Dylox®)	Propoxur *(Baygon®)*
Dichlorvos (Vapona®, DDVP®)	Naled (Dibrom®, Trumpet®)		

*Registrations for italicized products have been discontinued or will be soon after this publication is printed. The product still may be in an applicator's storage, so names are listed in the tables.
**Registration of this product has been discontinued, and it must not be used after December 31, 2013.

The effects of these materials, particularly organophosphate insecticides, are rapid. Signs and symptoms begin shortly after exposure, and in cases of acute poisonings, during exposure. Exposure to either of these insecticide classes may pose special risks to people with reduced lung function, seizures, or other conditions. In some cases, consumption of alcoholic beverages may worsen the effects of the pesticide.

The onset of symptoms in milder exposures usually occurs within 4 hours, but can occur up to 12 hours after exposure. Diagnosis of a suspected poisoning must be rapid. Signs and symptoms associated with mild exposures to organophosphate and carbamate insecticides include headache; fatigue; dizziness; loss of appetite with nausea, stomach cramps, and diarrhea; blurred vision associated with excessive tearing; contracted pupils; excessive sweating and salivation; slowed heartbeat, often less than 50 beats per minute; and rippling of surface muscles just under the skin. Some of these symptoms may be mistaken for those of flu, heat stroke, heat exhaustion, or an upset stomach.

Moderately severe organophosphate and carbamate insecticide poisoning cases exhibit all the signs and symptoms found in mild poisonings listed above. In addition, a victim may be unable to walk, complain of chest discomfort and tightness, have marked pinpoint pupils, exhibit muscle twitching, and have involuntary urination and bowel movement. Signs of severe poisonings include incontinence, unconsciousness, and seizures.

The order in which these symptoms appear may vary, depending on how contact is made with the pesticide. If the product is swallowed, stomach and other abdominal manifestations commonly appear first; if it is absorbed through the skin, gastric and respiratory symptoms tend to appear at the same time.

Fortunately, good antidotes are available for victims of organophosphate or carbamate poisoning at emergency treatment centers, hospitals, and many physicians' offices. As with all pesticide poisonings, prompt assistance is critical. If a pesticide is swallowed, obtain prompt medical treatment. If dermal exposure has occurred, remove contaminated clothing, wash exposed skin, and seek medical care.

Organochlorine Insecticides

The U.S. EPA has sharply curtailed the availability of many organochlorines because they persist in the environment. Organochlorines are formed from carbon and chlorine; examples include DDT, chlordane, dieldrin, aldrin, and lindane. Although few are available for purchase or registered for use, some organochlorine insecticides still may be present in storage areas. In addition, organochlorines, such as pesticides, dioxins, and polychlorinated biphenyls (PCBs), are in the environment due to drift from application, spills, leaks, and improper disposal of industrial wastes. Because of the persistence of organochlorines, traces of them still can be found in sediment, water, and living organisms, even though most use was banned in the U.S. decades ago. Some areas have advisories limiting the consumption of fish and shellfish due to the presence of these materials in their tissue. When fish and shellfish such as crabs and mollusks eat, they accumulate pollutants such as organochlorines and heavy metals present in their food, in tainted sediment, or water they filter to get food. The process called bioaccumulation or bioconcentration describes how pollutants accumulate or concentrate in living tissue. The potential for bioaccumulation increases as you go up the food chain, from tiny fish with organochlorines, eaten by larger fish, eaten by larger fish, eaten by humans.

Organochlorines affect the nervous system as stimulants or convulsants. Nausea and vomiting commonly occur soon after ingesting organochlorines. Other early signs and symptoms include apprehension (feelings of suspicion or fear of the future), excitability, dizziness, headache, disorientation, weakness, a tingling or pricking sensation on the skin, and twitching muscles. Loss of coordination, convulsions similar to epileptic seizures, and unconsciousness often follow. When chemicals are absorbed through the skin, apprehension, twitching, tremors, confusion, and convulsions may be the first symptoms. Chronic exposure may lead to cancer, birth defects, and mutations of genes.

No specific antidotes are available for organochlorine poisoning. People assisting a victim should wear chemical-resistant gloves and be careful to avoid contamination by the pesticide. Remove contaminated clothing immediately and bathe and shampoo the person vigorously with soap and water to remove pesticide from the skin and hair. If the pesticide has been swallowed, empty the stomach as soon as possible by giving the conscious patient syrup of ipecac and water or by inserting a clean finger into the throat while the victim is turned to one side, facing the floor. Never induce vomiting when a victim is unconscious: inhaling vomit may cause suffocation.

Pyrethroid Insecticides

Pyrethroids are synthetically produced compounds that mimic the chemical structure of naturally occurring pyrethrins found in a specific type of chrysanthemum plant. As with organophosphates and carbamates, pyrethroids affect the insect's nervous system, but in a different way: they are not cholinesterase inhibitors. Some examples of pyrethroids are listed in *Table IV*.

Table IV. Pyrethroid insecticides, with trade names for some products in parentheses.

Allethrin (Sniper®)	Fenvalerate (Evercide®)
Baythroid (Baythroid®, Discus®)	Fluvalinate (Mavrik® Perimeter)
Cyfluthrin (Tempo®)	Permethrin (Pounce®, Ambush®)
Cypermethrin (Barricade®)	Resmethrin (Rid®, Mosquito Beater®)
Deltamethrin (Battalion®)	Tetramethrin (aero® Assault)
Esfenvalerate (Asana® XL)	Tralomethrin (Dead-Fast® Insecticide Chalk)

Risk of poisoning by pyrethroids through inhalation and dermal absorption is low. Very few poisonings of humans by pyrethroids have been documented. Dermal contact may result in skin irritation such as stinging, burning, itching, and tingling progressing to numbness. Some people experience a range of allergic reactions from pyrethroids. Repeated exposures may increase the intensity of the reaction.

Although some pyrethroids may be toxic by the oral route, ingestion of this type of insecticide usually presents relatively little risk. Occasionally, a large dose may cause loss of coordination, tremors, salivation, vomiting, diarrhea, and irritability to sound and touch. Most pyrethroids are promptly excreted by the kidneys.

Biological Insecticides

Insecticides produced from plant materials or bacteria are called biological insecticides.

Azadirachtin, derived from the Neem tree, is an insect growth regulator that interferes with the insect molting process. For humans, exposure to azadirachtin causes slight skin and gastrointestinal irritation. Stimulation and depression of the central nervous system also have been reported.

Eugenol is derived from clove oil and used both as an insect attractant and insecticide. In humans, large doses can cause skin burns. Extremely large doses may result in liver problems and coma.

Pyrethrum and pyrethrins. Pyrethrum is found in the flowers of *Chrysanthemum cinerariaefolium*. Crude pyrethrum is a dermal and respiratory allergen for people. Skin irritation and asthma have occurred following exposures. Refined pyrethrins are less allergenic, but appear to retain some irritant and/or sensitizing properties.

In cases of human exposure to commercial pyrethrum products, realize that other toxicants may be present and will be listed on the label. Synergists may be added to insecticide products to enhance the killing power of the active ingredient. Synergists such as piperonyl butoxide, discussed later, have low toxic potential in humans, but organophosphates or carbamates included in the product may have significant toxicity. Pyrethrins themselves do not inhibit the cholinesterase enzyme.

Rotenone is a naturally occurring substance found in several tropical plants. Until 2011, it was formulated as dusts, powders, and sprays for use in gardens and on food crops. The Agriculture Health Study, involving 90,000 applicators and spouses from Iowa and North Carolina, showed a relationship between exposure to rotenone and the incidence of Parkinson's disease. More research is needed to reach any conclusions on the specifics of that relationship. Manufacturers of rotenone have voluntarily stopped producing the pesticide for all uses except the management of undesirable fish species. Rotenone is now a restricted use pesticide.

Antibiotics include abamectin, ivermectin, *Bacillus thuringiensis* (Bt), spinosad, and streptomycin. These compounds are practically nontoxic to humans. In studies involving deliberate ingestion by human subjects, slight inflammation of the gut occurred. Antibiotic insecticides in the form of emulsifiable concentrates may cause slight to moderate eye irritation and mild skin irritation due to the solvent carriers. Antibiotic pesticides are different from antibiotics taken by people to cure bacterial infections.

Inorganic Insecticides

Boric acid and borates. Boric acid, derived from borax and usually combined with an anti-caking agent, is commonly used to kill cockroaches. It can be harmful to humans if accidentally ingested. Avoid inhaling the dust during application. Inhaled borax dust causes irritation of the respiratory tract and shortness of breath. Borax dust is moderately irritating to skin. Infants have developed a red skin rash that most often affects the palms, soles of the feet, buttocks, and scrotum in severe poisonings. The skin developed a "boiled lobster appearance" followed by extensive skin peeling.

Diatomaceous earth (DE) is mined from the fossilized silica shell remains of diatoms, which are microscopic sea animals. Labels may refer to this ingredient as silicon dioxide, or "silicon dioxide from diatomaceous earth." DE is used commercially to control crawling insects, such as cockroaches, ants, and insects that infest grain. It is virtually nontoxic to humans. Avoid inhaling diatomaceous earth, however, as it can irritate the eyes and lungs.

Silica gel is a nonabrasive, chemically inert substance used as a dehydrating agent because the small particles absorb moisture and oils. Avoid inhaling the dust. Some grades of diatomaceous earth contain small amounts of crystalline silica, which is known to cause a respiratory disease called silicosis and cancer. The risk of cancer depends on the duration and level of exposure. Pesticide-quality diatomaceous earth and silica gel are amorphous (non-crystalline), and do ***not*** cause silicosis or cancer.

Sulfur is moderately irritating to skin and has been associated with skin inflammation. Dust is irritating to the eyes and respiratory tract. If swallowed, it acts like a strong laxative.

Other Insecticides

Fluorines. Sulfluramid (Spectracide terminate® and Firstline®) is formulated as an ant, roach, or termite bait and is slightly irritating to the skin. Sulfluramid has low toxicity in lab tests. However, with repeated exposure, it has caused developmental abnormalities in young laboratory animals and affected the reproductive systems of male laboratory animals.

Nicotinoids, sometimes called **neonicotinoids,** were introduced in the 1990s. They are chemically similar to nicotine. They have a lower toxicity to humans than organophosphates and carbamates. Imidacloprid and thiamethoxam are used to control termites, turf insects, and some crop insects.

Farm workers reported skin or eye irritation, dizziness, breathlessness, confusion, or vomiting after they were exposed to pesticides containing imidacloprid. Similar symptoms, along with increased heart and breathing rates, also were noted after a victim ingested a product containing imidacloprid; the victim suffered severe cardiac toxicity and death 12 hours after oral exposure.

Pyrazoles. Fipronil is a moderately toxic pyrazole that may cause mild irritation to the eyes and skin. It is used to control termites (Termidor®, Taurus™), cockroaches (Combat®, Maxforce®), certain insect pests of corn, and fleas and ticks of cats and dogs (Frontline®, Effipro®, PetArmor™). Lab animals exhibited reduced feeding, reduced urination, increased excitability, and seizures following a toxic oral dose. After ingesting fipronil, humans have reported sweating, nausea, vomiting, headaches, abdominal pain, dizziness, agitation, and weakness. Direct, short-term contact with skin can result in slight skin irritation. Inhalation or dermal contact while spraying fipronil for five hours may have caused a person to have a headache, nausea, dizziness, and weakness. Symptoms developed two hours after spraying and then disappeared. According to the National Pesticide Information Center, signs and symptoms from a brief exposure to fipronil generally improve and clear up without treatment (*http://npic.orst.edu/factsheets/fipronil.pdf*).

Pyrroles. Chlorfenapyr (Phantom®, Pylon®) is the only product in this group. It is formulated to control ants, cockroaches, termites, and some insect and mite pests on fruits and vegetables. It is slightly toxic if swallowed or if it contacts the skin, and can be moderately irritating to eyes and skin.

Tetronic acids. Spiromesifen is the sole insecticide in this group. It is used to control mites and whiteflies on some vegetable crops (Oberon®) and ornamental trees (Forbid™, Judo™, Oberon®). No indication of eye irritation has been reported.

Tetramic acids. Spirotetramat (Kontos®, Movento®) is a systemic insecticide that controls a number of major sucking insects and mites that are pests of trees, vegetables, potatoes, and other plants. Some products with tetramic acids may cause moderate eye irritation. Prolonged or repeated skin contact may cause allergic reactions in some individuals.

Insect Growth Regulators

Insect growth regulators (IGR) act on insects in different ways. Those that mimic juvenile hormones keep insects in immature stages and prevent insect reproduction. Chitin synthesis inhibitors prevent insects from molting and growing into adults. In general, IGRs are very low in toxicity and cause mild skin irritation with limited exposure. No human poisonings or adverse reactions in exposed workers have been reported. Some examples of insect growth regulators are listed in *Table V*.

Table V. Common insect growth regulators. Examples of trade names are in parenthesis.

Diflubenzuron (Adept®, Clarifly®)	Methoprene (Bio Spot®)
Hexaflumuron (Shatter™)	Noviflumuron (Recruit®)
Hydroprene (Gentrol®)	Pyriproxyfen (First Shield™)

Mosquito Repellents

Diethyltoluamide (DEET) was developed by the U.S. Army in 1946 as an insect repellent and has been available to the general public since 1957. Products containing DEET (Detamide®, OFF!®) have been effective and generally well tolerated when applied to human skin. If left on skin for an extended period, some people have experienced irritation, redness, a rash, and swelling. Tingling and mild irritation have occurred following repeated application. In some cases, DEET has caused skin irritation and worsened preexisting skin disease. It is very irritating to the eyes but not corrosive. When swallowed, it has caused nausea and vomiting.

Serious adverse effects have occurred when DEET was used under hot, humid conditions and not washed off before going to sleep. The skin became red and tender, then blistered and formed ulcers, leaving painful weeping bare areas that were slow to heal. Permanent scarring resulted from most of these severe reactions. Very rarely, seizures in people have been associated with exposure to DEET. Most have occurred after drinking products with DEET or using the products in ways that do not follow label directions.

Exercise great caution when using DEET on children: only use products containing lower concentrations. The American Academy of Pediatrics (AAP) recommends against using any repellent on infants 2 months of age or younger. The AAP cautions parents not to use DEET on the hands of a child and to avoid applying it to areas around a child's eyes and mouth. Consider applying DEET only to clothing, using as little repellent as possible. If a child experiences a headache or any kind of emotional or behavioral change, discontinue the use of DEET immediately. Limited information is available on childhood responses to DEET from research or Poison Control Center reports. Most adverse responses were the result of improper use or accidents.

Picaridin, a synthetic compound first made in the 1980s, resembles a natural compound found in the group of plants used to produce black pepper. Although widely used as an insect repellent in Europe and Australia, picaridin has been available in the United States only since 2005. Although uncommon, some people have experienced skin irritation. Picaridin also may cause irritation if it gets into a person's eyes. Rats lost weight and their kidneys were affected when fed large doses of picaridin. The material is considered practically nontoxic if inhaled. While children may be especially sensitive to pesticides compared to adults, no data suggest that children have increased sensitivity specifically to picaridin.

Oil of Citronella has been used for over 50 years as an insect and animal repellent. It is found in many familiar insect repellent products, including candles, lotions, gels, sprays, and towelette wipes. These products vary in effectiveness and may repel various insects, such as mosquitoes, biting flies, and fleas. When used according to the label, citronella products are not expected to harm humans, pets, or the environment. The only concern in studies involving laboratory animals is skin irritation. The EPA requires precautionary labeling because some citronella products are applied to human skin. Citronella is not expected to pose health risks to people, including children and other sensitive populations, if used according to label instructions.

Fumigants

Fumigants deliver the active ingredient to the target site in the form of a gas. Fumigants can completely fill a space, and many have tremendous penetrating power. They can be used to treat objects such as furniture, structures, grain, and soil for insect pests and other vermin. Fumigants are among the most hazardous pesticide products to use due to danger of inhalation.

Various fumigants produce differing physiological effects. Headache, dizziness, nausea, and vomiting are common early signs and symptoms of excessive exposure.

Prompt medical treatment is critical with fumigant poisoning. Immediately move a victim of fumigant inhalation to fresh air. Keep the individual quiet in a semi-reclining position even if initial signs and symptoms are mild. If breathing has stopped, give mouth-to-mouth or mouth-to-nose resuscitation. If the victim has no pulse, immediately give cardiopulmonary resuscitation (CPR) using chest compression. Some fumigant products, along with signs and symptoms of poisoning, are listed below.

Chloropicrin causes severe irritation of the upper respiratory tract, eyes, and mucous membranes. Symptoms of exposure to chloropicrin include burning eyes, tearing, coughing, difficulty breathing, headaches, nausea, and vomiting. Chloropicrin may be a stand-alone fumigant or may be combined with other fumigants to increase their potency. When present in low percentages, it serves as a warning agent.

Sulfuryl fluoride (Vikane®) poisoning symptoms include depression, slowed walking pattern, slurred speech, nausea, vomiting, stomach pain, stupor, itching, numbness, twitching, and seizures. Inhalation of high concentrations may irritate the respiratory tract and may be fatal due to respiratory failure. Sulfuryl fluoride almost always is applied with chloropicrin, so the first signs of poisoning are often associated with severe irritation of the eyes and mucous membranes. Skin contact with gaseous sulfuryl fluoride normally poses no hazard, but contact with liquid sulfuryl fluoride can cause pain and frostbite due to cold temperatures from rapid evaporation.

Phosphine fumigants, such as aluminum and magnesium phosphide (Phostoxin®, PhosFume®, Fumitoxin®, and Fumi-Cel®) affect cell function in the liver and lungs. Mild exposure is signaled by a sensation of cold, chest pains, diarrhea, and vomiting. Exposures that are somewhat more serious will be evidenced by cough, tightness in the chest, difficulty in breathing, weakness, thirst, and anxiety. Signs and symptoms of severe exposure include stomach pain, loss of coordination, blue skin color, pain in limbs, enlarged pupils, choking, fluid in the lungs, and stupor. Severe poisonings can lead to seizures, coma, and death.

Methyl bromide (Metabron, Meth-O-Gas®) affects the central nervous system, lungs, heart, and liver. People poisoned by methyl bromide experience the common signs and symptoms of fumigant poisoning along with abdominal pain, weakness, slurred speech, mental confusion, muscle twitching, and convulsions similar to epileptic seizures. Some liquid fumigants cause skin injuries indicated by areas of redness or blisters that rupture, leaving raw skin or deep ulcers. There are few registered uses of methyl bromide: those remaining are on a conditional year-by-year basis.

Acrolein (Magnacide H®) is an extremely irritating gas used as an aquatic herbicide. Inhalation of the vapor causes irritation in the upper respiratory tract, which may lead to a buildup of fluids in and narrowing of the air passages. If ingested, it attacks the stomach lining, resulting in open sores and cell death. Contact with skin may cause blistering.

Dazomet (Basamid® G) is a granular soil fumigant. It is used to sterilize soil to eliminate weeds, nematodes, and soilborne diseases. Dazomet is highly toxic if swallowed and can be fatal. Frequent or prolonged exposure to skin can result in irritation or more serious skin problems for some individuals. Inhalation can cause a variety of acute and chronic lung conditions, including local irritation, inflammation, fluid buildup, and lung disease.

Metam sodium (Vapam®) is a soil fumigant used to kill fungi, bacteria, weed seeds, nematodes, and insects. When combined with water, it produces a gas that is very irritating to respiratory mucous membranes, eyes, and lungs. Inhalation can cause severe respiratory distress, including coughing of blood and frothy sputum. It can only be used outdoors, and precautions must be taken to avoid inhaling the gas.

Dichloropropene (Telone®) is very irritating to skin, eyes, and the respiratory tract. Inhalation may cause spasms of the bronchi, where air passes into the lungs. Although limited data for humans exist, animals have experienced liver, kidney, and cardiac toxicity. Most dichloropropene products contain chloropicrin; severe irritation of the eyes and mucous membranes is an early sign of exposure. Apparently, risk for oral toxicity is low for humans unless large quantities of dichloropropene are ingested.

Rodenticides

Pesticides designed to kill rodents pose particular risks to humans. Since they are designed to kill mammals, their mode of action is toxic to humans as well. In addition, rodents often live near humans and other mammals, so accidental exposure to baits is a risk. In the effort to make more effective rodenticides, more toxic materials have been developed, increasing the risk to humans. Symptoms from ingestion of rodenticides can be delayed for days — up to four days for bromethalin, and up to seven days for anticoagulants.

Benzenamines. Bromethalin (Tomcat®), the only chemical in this class of rodenticide, is not an anticoagulant (substance that slows clotting of blood). Instead, it acts on the central nervous system. Possible signs and symptoms of exposure to this compound include skin and eye irritation, headache, confusion, muscle twitching, convulsive seizures, and difficulty breathing. Bromethalin poisoning in dogs usually results in paralysis or convulsions and sometimes swelling or bloating of the abdomen.

Coumarins are anticoagulants: they slow the ability of blood to clot and disrupt capillary and liver function. Examples include brodifacoum (Jaguar®, Talon®, WeatherBlok®, now d-CON®), bromadiolone (Contrac®, Maki®), and warfarin (Kaput®, formerly d-CON®). The main signs and symptoms are nosebleeds, bleeding gums, blood in the urine, tar-colored feces, and large irregular blue-black to greenish-brown spots on the skin. Vitamin K is an antidote.

Indandiones also are anticoagulants. Examples are chlorophacinone (Rozol®) and diphacinone (Ditrac®, Ramik®). Main signs and symptoms are similar to coumarin compounds, but some indandiones cause nerve, heart, and blood system damage in laboratory rats, leading to death before hemorrhage occurs. None of these signs and symptoms have been reported in poisonings of humans. Vitamin K is an antidote.

Strychnine is not easily absorbed through the skin nor does it accumulate in the human body. When ingested, however, it acts on the central nervous system within 10 to 30 minutes. Convulsions — violent seizures with involuntary jerky movements that cause the victim to stop breathing — also can occur. Treatment of strychnine poisoning is geared toward eliminating outside stimuli. If strychnine poisoning occurs, place the victim in a warm, dark room to reduce outside stimuli that trigger convulsions. Consequently, in the case of strychnine poisoning, bring medical help to the victim rather than transporting the victim to a medical center, because movement will trigger the convulsions.

Zinc phosphide causes severe irritation if ingested. It reacts with water and stomach juices to release phosphine gas, which enters the blood stream and affects the lungs, liver, kidneys, heart, and central nervous system. Zinc phosphide can be absorbed through the skin and inhaled from fumes. With repeated exposure, it accumulates in the body to dangerous levels. Signs and symptoms of mild zinc phosphide poisoning include diarrhea and stomach pains. In more severe cases, nausea, vomiting, chest tightness, excitement, coldness, loss of consciousness, coma, and death can occur from fluid buildup in the lungs and liver damage. No antidote for zinc phosphide poisoning exists. It is a slow-acting material, which allows time to get the victim medical assistance.

Wood Preservatives

Pesticides registered as wood preservatives extend the life of wood by reducing or preventing the establishment of populations of organisms such as fungi that cause rot or insects that degrade the wood. Some preservatives can leach slowly into the surrounding soil or water. Sometimes, touching treated wood can leave residue on exposed skin.

Creosote (coal tar) typically is found on railroad ties that sometimes are used for landscaping. Exposure can cause skin irritation and prolonged exposure may lead to inflamed skin. Vapors and fumes of creosote are irritating to the eyes and respiratory tract. Ingested creosote may result in severe liver damage. Creosote is considered a probable human carcinogen. Creosote-treated wood cannot be used in residential settings; it may only be used in commercial applications.

Pentachlorophenol (PCP, Penchlorol, Penta, Duratreat®), typically used on utility poles or fence posts, is irritating to the eyes, skin, and respiratory tract. It can cause a stuffy nose, scratchy throat, and tearing eyes. Prolonged exposure sometimes leads to an acne-like skin condition. Ingestion of PCP solutions, excessive skin contact, or inhalation of concentrated vapors may cause fever, headache, weakness, dizziness, nausea, and profuse sweating. Extreme cases of exposure can lead to a loss of coordination and seizures, high fever, muscle spasms and muscle twitching, difficulty breathing, a sense of tightness in the chest, abdominal pain and vomiting, restlessness, excitement, and mental confusion. Intense thirst also is a characteristic. Pentachlorophenol poisoning can be fatal.

Arsenical wood preservatives such as chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) were used extensively in the past to treat construction lumber for decks, play sets, and fence posts. CCA is not well absorbed through the skin, but hand-to-mouth contact can result in exposures. If swallowed, arsenicals can cause nausea, headache, diarrhea, and abdominal pain. Extreme signs and symptoms can progress to dizziness, muscle spasms, violent mental agitation, and seizures. Prolonged exposure to arsenical wood preservatives can result in persistent headaches, abdominal distress, salivation, low-grade fever, and upper respiratory irritation.

Herbicides

Herbicides kill weeds by affecting metabolic processes in plants. Therefore, risk to humans and other mammals is relatively low. Some herbicides, however, can pose a risk of poisoning if not handled according to label directions. Regardless of their chemical structure, the vast majority of herbicides often affect the human body in a similar way. In general, they can irritate the skin, eyes, and respiratory tract. Always read and follow label recommendations carefully to avoid any of these health risks. Herbicides that present the greatest potential health risks are covered in the next four sections.

Bipyridyl Herbicides

Diquat and **paraquat** are the most common bipyridyl herbicides. Paraquat is more toxic than diquat and produces chronic abnormal cell growth in the lungs, cornea and lens of the eyes, nasal mucous membranes, skin, and fingernails. Diquat affects the eye lens and intestinal tract lining but usually does not produce the frequently fatal lung changes characteristic of paraquat.

Ingesting diquat or paraquat causes severe irritation to the mucous membranes of the mouth, esophagus, and stomach. Repeated vomiting generally follows. Large doses of diquat also produce restlessness and reduced sensitivity to stimulation. Large doses, and sometimes even small doses, of paraquat initially can affect the kidneys, liver, adrenal glands, and lungs: potentially fatal fluid accumulation in the lungs can occur in 24 to 72 hours.

Lesser amounts of paraquat will cause decreased urine output because of kidney failure. Yellowing of the skin due to liver damage is sometimes observed. This initial phase is followed by an inactive period lasting up to two weeks, during which the victim appears to improve. The victim, however, may have permanent and gradually advancing lung damage caused by rapid growth of connective tissue. This prevents proper lung function and eventually leads to death through respiratory failure. Paraquat selectively concentrates in cells in the lungs.

Skin exposure to paraquat and diquat concentrates may cause severe skin irritation and burning. Contact with dilute liquids and diquat dusts may cause slight to moderate irritation. Skin absorption of paraquat apparently is slight. Diquat, however, is absorbed and after repeated contact will produce symptoms similar to those following ingestion.

Exposure to paraquat and diquat spray mist may produce skin irritation, nasal bleeding, irritation and inflammation of the mouth and upper respiratory tract, coughing, and chest pain. Exposure to paraquat concentrates may cause nails to blacken and grow abnormally.

No specific antidotes are available to counteract the effects of paraquat, diquat, and other bipyridyl herbicides once significant exposure and absorption has occurred. Seek medical attention promptly. If ingested, and the victim is conscious, induce vomiting immediately unless a physician advises not to. Flush affected eyes with water, and wash skin with soap and water.

Chlorophenoxy Herbicides

2,4-D and MCPA are examples of chlorophenoxy herbicides. These compounds are moderately irritating to skin and mucous membranes. Inhalation may cause a burning sensation in the nose, sinuses, and chest, which may result in coughing. Prolonged inhalation sometimes causes dizziness.

Stomach irritation usually leads to vomiting soon after ingestion. Victims may experience chest and abdominal pain and diarrhea. Headache, mental confusion, and bizarre behavior are early signs and symptoms of severe poisoning, which may progress to unconsciousness.

Arsenical Herbicides

Ansar®, Montar®, MSMA, and **cacodylic acid** are some examples of arsenical herbicides. Acute arsenic poisoning usually appears within one hour of ingestion. Garlic odor of the breath and feces may help to identify the responsible toxicant in severe cases. Effects on the digestive tract include inflammation of the mouth and esophagus, burning abdominal pain, thirst, vomiting, and bloody diarrhea.

Arsenic may affect the central nervous system as well. Effects include headache, dizziness, muscle weakness and spasms, low body temperature, sluggishness, delirium, seizures, and coma. Liver damage may lead to yellowness of the skin. Injury to tissues that form blood may cause a reduction in red and white blood cells and blood platelets. Death usually occurs one to three days after the onset of symptoms and is usually the result of circulatory failure.

Chronic arsenic poisoning through skin exposure usually is more of a problem than acute poisoning, characterized by effects in the intestinal tract. Chronic arsenic poisoning may result in cancer. Symptoms of chronic exposure include overgrowth of the eye's cornea; scaling off of dead skin; excessive fluids under the skin of the face, eyelids, and ankles; white streaks across the nails; loss of nails or hair; and brick red coloration of visible mucus membranes.

Other Herbicides

Endothall (Aquathol®) is commonly used as an aquatic herbicide or algaecide. It is irritating to skin, eyes, and mucous membranes. In one case, a man died after ingesting endothall. In this case, bleeding and swelling were noted in the gut and the lungs.

Sodium chlorate (Drexel®, Defol®) is used as a defoliant, nonselective herbicide, and soil sterilant. It is irritating to skin, eyes, and stomach. Even though sodium chlorate is poorly absorbed in the digestive tract, ingestion of a large dose will cause severe poisoning. Irritation to the gut causes nausea, vomiting, and abdominal pain. Bluish skin sometimes is the only visible sign of poisoning. Dark brown staining of the blood and urine can indicate sodium chlorate poisoning.

Fungicides

Fungicides are used extensively in industry, agriculture, and the home and garden. Fungicides vary in their potential for causing adverse effects in humans. According to the EPA manual, *Recognition and Management of Pesticide Poisoning* (Morgan, 1999), "… most fungicides currently in use are unlikely to cause frequent or severe systemic poisonings for several reasons. First, many have low inherent toxicity in mammals and are inefficiently absorbed. Second, many fungicides are formulated as suspensions of wettable powders or granules, from which rapid, efficient absorption is unlikely. And third, methods of application are such that relatively few individuals are intensively exposed." Fungicides probably have caused a large number of irritant injuries to skin and mucous membranes, as well as some skin sensitization. As with any pesticide, always read and follow label recommendations carefully to avoid any health risks that a specific fungicide may pose.

Other Pesticides and Synergists

The three chemicals listed in this section are among the many pesticides and synergists that have not been discussed. These are listed because they have a relatively high potential for harming humans and nontarget animals.

4-aminopyridine (Avitrol®) is a highly toxic powder used as a bird repellent, often mixed with whole or cracked corn. It is toxic to all vertebrates. No human poisonings have occurred when used according to label directions. However, intentional ingestion has resulted in immediate abdominal discomfort, nausea and vomiting, weakness, dizziness, profuse sweating, and, sometimes, death.

Metaldehyde (Deadline®) has been used to control slugs and snails for many years. Poisoning of animals (particularly dogs) and children occurs occasionally when metaldehyde is swallowed. Ingestion of a toxic dose often is followed by nausea and vomiting, then fever, seizures, and changes in mental status, sometimes leading to coma. Other signs and symptoms that can occur are excessive salivation, facial flushing, dizziness, rapid breathing, and high acidity in the blood. While most poisonings are dramatic, they are rarely fatal. Deaths of dogs are common, however, when they eat enough of the product.

Piperonyl butoxide (PBO) is not a pesticide but one of the most common synergists in use. Synergists typically are added to insecticide products to enhance the effectiveness of the active ingredient. For example, PBO slows the ability of an insect to break down a pesticide. If PBO was not added to a particular insecticide, the insect could break down the pesticide before it could have an effect. As a synergist, PBO reduces the amount of a pesticide that is needed to be effective. Toxicity of PBO in mammals is low, although based on limited evidence of cancer in laboratory animals, it was considered a possible human carcinogen. PBO may trigger allergic responses in some people. Another common synergist that works the same way is known by either MGK 264 or n-octyl bicycloheptene dicarboximide.

What if a Pesticide Poisoning Occurs?

The key to surviving and recovering from a pesticide poisoning is ***rapid*** treatment. **Take emergency action immediately when you suspect a pesticide poisoning has occurred.** As time elapses after exposure, the toxic effects are heightened, and the victim may need more time to recover.

Immediately dial **911** whenever you suspect a pesticide poisoning. An advanced life support team will be dispatched to provide assistance. In addition, you may wish to contact the following:

1. **The Poison Control Center (800-222-1222)** will provide specific directions on procedures to follow until a life support team arrives.
2. The nearest hospital or a physician. These can benefit by having preliminary information before the patient arrives.
3. Another source of medical and consumer information related to pesticides during non-emergencies is the National Pesticide Information Center (**800-858-7378** or online at *http://npic.orst.edu*).

What a victim might think is a cold or the flu could be a fatal pesticide poisoning. Whenever possible, get answers to the following questions.

1. Has the victim been exposed to a pesticide?
2. If so, which one and how did the exposure occur?
3. What emergency actions are given on the pesticide label?

Many pesticide labels direct that vomiting be induced. You can do this by giving the patient syrup of ipecac and water or by inserting a clean finger into the throat of the victim. **Do not induce vomiting when:**

- the label says not to,
- the victim is having or has had seizures accompanied by involuntary jerking movements,
- the victim is unconscious, or
- the pesticide contains petroleum products such as xylene.

Caution: Inhaling vomit can be life-threatening. Timely emergency treatment is vital to survival.

After exposure to a pesticide, always wash the victim's exposed skin with soap or detergent and plenty of water, then obtain medical treatment. Skin irritation can result from continuous exposure if not treated. If the victim's clothing has been contaminated by a pesticide that is readily absorbed by the skin, remove the clothing and wash or rinse the victim's skin.

Remember to protect yourself as you help the victim. Wear chemical-resistant gloves. If a pesticide spill is involved, move the victim away from the spill. Assist the victim first; take action to clean up the spill after all first aid has been completed.

Even though most people are careful when working with pesticides, accidents can happen. Be prepared. Keep the telephone number for the Poison Control Center readily available either in your telephone directory or near your telephone. Do not hesitate to contact medical authorities if any symptoms of pesticide poisoning occur. It is better to be safe than sorry.

Most pesticides used by Nebraska farmers, ranchers, and people with lawns and gardens have lower toxicity levels than many of the pesticides discussed in this publication. When applied properly, with the required protective clothing and equipment, they are unlikely to cause problems for the user. However, ***any*** pesticide ***can*** cause problems due to exposure or overexposure. **Use all pesticides safely. Federal and state laws require that you read the pesticide label completely and comply with all directions. Failure to do so may subject you to federal and/or state sanctions or penalties.**

References

2010 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 28th Annual Report. 2010. 515 King Street, Suite 510, Alexandria, VA 22314. *http://www.aapcc.org/dnn/Portals/0/2010%20NPDS%20Annual%20Report.pdf*

Crop Protection Handbook. 2006. Meister Publishing Company. Willoughby, Ohio.

Handbook of Pesticide Toxicology. 1991. Wayland J. Hayes Jr. and Edward R. Laws Jr., Editors. Academic Press, Inc. San Diego, California.

National Pesticide Information Center. 2011. Oregon State University. *http://npic.orst.edu/*

Pesticide Education Resources website. 2012. University of Nebraska–Lincoln Extension. *http://pested.unl.edu/*

Recognition and Management of Pesticide Poisonings. 1999. Donald P. Morgan. Fifth Edition. Document No. EPA735-R98-003. Supt. of Documents, U.S. Government Printing Office, Washington, D.C. 20402-9325. *http://npic.orst.edu/rmpp.htm*

Rotenone, Paraquat, and Parkinson's Disease. Caroline M. Tanner, Freya Kamel, G. Webster Ross, Jane A. Hoppin, Samuel M. Goldman, Monica Korell, Connie Marras, Grace S. Bhudhikanok, Meike Kasten, Anabel R. Chade, Kathleen Comyns, Marie Barber Richards, Cheryl Meng, Benjamin Priestley, Hubert H. Fernandez, Franca Cambi, David M. Umbach, Aaron Blair, Dale P. Sandler, J. William Langston *in* Environmental Health Perspectives. 2011 June; 119(6): 866–872. Published online 2011 January 26. *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3114824/*

The Pesticide Book. 2004. George W. Ware and David M. Witacre. Sixth Edition. MeisterPro Information Resources. Willoughby, Ohio.

Toxic Syndrome Condition — Nerve Agent and Organophosphate Pesticide Poisoning. 2005. U.S. Centers for Disease Control and Prevention. *http://emergency.cdc.gov/agent/nerve/tsd.asp*

Pesticide Safety Telephone Numbers

Emergency Telephone Numbers	**911**
Poison Control Center For aid in human poisoning cases	**800-222-1222**
Nebraska Department of Environmental Quality 8 a.m. to 5 p.m. Central Time, Monday through Friday To report chemical spills or releases after hours and holidays, contact the Nebraska State Patrol Dispatch.	**402-471-2186 or 877-253-2603**
Nebraska State Patrol Dispatch	**402-471-4545 or 800-525-5555**
Nonemergency Telephone Number	
National Pesticide Information Center 8:30 – 4:30 Mountain time, 9:30 – 5:30 Central time, Monday through Friday	**800-858-7378**

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EC2507
(Revised May 2013)

SAFE Transport, Storage, and Disposal of Pesticides

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Most accidental pesticide poisonings occur when pesticides are mishandled. Young children are often the victims. Pesticide accidents can be prevented by careful planning, using a secure storage location, adopting safe handling methods during transport, and following proper disposal guidelines for both products and containers.

The first step in preventing accidental poisonings and environmental contamination is to use good judgment when buying pesticides.

- Buy only the amount that can be used in a reasonable length of time.
- Don't be tempted by "sale prices."
- Buy pesticides in quantities that you will use in the near future. Some pesticides should not be stored for long periods of time, allowed to freeze, or be stored in direct sunlight because they may become less effective.

Always keep pesticides in their original containers. Using any other container is illegal and could cause an accidental pesticide poisoning. Also, using another container could make it very difficult to retrieve the pesticide label information in the case of pesticide poisoning or environmental contamination.

Transporting Pesticides

Certain precautions should be taken when transporting pesticides. Traffic accidents can happen even when you travel only a short distance, and improperly loaded pesticide containers can fall off your vehicle or become punctured or torn. Because pesticides are transported on public roads, the potential damage from such accidents is great.

Never transport pesticides with food, livestock/poultry feed, or minerals. Also, transport pesticides separately from seed, grain, or consumer goods.

Keep a pesticide spill kit in your vehicle at all times. A spill kit commonly contains chemical-resistant gloves, coveralls, and goggles; sorbent pads and absorbent material (such as kitty litter); shovel; and a plastic temporary storage bag or container.

In case of a pesticide spill follow the three "C's": control, contain, and cleanup. Control the spill immediately to prevent further spillage. Turn off or close the valve on a leaky hose or upright a container that has tipped over. Contain the spill. Dike the spill with absorbent material or sorbent pads to keep it out of water and prevent environmental contamination. Clean up the spill. Use absorbent material to soak up the spill, then shovel contaminated material into a plastic storage container for disposal. Additional information may be found in the shipping papers or the label.

What Vehicle to Use

The safest way to transport pesticides is in the back of a truck or pickup. Never carry pesticides in the passenger compartment of a vehicle. If you use a flatbed truck, it should have side and tail racks. If the truck has a wooden bed, insert an impervious liner such as plastic or a truck bed liner before loading pesticides. Nonporous beds are preferred because they can be easily decontaminated in case of an accidental spill. Make sure your truck is in good operating condition to help reduce the chance of an accident (see **Vehicle Maintenance Checklist,** page 12).

Loading Pesticides

Wear work clothing and chemical-resistant gloves even when handling unopened pesticide containers, in case the container should leak. Also, carry protective clothing and equipment in the passenger compartment of the vehicle. You will need protective equipment if a spill or other pesticide-related accident should occur.

Thoroughly inspect all containers at the time of purchase, before loading. Accept them only if the labels are legible and firmly attached. Check all caps, plugs, or bungs and tighten them if necessary. If leakage has occurred, do not accept the container. Request another container.

When loading containers, handle them carefully; don't toss or drop them. Avoid sliding containers over rough surfaces that could rip bags or puncture rigid containers. Know safe handling procedures when using forklifts. Secure all containers to the truck to prevent load shifts and potential container damage. Protect containers made of paper, cardboard, or similar materials from rain or moisture.

Unloading Pesticides

Never leave pesticides unattended. You are legally responsible if people are accidentally poisoned from pesticides left unattended in your vehicle. Move the pesticides into your storage facility as soon as possible. Inspect the vehicle thoroughly after unloading to determine if any containers were damaged or any pesticide leaked or spilled.

Always carry a pesticide spill kit and carefully secure all pesticide containers.

Transporting Hazardous Pesticides

The U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration has designated many chemical compounds, including some pesticides, as hazardous materials (hazmat). If you transport any of these materials on public roads in commerce, you are required to comply with DOT Hazmat Regulation 49 Code of Federal Regulations (CFR) parts 100-185. To determine which pesticides are classified as hazardous, refer to Hazmat Tables (HMT) I and II (49 CFR part 172.101). To be in compliance, you may be required to:

- Carry shipping papers in your vehicle including an emergency response phone number and Material Safety Data Sheets (MSDS) for the pesticides in transport,
- Receive training concerning DOT Hazmat regulatory requirements,
- Be sure that packages are properly labeled and/or marked,
- Placard your vehicle if transporting a bulk container or 1,000 pounds or more of a pesticide from HMT II or any amount of a pesticide from HMT I, and
- Obtain a Commercial Driver's License (CDL) when required.

Shipping Papers. When you transport any hazardous pesticide, carry the proper shipping papers in the passenger compartment of the vehicle. While you are driving (belted and operating the vehicle), the papers must be within your reach or placed in a door pouch and readily recognizable by emergency personnel. These papers provide information about the chemical that can be used to prevent further damage or injury in case of an accident. Your pesticide dealer will help you obtain the proper papers. Also, carry the Material Safety Data Sheet (MSDS) for each hazardous pesticide or an emergency response guidance manual that cross-references a chemical's shipping name with emergency response information.

Hazardous Materials (Hazmat) Training. The DOT Hazmat training increases your awareness of safety considerations involved in loading, unloading, handling, storing, shipping-paper preparation, marking, labeling, placarding, and transporting of hazardous pesticides. It also improves emergency preparedness for responding to transportation accidents. Hazmat training includes general awareness training, function-specific training, and safety training.

DOT Training Is Available. The DOT Office of Hazardous Materials Safety has prepared training modules that meet the requirements for general awareness Hazmat training. These modules are available online (*http://phmsa.dot.gov/hazmat/training/publications/modules*) or on an interactive CD-ROM. (For more information, phone: 202-366-4900 or email: *phmsa.hm-training@dot.gov*.) A list of training opportunities for the function-specific and safety training sections is available online (*http://www.phmsa.dot.gov/hazmat/training-outreach*) or can be obtained by contacting the DOT Office of Hazardous Materials Initiatives and Training (Phone: 202-366-4900 or email: *phmsa.hm-training@dot.gov*). Specialized training is available from the DOT Transportation Safety Institute as well (405-954-5000).

Labeling and Marking. Always check each package (e.g., cardboard box, plastic or metal drum) to be sure it is properly labeled and/or marked. Labeling means a prescribed hazard warning notice (usually diamond-shaped) on the outer package. Marking means the required words are written on the side of the outer package, including shipping name, identification number, specifications or UN marks, plus other required information, instructions, or cautions.

Accessing the Regulations

Hazardous materials regulations are available online and in print versions.

The U.S. Code of Federal Regulations is available online by searching for US Code of Federal Regulations.

The print version can be ordered through: *http://bookstore.gpo.gov/catalog/laws-regulations*

It is published by the Office of the Federal Register National Archives and Records Administration as a Special Edition of the Federal Register.

Placarding. For most hazardous pesticides (HMT II) in non-bulk, you will need to placard your vehicle when you transport as little as 1,000 pounds of the chemical. When transporting hazardous pesticides (HMT II) in bulk (over 119 gallons) or any amount from HMT I, placarding is required at all times. Place placards, which are available from your pesticide dealer, on all four sides of your vehicle.

Commercial Driver's License. Contact the hazardous materials coordinator at the Nebraska State Patrol (402-471-0105) for more information on training, shipping papers, labeling, marking, and placarding. For more information on the CDL, contact the Nebraska Department of Motor Vehicles office (402-471-2281) or your local driver's license examiner.

Check all shipping containers for proper DOT labeling and marking.

Farmer Exception

Farmers have been granted exceptions from the DOT Hazmat regulations if they are private motor carriers transporting pesticides within the state of Nebraska. Farmers can transport DOT-defined hazardous pesticides (other than compressed gases) between fields of the same farm over any roadway EXCEPT the interstate highway system. Farmers also have had emergency response information and Hazmat employee training requirements waived when they were transporting agricultural pesticides to or from their farm (within 150 miles of the farm).

Transporting Hazardous Pesticide Waste

Certain pesticide wastes are listed as hazardous under the Resource Conservation and Recovery Act (RCRA). RCRA defines "hazardous wastes" (40 CFR parts 240-299) as either:

• "Characteristic" wastes. These are waste materials with one or more of these characteristics: ignitable, corrosive, reactive, TCLP toxic1. These are considered "hazardous wastes" even though they may not be "listed," or,

• "Listed" substances. See the Code of Federal Regulations 40, parts 261.3 and 261.32 for those pesticides that have been declared to be "hazardous waste."

Except for those taking their own pesticides to an approved excess pesticide waste collection/disposal site, only a permitted hazardous waste hauler can transport such waste. For more information, contact the hazardous waste specialist at the Nebraska Department of Environmental Quality at 402-471-2186.

As soon as pesticides arrive at their destination, they should be properly stored and the area immediately secured. This not only helps discourage theft, but also prevents access to the materials by pets, children, and others not trained to use pesticides. Always keep personal protective equipment (PPE) and a pesticide spill kit (chemical-resistant gloves, coveralls, and goggles; sorbent pads and absorbent material such as kitty litter; and a plastic temporary storage bag or container) readily available in or near the pesticide storage area.

When storing pesticides on shelving, place liquid formulations on lower shelves and dry formulations above them. If a liquid formulation container leaks, the dry formulations will not be contaminated. Keeping the liquid containers on lower shelving also helps reduce the risk of accidental spills if the container is knocked off the shelf.

To prevent contamination or accidental use of the wrong chemical, store herbicides, insecticides, and fungicides in separate areas within the storage unit. Dry formulations of insecticides or fungicides can become contaminated if stored with certain volatile herbicides and may cause plant injury when used. Treated baits (for rodents, insects, and birds) should not be stored near other chemicals because they can absorb odors and may repel the pest.

Always store a pesticide in the original container with the label intact. Once a container is opened, the shelf life is considerably reduced. Never store a pesticide, for even a short time, in any container other than the original. **Doing so is a violation of the law.** Pesticides in soft drink bottles, fruit jars, milk cartons, margarine tubs, or glassware are a common cause of accidental poisonings. Store pesticides away from food, pet food, animal feed, seed, fertilizers, veterinary supplies, and plants.

Check all stored pesticide containers (see **Pesticide Storage Checklist**, page 13) for any existing or potential problems, including leaks or spills. Transfer the contents of any leaking container into a container with exactly the same original formulation and label. When this is not possible, put the leaking container with the pesticide into a liquid-proof container and dispose of it as discussed under **Disposal of Excess Pesticide Waste**. If necessary, contact the pesticide manufacturer for specific directions.

The pesticide storage location should be a cool, dry, well-ventilated area away from sources of heat or flame. See the pesticide label for specific storage recommendations. Some pesticides may not be as effective if they are or have been frozen or overheated. Expansion of pesticides caused by freezing or heating can cause containers to crack or break, resulting in potentially dangerous leaks or spills. Heat expansion of a liquid pesticide also may result in contents that are under pressure. When the container is opened, the pressure may cause an overflow and/or contamination of the user or storage site. Excessively high temperatures (120^{o}F or higher) also can change the effectiveness of a pesticide and may produce dangerous fumes, making the storage area unsafe.

To prepare for pesticide applications, remove the pesticide containers from storage and take them to an open area. Always measure and mix pesticides in a well-lit, well-ventilated location. Regardless of whether they are partially or completely emptied, never leave pesticide containers open or unattended while the pesticide is being applied. Return all containers to storage prior to application to prevent accidental spills, ingestion, or exposure to people, pets, livestock, or wildlife.

Mixing and applying pesticides requires detailed attention to label instructions, along with common sense and good judgment. So, too, does pesticide storage. **Being careless or using improper storage procedures is an open invitation to disaster.** While all pesticide labels have a section on storage and disposal, the guidelines do not answer every question. If you have questions about pesticide storage, contact the Nebraska Department of Agriculture (402-471-2394).

Be Prepared for Pesticide Spills

Despite all safety precautions, accidents can happen. If a pesticide spills in a storage area, quick action is imperative. **Have a pesticide spill kit on hand**. If a pesticide spill occurs on a public right-of-way, contact the Nebraska State Patrol at 800-525-5555 for assistance.

If a pesticide is spilled on a person's body or clothing, the person should leave the area immediately. All contaminated clothing should be removed as quickly as possible — this is no time for modesty! Wash affected areas of the body thoroughly with detergent or soap and water. In any pesticide contamination incident, follow the instructions given in the label's first aid treatment guidelines. If the label is not available or if there are further questions, seek medical attention. If necessary, contact The Poison Center in Omaha (800-222-1222).

If toxic fumes are present at the spill site, evacuate people and animals from the immediate area. In addition, secure the area until qualified rescue personnel, with proper protective equipment, arrive at the scene. Except for a small, properly equipped cleanup crew, don't allow anyone to enter the area until it is thoroughly decontaminated.

Spilled pesticides must be contained. If the pesticide starts to spread, contain it by diking with soil or sorbent materials, if this can be done safely without contacting the pesticide or breathing the fumes. Never hose down a contaminated area. This will cause the pesticide to spread and infiltrate into the soil, possibly reaching groundwater. If the spill is liquid, use activated charcoal, absorptive clay, vermiculite, pet litter, or sawdust to cover the entire spill area. Use enough absorbing materials to completely soak up the liquid. Then sweep or shovel the material into a leak-proof drum. Dispose of this material according to the label of the pesticide involved.

Always refer to the product label and, if necessary, contact the chemical manufacturer for information about the appropriate neutralizing materials to be used following a pesticide spill. As a precaution, it is wise to read all product labels thoroughly at the time of purchase and/or delivery to be able to deal quickly and safely with any pesticide emergency.

Pesticide Storage and Spill Reporting Requirements

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) requires that spills or releases of reportable quantities (RQ) of hazardous substances must be reported immediately to the National Response Center (800-424-8802). The reportable quantity for some chemicals can be as low as 1 pound; however, the majority are 100-5,000 pounds. Definitions of hazardous substances and specific reportable quantities can be found in 40 CFR 302. General information is available by calling 800-424-9346.

The Superfund Amendments and Reauthorization Act (SARA) amended CERCLA. One part of the provisions, the Community Right-to-Know Act (Title III), established new lists of "Extremely Hazardous Substances" (EHS) and "Toxic Chemicals" for additional notification and reporting requirements. It also added new reporting requirements for the CERCLA list of "hazardous substances."

SARA Title III established threshold planning quantities (TPQ). Any facility that produces, uses, or stores these Extremely Hazardous Substances (EHS), in amounts equal to or in excess of the threshold planning quantities, has reporting and notification obligations under section 302 of SARA Title III (40 CFR Part 355). If the facility produces, uses, or stores hazardous chemicals or Extremely Hazardous Substances exceeding the designated amounts (10,000 pounds for hazardous chemicals and either 500 pounds or the threshold planning quantities, whichever is lower, for Extremely Hazardous Substances), specific information must be submitted to state and local officials as defined in sections 311 and 312 of the Act (40 CFR 370).

In addition, owners and operators of most business facilities must report spills or releases of CERCLA hazardous substances and Extremely Hazardous Substances to state and local authorities (section 304, 40 CFR 355). If the spill occurs while in transport, the notification can be made either by the owner or the operator of the motor vehicle. Report spills and releases to the Nebraska State Patrol (800-525-5555) or to the 911 emergency operator.

Selecting a Site for Pesticide Storage

Several points must be considered when selecting the site for pesticide storage. One of these factors is prevailing wind direction. The best site is downwind and downhill from sensitive areas, such as houses, play areas, feedlots or animal shelters, gardens, and ponds. Locating storage facilities away from dwellings and livestock facilities will minimize possible contamination.

The site also should be in an area where flooding is unlikely. It should be located where runoff can be diverted and drainage from the site cannot contaminate surface or groundwater.

Ideally, a drainage system should be built to collect any runoff water from the storage area. Pesticides that may be present in tank rinsate, spills, seepage from storage, and heavy runoff in the event of fire or flooding must be controlled. Dikes, collecting pools, and washing slabs with sumps provide a proper drainage system. All of the collected runoff water should be treated as a surplus pesticide and disposed of properly.

Storage Area

Depending on inventory size, a separate building, room, or enclosure may be best for pesticide storage. If the inventory is not large enough to warrant a separate facility, enclose the storage area on the first floor of an existing building. In either case, store pesticides and pesticide containers in a fire-resistant structure having good ventilation and a sealed, concrete floor that slopes toward drainage and secondary containment.

Post weatherproof signs, stating “Danger – Pesticides – Keep Out!” or a similar warning on each door and in any windows of the facility. In some cases, it may be advisable to post the warning signs in one or more languages in addition to English. Post the name, address, and phone number of a contact person at the primary entrance to the storage area.

Regardless of whether it is a cabinet, room, or an entire building, the pesticide storage area should be lockable to prevent unauthorized entry and should be used only for pesticides and pesticide equipment.

An electrically shielded exhaust fan may be needed in a confined storage area to reduce the temperature and/or concentrations of toxic fumes. The fan should be installed so that fumes can be vented outdoors without endangering people, animals, or plants in the area.

Whenever large quantities of pesticides must be stored, it is strongly recommended that fire detection sensors and fire-fighting equipment be provided. A floor plan, records related to the storage location, and an annual inventory of the pesticides and containers in storage must be provided to the local emergency response coordinator as well.

Wooden pallets or metal shelves must be provided for storing granular and dry formulations packaged in sacks, fiber drums, boxes, or other water-permeable containers. If metal pesticide containers are stored for a prolonged period, they should be placed on pallets, rather than directly on the floor, to help reduce potential corrosion and leakage.

Danger! Pesticide storage sign.

Disposing of Excess Pesticides and Pesticide Containers

Despite one's best efforts to avoid accumulating excess pesticides, it is sometimes necessary to dispose of leftover chemicals. And, occasionally it may be necessary to dispose of pesticide wastes, such as materials collected while cleaning up a spill. Pesticide wastes are as hazardous as the pesticide itself. These guidelines should be followed in handling both excess pesticides and pesticide wastes.

In addition, empty pesticide containers must be disposed of properly. Empty containers that have been properly rinsed may be disposed of in a sanitary landfill if allowed by state and local laws/regulations. Some plastic containers may be recycled after they have been rinsed properly. Refillable containers, described later, may be returned to the supplier unrinsed.

Types of Pesticide Containers

There are several types of pesticide containers. A common agricultural pesticide container is the 2.5-gallon plastic jug. Many liquid agricultural pesticides also are sold in bulk containers (mini-bulks, shuttles, shuttle juniors, etc.), which are intended to be returned and reused by the supplier. Liquid, dry, and granular pesticides often are sold in various sizes of plastic containers and some granular pesticides are sold in bags. Another type of pesticide container is the pressurized can, which is commonly used for indoor pesticides.

Some containers are designed to be returned to the supplier upon emptying without rinsing. These containers commonly are referred to as "refillables." Refillable containers must not have the seal broken or the container opened. They should never be rinsed. NebGuide G2033, *Nebraska Pesticide Container and Secondary Containment Rules*, has information about rules for refillable and nonrefillable containers.

Removing Pesticide Residues from Nonrefillable Liquid Containers

Proper rinsing of nonrefillable liquid pesticide containers is easy to do, saves money, is required by state and federal regulations, and is a good, sound management practice that helps protect the environment. Even during a busy season, the few extra minutes it takes to properly rinse empty pesticide containers is time well spent. Here are some rinsing guidelines:

• Rinse the container immediately, as otherwise the remaining residue may dry and become difficult to remove. Typically, an unrinsed pesticide container is considered hazardous waste, but once rinsed, the same container usually is considered solid waste. Rinsing containers also removes a potential source of pesticide exposure to people, pets, livestock, wildlife, and the environment.

• The rinse solution (rinsate) should be added directly into the sprayer tank. This action eliminates the need to store and later dispose of the rinsate.

Proper Rinsing

Two commonly used procedures are effective for properly rinsing nonrefillable liquid pesticide containers: pressure-rinsing and triple-rinsing.

Pressure-rinsing a pesticide container.

Pressure-rinsing

Usually, pressure-rinsing is faster and easier than triple-rinsing. A special nozzle, generally available from your pesticide supplier, is attached to the end of a pressure hose and used to flush the remaining pesticide from the container. The hydrant or water source should have an anti-siphon valve or a back-flow protection device attached.

1. Remove the cap from the pesticide container. Empty pesticide into the spray tank and allow the container to drain for 30 seconds.
2. Insert the pressure-rinser nozzle by puncturing through the lower side (not the bottom) of the pesticide container.
3. Hold the pesticide container upside down over the spray tank opening so rinsate will run into the spray tank.
4. Rinse for the length of time recommended by the manufacturer (usually 30 seconds or more). Rotate the nozzle to rinse all inside surfaces.
5. Rinse caps in a bucket of water for at least one minute and pour this rinse water into the spray tank.
6. Return the container to the supplier or pesticide container recycling site or dispose of the pesticide container according to label directions. Plastic caps and containers usually are made from different materials, and often are recycled separately. For more information on pesticide container recycling sites, contact your local Extension office.

Triple-rinsing

Triple-rinsing can be done as follows:

1. Remove the cap from the pesticide container. Empty all remaining pesticide into the spray tank, allowing the container to drain for 30 seconds.
2. Fill the container 20 percent full of water or rinse solution (i.e., fertilizer solution).
3. Secure the pesticide container cap.
4. Swirl the liquid within the container to rinse all inside surfaces.
5. Remove the cap from the container. Pour the rinsate from the pesticide container to the spray tank and drain for 30 seconds or more.
6. Repeat steps 2 through 5 two more times.
7. Puncture the container so that it cannot be reused.
8. Return the container to the supplier or pesticide container recycling site or dispose of the pesticide container according to label directions. Usually, plastic caps and containers are made from different materials and typically are recycled separately. For more information on pesticide container recycling sites, contact your local Extension office.

When Rinsing Is Not Possible

In certain situations it is not possible to triple- or pressure-rinse pesticide containers. Thorough removal of the pesticide material packaged in bags or pressurized cans may be done as follows:

Bags

1. Empty contents of the bag into the spray tank.
2. Shake the bag to remove as much product as possible.
3. Cut the sides and folds to fully open the bag; add the remaining product to the tank.
4. Dispose of the empty bag in a sanitary landfill, if allowed by state and local laws/regulations. Some labels may allow alternate disposal methods.

Pressurized cans

1. Spray any remaining contents according to label instructions. Be sure to use it on the proper site and to use it at the correct rate, as listed on the label.
2. Dispose of the empty can according to label directions in a sanitary landfill if allowed by state and local laws/regulations.

Disposal of Excess Pesticide Waste

The best way to dispose of small amounts of pesticide is to apply it to a labeled site (specific plant, animal, or structure) for which the product is registered. Always double check the product label to be certain that the site is listed and that the maximum application rate will not be exceeded.

Large quantities of stored excess pesticides may be hazardous. When disposing of large quantities of such materials, contact the Nebraska Department of Environmental Quality (402-471-2186) or the Nebraska Department of Agriculture (402-471-2394) for specific disposal instructions.

The Nebraska Department of Agriculture occasionally sponsors disposal programs for excess or unwanted pesticides.

Preventing accidental poisonings and damage to the environment requires pesticides to be transported, stored, and disposed of in a safe manner. Read and follow the label carefully. It tells you how to use pesticides, provides information about special hazards, and gives proper storage and disposal methods.

Vehicle Maintenance Checklist

Cab Interior

_____ Clean cab — no food wrappers or trash
_____ Extra change of clothes
_____ Post emergency phone numbers:
911 for help involving spills, leaks, and fires
Poison Center 800-222-1222
For aid in human poisonings
NE State Patrol 800-525-5555
To report chemical spills or vehicle accidents
_____ Record of on-board pesticides
_____ Label and MSDS available
_____ First aid kit
_____ Pesticides NOT stored in cab
_____ Pesticide application equipment NOT present

On-board Pesticide Containers

_____ Lockable pesticide storage compartment
_____ Containers properly sealed and secured
_____ Legible labels on all containers
_____ Pesticides in original containers
_____ Adequate amount of pesticides for day's use
_____ Empty containers properly rinsed and positioned for removal at end of day. **Never reuse pesticide containers!**

Spill Control

_____ Absorbent materials and rags on board
_____ Shovel, broom, plastic bags on board
_____ Pesticide spill kit with chemical-resistant gloves, coveralls, goggles, absorbent material, shovel, disposal bag or container

Equipment Check

_____ Sprayers NOT pressurized
_____ Supplies in moisture-proof containers
_____ Lids fit securely on pesticide tanks
_____ Spray hoses and fittings in good condition
_____ Pressure gauges operable
_____ All application equipment cleaned
_____ Water containers labeled

Personal Protective Equipment

_____ Goggles or other eye protection
_____ Chemical-resistant gloves
_____ Boots, apron, hat — if required by label
_____ Respirator — stored in sealed plastic bag
_____ Other — as directed by the label

Tires

_____ Proper pressure
_____ Tread wear acceptable
_____ No cuts or cracks
_____ Spare tire inflated properly

Lights

_____ High beam headlights
_____ Low beam headlights
_____ Turn signals
_____ Running lights
_____ Emergency flashers
_____ Tail lights
_____ Brake lights
_____ Backup lights

Wipers

_____ Wiper blades in good condition
_____ Washer fluid dispenser filled
_____ Washer fluid pump in working order

General Vehicle Maintenance

_____ Horn in good working order
_____ Seat belts in good working order
_____ Brakes in good working order
_____ Windshield free of obstructions
_____ Truck bed free of debris

Vehicle ID ________________________________ Notes________________________________

Inspected by ________________________________ ________________________________

Date ________________________________ ________________________________

Adapted from Pesticides and Commercial Vehicle Maintenance, Purdue University.

Pesticide Storage Checklist

Safety is the key in proper pesticide storage. If you answer "no" to any of the statements below, you should correct your storage facility immediately.

Enter date of each inspection: ____________ ____________ ____________

	Yes	No	Yes	No	Yes	No
General Information						
Clean, neat pesticide storage site	____	____	____	____	____	____
Current, on-site pesticide inventory	____	____	____	____	____	____
Emergency phone numbers posted	____	____	____	____	____	____
Labels and MSDS available	____	____	____	____	____	____
Accurate storage inspection log maintained	____	____	____	____	____	____
Pesticide Containers						
Containers marked with purchase date	____	____	____	____	____	____
Insecticides, herbicides, and fungicides segregated	____	____	____	____	____	____
Pesticides stored in original containers	____	____	____	____	____	____
Dry formulations stored on pallets	____	____	____	____	____	____
Feeds stored separately from pesticides	____	____	____	____	____	____
Used containers rinsed and drained	____	____	____	____	____	____
Rinsed and unrinsed containers separated	____	____	____	____	____	____
Liquid formulations stored below dry formulations	____	____	____	____	____	____
Spills and Disposal						
Storage area free of spills or leaks	____	____	____	____	____	____
Shovel and absorbent materials available	____	____	____	____	____	____
Sealed floors	____	____	____	____	____	____
Floor drains closed off (if present)	____	____	____	____	____	____
Safety Information						
No smoking signs posted	____	____	____	____	____	____
Personal protective equipment available	____	____	____	____	____	____
Fire extinguisher in good working order	____	____	____	____	____	____
Storage room locked, limited access to keys	____	____	____	____	____	____
Storage room posted: **Pesticides — Keep Out!**	____	____	____	____	____	____
Storage site well lit and ventilated	____	____	____	____	____	____

Adapted from Pesticides and Commercial Vehicle Maintenance, Purdue University.

Understanding Fungicide Resistance

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Introduction

Fungicide resistance has developed in some diseases of row crops as well as specialty crops. This implies that fungicide applications to control such diseases may no longer be effective. Scientific studies have shown that fungicide resistance develops through natural selection of a mutant strain of a pathogen in a population that is resistant to fungicides. Resistance is very difficult to eliminate but can be delayed through appropriate management practices. The availability of inexpensive options with single mode of action products being available makes this an important issue so we do not repeat what was done in weed management.

The organization known as the Fungicide Resistance Action Committee (FRAC) was established by industry and research scientists to be an overseeing group to monitor fungicide resistance and provide guidelines for development of products with long term utility. This committee established the FRAC code which identifies different target sites within specific modes of action for all active ingredients. Usually, there is a small rectangular box on every fungicide label where the FRAC number is located (Table 1). When the FRAC code shows only one number, it implies that the fungicide contains a single active ingredient but if a fungicide contains two active ingredients, two numbers will be shown. For example, a FRAC code shown as 'group 7' indicates that the fungicide is a succinate dehydrogenase inhibitor (SDHI) whereas group 11 are Quinone outside inhibitors (QoI which includes strobilurins). However, if both 7 and 11 appear in the label, it means the fungicide has active ingredients belonging to the two groups. Some specific examples of fungicide resistance that have been seen in different crops and are discussed below. If a fungus is resistant to a specific fungicide active ingredient within a FRAC Code, then it will most likely be resistant to all fungicides with the other active ingredients in the same FRAC Code.

Frogeye Leaf Spot of Soybean

Frogeye leaf spot caused by the fungus *Cercospora sojina* is becoming a common foliar fungal disease in Nebraska. The disease is most severe when soybean is grown continuously in the same field, particularly in fields where tillage is reduced, since this is a residue-borne disease. The primary source for this disease is infested residue, infected seed and airborne spores.

In 2010, resistance to strobilurin fungicide (QoI) was reported for the first time to this pathogen in Tennessee. Since this time there has been significant spread in the Mississippi valley but we have not observed this in Nebraska yet. Current distribution of confirmed resistant populations are located on the IPM PIPE website (http://frogeye.ipmpipe.org/cgi-bin/sbr/public.cgi). Resistance to QoI fungicides in *C. sojina* is a result of a single site mutation. This mutation is not known to have any fitness cost and has resulted in it being held in the population once it occurs.

General Management of Frogeye Leaf Spot

Resistance

Soybean varieties vary in their resistance to Frogeye Leaf Spot and there are several genes commonly used for resistance. This will reduce inoculum and exposure to fungicide for selection of resistance.

Cultural Practices

Frogeye Leaf Spot is more severe in continuously cropped soybean fields. Reduced tillage systems will tend to have more as the pathogen overwinters in residue. This will reduce inoculum levels and exposure to fungicide for selection of resistance.

Fungicide Application

Application of fungicides to manage frogeye leaf spot in Nebraska is typically not warranted in most fields. Fields with a history of frogeye should be watched carefully and if disease develops application of a strobilurin fungicide at the R3 (pod set) – early R4 growth stage are considered the most effective. Avoid applying products when disease development is significantly developed.

Gray Leaf Spot of Corn

The disease, gray leaf spot of corn, is a common fungal disease in much of Nebraska. The causal agent, *Cecospora zeae-maydis* (Czm), is closely related to the fungus causing frogeye leaf spot of soybean, being in the same genus, *Cercospora sojina*, albeit a different species. These pathogens have many biological characteristics in common, such as survival in infested plant debris from the previous season(s) and have similar weather conditions that are favorable for disease development, namely warm temperatures and high relative humidity. Whereas fungicide resistance to strobilurin fungicides (QoI fungicides) has been well-documented in the soybean frogeye leaf spot pathogen in other parts of the U.S., there have not been confirmed reports of fungicide resistance for the gray leaf spot pathogen of corn in the field. But, fungicide resistance has been documented in the laboratory in vitro tests where the fungus can utilize alternative respiration pathways to overcome the effects of the fungicides allowing for spore (conidia) germination. Baseline QoI fungicide sensitivities were identified for the gray leaf spot fungus collected from several states (including Nebraska). The results of these experiments indicated that resistance is possible in naturally-occurring populations, but that it may be less likely than in other closely related species. However, frequent applications of QoI fungicides over a large area of corn increases the probability that fungicide resistance may develop. Populations of the fungus should continue to be monitored over time to assess for a reduction in fungicide sensitivity.

Management of Gray Leaf Spot

Hybrid resistance

Corn hybrids vary widely in their resistance to gray leaf spot, which reduces the size and number of lesions. Disease immunity does not exist and highly resistant hybrids may still develop some lesions. Consult ratings provided by seed companies to help predict how the hybrid will react to gray leaf spot and position more resistant hybrids in fields with a history of severe disease and other high risk factors, such as continuous corn and minimum tillage.

Cultural practices

Residue management with tillage may provide some benefits for disease reduction, but is not practical for all production systems or locations. Tillage buries infested crop debris promoting degradation and reduces overwintering inoculum of the fungus causing disease. Crop rotation to nonhost crops can provide similar benefits, although neither strategy eliminates the risk of some disease, especially during seasons with very favorable weather conditions.

Fungicides

Foliar fungicides can be very effective at managing gray leaf spot when applied at optimal times. Applications of fungicides are most effective when applied before severe disease development and can be economical, especially in high-yielding, susceptible hybrids. Minimizing the disease in the upper plant canopy during grain fill reduces its impact on yield.

Integrated management

Deploying a combination of management strategies is more likely to provide satisfactory results. Planting more resistant hybrids in high risk production systems and monitoring disease development and progression up the plants in susceptible hybrids to make fungicide application decisions can more effectively manage gray leaf spot.

Fusarium Head Blight of Wheat

Fusarium head blight (FHB), also known as scab, is a destructive disease of wheat. In North America, it is caused primarily by *Fusarium graminearum*. The disease causes premature bleaching of spikelets, causing sterility or production of discolored, shriveled kernels commonly referred to as Fusarium-damaged or “tombstone” kernels. In addition, *F. graminearum* produces trichothecene mycotoxins, mainly deoxynivalenol (DON) and nivalenol, which contaminate grain and are harmful to humans and animals. FHB epidemics occur sporadically in Nebraska due to a variable climate. The disease tends to occur during years with high rainfall before and during flowering. The most recent major epidemics occurred in 2007, 2008, and 2015.

FHB is controlled by applying a triazole fungicide to the heads during the flowering growth stage. Triazoles used for FHB control include tebuconazole, prothioconazole, and metconazole. In 2011, the first isolate of *F. graminearum* resistant to tebuconazole was collected from a wheat spike during a survey in Steuben County, New York. It is the first tebuconazole-resistant field isolate of *F. graminearum* reported in the Americas. *F. graminearum* resistance to triazole fungicides has not been documented in Nebraska. However, the discovery of a tebuconazole-resistant isolate in New York indicates that the potential exists for resistance to develop in Nebraska isolates.

Management of FHB

Cultivar Selection

The majority of wheat cultivars grown in Nebraska have little or no resistance to FHB. Breeding efforts in recent years have yielded several cultivars in the central Great Plains States with moderate resistance to FHB. They include Overland, Everest, and Lyman. Because *F. graminearum* infects wheat heads mostly during flowering, planting cultivars with different flowering dates increases the probability that some can escape infections.

Cultural practices

Because FHB epidemics are initiated by inoculum produced on crop residues, reducing residue can reduce inoculum potential. In Nebraska, a practical cultural management practice that can reduce residue-borne inoculum is rotation with non-host crops such as soybean and alfalfa. Irrigation management to allow the crop canopy to dry between irrigations can reduce disease severity.

Fungicides

The two most effective fungicides in controlling FHB are Prosaro (prothioconazole + tebuconazole) and Caramba (metconazole). Fungicide application should be timed to protect the head. Optimal timing is at approximately 15% flowering (Feekes 10.51). Thorough coverage of heads is essential for maximum control.

Biological control

Certain bacteria and fungi have been identified that are antagonistic to *F. graminearum*, but their efficacy in the field has been poor and commercial formulations are not available. Significant progress has been made in Canada where the fungus *Clonostachys rosea* has been formulated to a product that is effective in reducing production of perithecia (sexual fruiting structures) on crop residues by *Gibberella zeae* (sexual stage of *F. graminearum*) and in suppressing FHB in the field.

Integrated Management

Because of the lack of highly resistant or tolerant cultivars, integrating available FHB management strategies is the best approach to managing the disease. Use of moderately resistant cultivars with different flowering dates, residue management, crop rotation, irrigation management, and judicial use of fungicides should all be integrated into an FHB management program.

Ascochyta Blight of Chickpea

Ascochyta blight, caused by the fungal pathogen, *Ascochyta rabiei*, is the most serious and damaging disease of chickpeas worldwide. It attacks all aerial parts of the chickpea plant, and is considered to be the primary constraint to successful chickpea production wherever the crop is grown. The pathogen can survive in both crop residue and infected seeds, which also represents the major source of spread and dissemination.

Resistance to strobilurin fungicides by *A. rabiei* was first noted from North Dakota and Montana in 2005 and 2007, respectively. In 2010, fields in South Dakota and Nebraska exhibited limited disease management after being treated with pyraclostrobin (Headline). Isolates from these locations were confirmed to contain a gene mutation which has been previously correlated with resistance to QoI fungicides in other fungal pathogens.

Management of Ascochyta Blight

Resistance

Until recently, only moderately resistant cultivars have been available, but none were completely resistant, requiring additional integrated techniques for better control. A new regionally adapted, resistant cultivar has been developed, but is currently being increased and will not be available for commercial use for another several years.

Cultural

Due to the seed- and residue-borne nature of the pathogen, burial of residue and seeds from harvest losses from infected crops and rotating out of chickpeas will help reduce pathogen populations.

Chemical

Seed treatments will help to suppress early infection and improve stand establishment, but will not provide season-long protection. Fungicide applications can also be used to reduce losses, but due to the known presence of resistant pathogen populations in Nebraska, care must be taken to select the proper chemicals for use. Although resistance in Nebraska has only been identified to pyraclostrobin, the use of azoxystrobin (Quadris) should also be discontinued. Resistance also to azoxystrobin is unproven, but still highly probable.

Optimal Ascochyta blight management in chickpeas in the future will most likely consist of an integrated approach utilizing crop rotation, genetic resistance, and fungicidal seed treatments and foliar applications with varying modes of action other than the strobilurin fungicides.

Risk Factors for Development of Fungicide Resistance

- Repeated applications during a single or across multiple growing seasons
- Use of products with active ingredients with only one FRAC code.
- Applications made after disease symptom development
- Application of reduced rates of fungicides
- Certain fungicide classes and some fungal pathogens have been identified by FRAC as being at greater risk

Management Recommendations

While fungicide resistance cannot be eliminated, it can be managed to reduce the potential for development. New fungicide groups are not easily identified and currently there are only 3 main FRAC codes used in our main crop production systems. Therefore it is critical that we take steps to prolong the usefulness of the current products.

The following recommendations should be considered when using a fungicide:

- Fungicides should be applied when disease development is at a low level of severity to avoid high numbers of the pathogens spores being exposed (selected) to the fungicide.
- Use fungicides containing more than one FRAC code.
- When using single mode of action fungicides - Tank-mix more than one fungicide with a different FRAC code.
- Use labelled rates and avoid using reduced rates. Know the risk factors associated with reduced rates for specific FRAC codes (i.e. - reduced rates of triazole fungicides increase the risk of resistance).
- Evaluate the level of disease control after an application is made. If you suspect you are having reduced control resistance may be occurring. Contact your local University of Nebraska Extension employee if you believe fungicide resistance may be an issue in your field. It will be important to report this quickly so that the selection pressure is not continued in the region.

Additional Resources

Additional information on identification of common field crop diseases can be found at: http://cropwatch.unl.edu/plantdisease

Giesler, L., Bradley, C., Chilvers, M., Freije, A., Mueller, D., Sisson, A., Smith, D., Tenuta, A., and Wise, K. 2016. Frequently asked questions about fungicide resistance in field crop diseases. Website: Crop Protection Network. CPN 4001. http://cropprotectionnetwork.org/general-crop-management/faqs-about-fungicide-resistance/
Bradley, C. A., Hollier, C., and Kelly, H. Principles of Fungicide Resistance. Plant Management Network. https://www.plantmanagementnetwork.org/hub/soyfungicideresistance/files/FungicideResistance.pdf

Bradley, C. A., and Pedersen, D. K. 2011. Baseline sensitivity of *Cercospora zeae-maydis* to quinone outside inhibitor fungicides. Plant Disease 95:189-194.

Table 1. Example of Fungicide Resistance Action Committee (FRAC) fungicide classification for azoxystrobin and propiconazole.

Fungicide active ingredient	FRAC Code	Group Name	Chemical group	Mode of Action
azoxystrobin	11	Quinone outside inhibitor (QoI)	Methoxy-acrylates (strobilurin)*	Respiration inhibitor
propiconazole	3	Demethylation inhibitor (DMI)	Triazole	Sterol biosynthesis in membranes

*Fungicides in this group are commonly referred to as strobilurins, however these active ingredients are no longer specified as strobilurins by FRAC. (Originally developed in Giesler et al., 2016)).

What's New in Plant Pathology

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Changes to the Disease Management Section of the 2017 Guide for Weed, Disease, and Insect Management in Nebraska

The Disease Management Section of the 2017 Guide for Weed, Disease, and Insect Management in Nebraska underwent several formatting changes this year to increase the usability for growers. Products are now listed alphabetically within their mode of action, and modes of action are listed numerically. A column was added to the product information charts to indicate the formulation of each product. Numerous seed treatment products contain an insecticide component, and these active ingredients are now italicized to distinguish these active ingredients from fungicidal active ingredients. Several products were also added to individual charts, summarized in Tables 1, 2 and 3. Additionally, Fortix is now listed as Fortix / Preemptor to reflect the offerings of both Arysta and FMC.

Changes were also made to emphasize the importance of resistance management. The "Mixed Modes of Action" label for chemical class is now subdivided into the specific combinations of modes of action. This change was made to aid in the selection of fungicide products with unique modes of action. A majority of commercially-available foliar fungicides are Group 3 (triazoles) or Group 11 (strobilurins), so it is important to know what modes of action are included in combination products to be able to rotate classes. For example, using two products sequentially that are both premixes of Group 3 and 11 fungicides may not be an adequate rotation if there is already concern of resistance to group 11 fungicides.

Bacterial Leaf Streak of Corn – An Emerging Disease in Nebraska and First Report in the United States

Bacterial leaf streak of corn, which was previously only been reported on corn in South Africa, was confirmed in 50 counties in Nebraska during 2016. The causal agent, *Xanthomonas vasicola*, is known to infect dent (field) corn, popcorn, seed corn, and sweet corn. Symptoms appear on the leaves, and include yellow, orange, or light to dark brown striped lesions, usually with wavy margins. The disease has been observed as early as the beginning of June and in seven-leaf (V7) corn. The pathogen is believed to survive for years in infested residue, which becomes a source of inoculum the next time corn is planted in the field. Management strategies include tillage, which accelerates the degradation of the residue by burying it, and crop rotation to a non-host species, although neither of these strategies will eliminate the disease. More information will be presented in the Corn Disease Update during the afternoon session.

Pest and Plant Diagnostic Clinic Position Change

At the end of September in 2016 the Extension Educator in charge of the Plant & Pest Diagnostic Clinic at UNL left his position to pursue other professional interests. We are in the process of filling the position at the time of this article's submission and hope to have the position filled prior to the beginning of the 2017 season. This is a critical position for our extension plant pathology team at UNL.

New Products

Ethos XB™ [*Bacillus amyloliquefaciens* strain D747 + bifenthrin insecticide].

A biofungicide that builds on FMC's in-furrow insect control product and provides additional seedling disease suppression for early season damping-off and seedling blights caused by *Pythium*, *Rhizoctonia*, *Fusarium*, and *Phytophthora*. Product contains 1.5 lb per gallon of bifenthrin plus *B. amyloliquefaciens* at 1×10^{10} cfu per milliliter. Use rate is 3.4-17.0 oz per acre (0.2-0.98 oz/1000 ft of row) for pests other than corn rootworm. For corn rootworm, the rate is 6.8-17 oz / acre (0.39 oz -0.98 oz/1000 ft of row). FMC Corporation EPA Reg No. 279-3473.

Majestene™ [*Burkholderia* sp strain A396 heat-killed cells].

A bionematicide with application rate of 1-2 gallon per acre. Crops include alfalfa, apples, corn, potatoes, soybean, tomatoes, and wheat. Product can be used in-furrow, foliar applied or in chemigation. It is listed by the Organic Materials Review Institute (OMRI). Marrone Bio Innovations, Inc. EPA Reg No. 84059-14.

Table 1. Foliar products for disease control that were updated in the 2017 Guide for Weed, Disease, and Insect Management in Nebraska.

Trade Name	Active Ingredient(s)	Fungicide Class	Change(s) Made
Affiance	Azoxystrobin (9.35%) + Tetraconazole (7.48%)	Mixed Modes of Action (Groups 3 + 11)	Added to Corn and Soybean tables
Priaxor D	Fluxapyroxad (14.33%) + Pyraclostrobin (28.58%) + Tetraconazole (20.5%)	Mixed Modes of Action (Groups 3 + 7 + 11)	Added to Soybean table
Quadris Top SBX	Azoxystrobin (19.8%) + Difenconazole (19.8%)	Mixed Modes of Action (Groups 3 + 11)	Added to Soybean table
SuperTin 80WP	Triphenyltin hydroxide (80%)	Organo Tin Compounds (Group 30)	Added to Sugar beet table
Topsin XTR2	Tebuconazole (7.5%) + Thiophanate-methyl (37.5%)	Mixed Modes of Action (Groups 1 + 3)	Added to Soybean table
Trivapro Co-Pack	Azoxystrobin (13.5%) + Benzovindiflupyr (10.27%) + Propiconazole (11.7%)	Mixed Modes of Action (Groups 3 + 11)	Added to Corn and Soybean tables
Vertisan	Penthiopyrad 20.6%	SDHI Carboximides (Group 7)	Added to Soybean table
Zolera FX	Fluoxastrobin (17.76%) + Tetraconazole (17.76%)	Mixed Modes of Action (Groups 3 + 11)	Added to Soybean table

Table 2. Seed treatment products for disease control that were updated in the 2017 Guide for Weed, Disease, and Insect Management in Nebraska.

Trade Name	Active Ingredient(s)	Fungicide Class	Change(s) Made
UpShot Soybean Seed Treatment	Fludioxonil (1.15%) Mefenoxam (3.46%) *Thiamethoxam (23.1%) (I)*	Mixed Modes of Action (Groups 4 + 12) (Group *4A Insecticide*)	Added to Soybean table

Table 3. Biological products that were updated in the 2017 Guide for Weed, Disease, and Insect Management in Nebraska.

Trade Name	Active Ingredient(s)	Function	Registered Crops
Ethos XB Biofungicide	*Bacillus amyloliquefaciens* strain D747 + bifenthrin insecticide	Biofungicide	Corn
Majestene	*Burkholderia* sp. strain A396 heat-killed cells	Bionematicide	Alfalfa, apples, corn, potatoes, soybean, tomatoes, and wheat

Specialty Crops Update

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Introduction

This report will summarize some of the major and unusual disease/pest occurrences encountered during 2016 for sugar beets, dry beans, sunflowers, field peas, chickpeas, and fenugreek. Overall, environmental conditions in western Nebraska in 2016 were similar to 2015. Spring and early summer were characterized by high levels of rainfall and generally cooler temperatures than normal.

These climatic conditions had major effects on the development of several plant production problems experienced during the season. For example, the cooler conditions slowed crop development in several crops, such as beans and sunflowers in a manner similar to that in 2015. Additionally, a number of scattered severe hailstorms caused mechanical damage to crops accompanied with varying levels of disease due to several bacterial pathogens in dry beans and peas in many locations.

Sugar Beets

Root Rots

Root rot diseases in 2016 were overall not as severe as recent years. However, due to the higher rainfall levels, Aphanomyces root rot was seen later in the year and at harvest. The dry rot canker variant of Rhizoctonia root rot was not identified in 2016, however it has been found occurring widely across Scotts bluff and Morrill counties in three of the last six years. This is a rarely occurring root rot that is caused by a different species of Rhizoctonia than the "typical" pathogen, R. solani, which causes the more familiar Rhizoctonia root and crown rot. Little is known about the dry rot pathogen due to its seldom-seen status. We have conducted some preliminary studies over the last two years comparing their response to Rhizoctonia root rot resistance and fungicides. We have shown that this pathogen responds to these management techniques in a similar manner as R. solani.

Foliar Diseases

Cercospora leaf spot (CLS) was about average this year, being sporadically found region-wide. It did appear in isolated areas later into September with the additional moisture with the occurrence of several rain events. The most severe damage is generally observed with the disease, occurs when night temperatures (midnight to 7 AM) exceed 70 F. However, high humidity or long periods of leaf wetness are also required.

Insect Pest

One very unusual pest problem was identified in Box Butte County. Severe stunting and masses of secondary rootlets on affected plants were observed occurring in patches in a field north of Alliance. Small pin-prick necrotic spots were also found on sugar beet roots. It was determined to be caused by symphylans, soil dwelling arthropods that can cause damage by feeding on seeds, roots and root hairs.

Dry Beans

Dry beans in 2015 were strongly affected by all of the bacterial blights due to the high levels of rainfall and several severe hail events. All four pathogens (halo and common blight, wilt and brown spot were detected), but brown spot appeared to be the predominant disease overall. The cooler weather further resulted in widespread, white mold epidemics problems. Rust showed late in some areas but did not affect yields, as often is the case.

Sunflowers

The primary disease problems in sunflowers in 2016 were due to rust and Phomopsis stem rot, due to the cooler wet weather, very similar to 2015. Both diseases appeared later in 2016 than 2015, but were still very commonly observed across the region. We continued to conduct fungicide application studies on both rust and Phomopsis stalk rot and were able to successfully produce measurable levels of disease.

Rhizopus head rot also appeared late in many fields due to the hail storms. Rhizopus head rot is a disease we see commonly after heads experience some form of mechanical damage, including hail storms, or insect feeding. We are currently seeking funding to begin addressing this disease in 2017 in Nebraska, North Dakota and South Dakota. Lastly, these cool wet conditions also allowed Sclerotinia (white mold) to cause some problems as both a vascular wilt and stem rot, and a head rot.

Another presumed virus-like pathogen of unknown identity was discovered from multiple locations in Scottsbluff County. It does not appear to be the same as one we found several years ago. It is not known at this point how serious a problem this will become, but right now is more of an oddity than a problem.

Chickpeas

Ascochyta blight was a persistent problem in 2016, as a result of the weather. The conditions required for this disease are similar to that of CLS for sugar beet – warm, but not hot with high humidity levels. Disease was severe throughout the season, particularly on disease susceptible breeding lines and varieties. We continued to conduct fungicide and variety trials for determining the best management options for the disease in the event that this crop will eventually expand in acreage. In fact our work with bean breeder, Carlos Urrea has resulted in the anticipated release of a new resistant cultivar in 2017.

Other New Crops

Fenugreek

Fenugreek is a new alternative crop that is being tested for production potential in western Nebraska. It is a legume whose seeds are utilized as a spice in various curries in Asia. The crop also has additional benefits that could potentially be used in human medicine or as source of gluten-free food products. Several root diseases were observed again in 2016 including those caused by Fusarium spp. and Rhizoctonia. Few other serious potential disease issues have been noted as yet.

Dry Field Peas

A continued large increase in yellow field peas was seen across the region in 2016. A bacterial complex was observed statewide after the second year of a comprehensive survey was conducted. This complex consists of several pathogens, yet to be completely determined. However we have detected several different variants of the fluorescent bacterium, Pseudomonas syringae. One of these is specific to pea and the other also causes brown spot of dry beans. It is also similar to those Pseudomonas pathogens infecting corn, sugar beets, and sunflowers.

We have also identified numerous isolates of *Xanthomonas* and a non-fluorescent *Pseudomonas* sp. At this point we do not know whether they are involved with disease or just saprophytic on the blight-infected tissues. White mold and several root rots were also observed in several fields. The presence of these diseases can be readily explained by our cool wet weather early in the season.

Chicory

An interest in the production of chicory has additionally been on the increase in 2016. As we found 10-15 years ago, the crop is relatively disease-free in most locations. One root disease that has been consistently seen in every field, but at low levels is a bacterial root rot. At this point we are working to establish its identity and are testing isolates obtained from rotted roots in the field for pathogenicity. Full identification of the pathogen is in progress, but at the present it appears to be another *Pseudomonas* species.

Corn Disease Update

Tamra A. Jackson-Ziems, Extension Plant Pathologist
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Introduction

Several diseases were important in the 2016 Nebraska corn crop and impacted yield in some areas. Many of these diseases developed as a result of extreme weather events that were favorable for disease development. Most of those diseases are caused by pathogens that are capable of survival in the crop debris or residue and so they are more likely to develop again in future years if environmental conditions are favorable again. This article will summarize some of Nebraska's most important corn disease problems in 2016, tips for diagnosis and management strategies.

Bacterial Leaf Streak

Bacterial leaf streak of corn, caused by *Xanthomonas vasicola*, was confirmed in 50 counties in Nebraska in 2016. A survey funded by the Nebraska Corn Board was conducted to investigate the distribution of the disease and to gather information about agricultural practices that may contribute to disease development. Results of the survey showed that this disease was prevalent across much of Nebraska with the exception of the Panhandle and the extreme eastern parts of the state. It was also confirmed in Colorado, Kansas, Iowa, Illinois, and Texas in 2016. Bacterial leaf streak was confirmed in dent (field) corn, popcorn, seed corn, and sweet corn. The pathogen was previously reported on corn in South Africa, but has never been reported in the United States until now.

Symptoms of bacterial leaf streak appeared on the leaves, and included yellow, orange or dark to light brown stripes with wavy margins. Lesions may be concentrated around the midrib or across the leaf blade, and often appeared yellow when backlit. Symptoms were observed on the lower leaves as early as the beginning of June in Nebraska on V7 corn and moved up the plant as the infection progressed; however, there have been cases where symptoms first appeared in the mid-canopy or upper leaves in July reportedly after severe storms. Because of this behavior, and the similarity of the lesions to the fungal disease gray leaf spot, the two diseases are often mistaken for each other. There are a few differences to look for when attempting to distinguish between these two diseases: first, consider the time of year that the symptoms began to develop. If the symptoms first developed in June, it is likely bacterial leaf streak, since gray leaf spot usually doesn't develop until later. Also, lesions caused by bacterial leaf streak will typically have a wavy margin, whereas gray leaf spot lesions will typically be a perfect rectangular shape with smooth, linear margins. While these considerations can be useful, neither will provide a correct diagnosis every time, and it can be especially confusing when both diseases are present on the same leaf. When making management decisions it is important to make a correct diagnosis, as fungicides used to treat gray leaf spot are not expected to be effective against bacterial leaf streak.

Xanthomonas vasicola is thought to overwinter in infested crop residue from the previous year, where it can survive until the next growing season. It can then infect the next year's crop when environmental conditions become favorable for its growth. This bacterium does not appear to require wounds to establish an infection, as it is believed to infect the plant through natural openings, such as the stomata. Center pivot irrigation and wind driven rain may increase the severity of infection.

Crop rotation may help to reduce disease the following years, however disease development has been observed in corn after one-year rotations to soybeans, wheat, and after fallow. Tillage may also reduce infection by burying the infected residue and promoting degradation, but it will not completely eliminate disease and is not practical in all areas or production systems. Using good sanitation practices, such as cleaning equipment when moving from infested fields to non-infested fields, may help slow the spread of the disease.

Gray Leaf Spot

Gray leaf spot development was somewhat delayed in 2016 compared to other years. This delay in disease development may have contributed to misdiagnoses of bacterial leaf streak (which often developed early) as gray leaf spot. However, the disease quickly became very important late season across in corn across much of the state as it increased rapidly during favorable weather conditions. Gray leaf spot is caused by a fungus (*Cercospora zeae-maydis*) that survives in infested plant debris from the previous seasons. It consistently develops on the lower leaves and continues to move higher on the plant as long as weather conditions remain favorable. This disease is favored especially by temperatures of 70-90°F and periods of 12 or more hours of very high relative humidity in the canopy (>90%). Gray leaf spot lesions begin as yellow flecks that expand to form rectangular gray to tan lesions between leaf veins. Severity of symptoms is evaluated by the amount of leaf area covered by lesions and how high on the plant they have reached. Lesions may take as little as 14 days to develop in susceptible hybrids and up to 28 days to develop in more tolerant hybrids. Keep in mind that conditions are often more favorable later in the season for gray leaf spot, after tasseling when the disease tends to increase in severity more quickly. Late season in 2016, gray leaf spot became very severe in some areas.

Some high risk factors include:

- History of severe gray leaf spot
- Sensitive hybrid with poor ratings for gray leaf spot
- Continuous corn
- Minimum tillage that maintains more corn residue on the soil surface
- Warm conditions with high relative humidity

Gray leaf spot has also been the predominant disease in fungicide trials conducted at the UNL South Central Agricultural Laboratory during recent years. When they were needed, applications made at tasseling and soon thereafter have most consistently provided yield returns under significant disease pressure. In addition, fungicide applications made at tasseling or soon thereafter also often provided improvements in standability (as measured in push tests) compared to the non-treated control treatments during several trial years. Results from these trials can be viewed on the Crop Watch website under Plant Disease Management Trials for Corn.

For more information on GLS and fungicide application timing, see the article, "Fungicide Application Timing and Disease Control" in the 2016 Crop Production Clinics Proceedings.

Southern Rust

Southern rust was quite widespread and severe in the southern United States in 2016 and confirmed as early as July in Nebraska. Eventually, southern rust was confirmed in many counties across the state. In some areas, it became very severe, especially in southern counties in Nebraska. Some of the worst affected fields were those that were delayed in planting due to heavy rains during the spring and delayed corn maturity.

Warm temperatures and high humidity are enough to promote development and spread of the disease. Rust diseases produce large amounts of spores quickly that can be easily moved by wind for long distances. The fungus can quickly cause disease during favorable conditions and because many commercial dent corn hybrids have little to no resistance to the disease. Having a history of southern rust in corn does not have any impact on disease development now, because this pathogen does NOT overwinter in infected residue. The spores must be carried into the area from other locations by winds from diseased areas. It is important to remember that it can take anywhere from a few days to several weeks for widespread and severe southern rust to develop if it is going to do so. For that reason, we recommend scouting fields frequently especially those at higher risk, such as later planted fields and after alerts have been issued for southern rust development in nearby fields and counties.

Stalk Rot Diseases

Much of the 2016 Nebraska corn crop experienced repeated and prolonged stress (and sometimes wounding) during the growing season. Stress during any part of the season can promote stalk rot and lodging at the end of the season as harvest approaches. Some fields experienced marked lodging, crown rot, top dieback, and stalk rot during the 2016 season due to numerous crop stress events.
Some high risk factors for stalk rot diseases and lodging are:

- Higher yielding hybrids
- Thin stalks
- Lost leaf area (due to leaf diseases, hail, etc.)
- Excessive rainfall/ponding
- Drought conditions
- Stalk wounding, usually by hail
- High planting populations

Scouting for Stalk Rot Diseases

The first indication of a problem is often the early, and sometimes rapid, discoloration of the corn plant turning from green to brown or gray. Individual plants may be affected or patches of several plants. Affected plants often have stalks that are hollow and easily crushed by hand or bent using the "push or pinch" test. Stalk rots can occur at any place in the stalk from the crown at/below the soil line to the tassel. Rotting that occurs at an upper node and kills only the upper plant parts is referred to as "top rot" or top dieback and does not necessarily cause lodging of the whole plant. However, top dieback predisposes plants to lower stalk rot and loss of the upper leaves can lead to yield loss if it develops early enough. Degradation of the stalk below the ear can lead to plant lodging and losses during harvest.

Assessing stalk rot diseases and standability

Walking through a field, randomly select a minimum of 100 plants representing a large portion of the field. To test for stalk rot you may choose to PUSH the plant tops away from you approximately 30° from vertical. If plants don't snap back to vertical, then the stalk integrity may have been compromised by stalk rot. An alternative method is to use the PINCH test to evaluate plants for stalk rots. Pinch or squeeze the plants at one of the lowest internodes above the brace roots. If the stalks crush easily by hand, then their integrity is reduced by stalk rot and they are prone to lodging. If more than 10% of plants exhibit stalk rot symptoms, then harvesting that field should be a priority over others at less risk in order to reduce the chance of plant lodging and the potential for yield loss.

There are several fungi that are common in our production fields and can opportunistically cause stalk rot diseases in stressed plants. Some of the most common stalk rot diseases in 2016 were Fusarium stalk rot, Anthracnose stalk rot, and sometimes charcoal rot.

Management

There is nothing that can be done late in the season to stop stalk rots as affected stalks will continue to degrade over time further weakening them. But, you can work to minimize your losses by identifying which fields have the worst stalk rot diseases and adjust the harvest order of those fields. Consider harvesting or chopping those fields that are heavily impacted by stalk rots first or earlier to minimize losses that can occur after lodging. Any stresses that can be avoided during the growing season may help reduce the incidence of stalk rot diseases.

Ear Rot Diseases

Several ear rot diseases were confirmed in corn late in 2016, as well. Many of those diseases developed in corn that was injured by insect feeding, such as by western bean cutworm. Unfortunately, these fungi can continue to grow in bins during storage. Cold temperatures and low moisture can slow growth of grain mold fungi. Grain affected by ear rot fungi may need to be handled differently if it to be stored, especially for an extended time period. Maintaining moisture <15% and running bin fans to maintain uniform temperature and moisture conditions will slow fungal growth.

Ear rot diseases may cause both yield loss and reduction in grain quality. Ear rot diseases are caused by several species of fungi that can also continue to grow in grain after harvest during storage causing further quality loss. In addition, some fungi may produce secondary mycotoxins that can be harmful at higher concentrations to livestock and other consumers. Ear rot diseases and mycotoxins occur to some extent every year, usually at safe levels. Knowing which ear rot pathogens are present can help to predict which, if any, mycotoxins may be present and can be measured in grain samples by certified labs.

Fusarium Ear Rot

Fusarium ear rot is a common disease in corn. Fusarium may infect any part of the ear and take advantage of wounds created by insects or hail. The species that cause this disease can also produce mycotoxins in the grain called fumonisins. Fusarium ear rot is favored by a wide range of environmental conditions and can be recognized by its scattered tufts of mold on the ears that may be white to pink in color and may be accompanied by starburst patterns on the kernels.

Diplodia Ear Rot

Diplodia (also called Stenocarpella) ear rot is a common disease in the Corn Belt. The fungus that causes this disease does not usually produce a mycotoxin in the United States, but can significantly reduce grain quality. Extensive fungal growth usually begins at the base of the ear and can overtake the entire ear creating a lightweight mummified ear. In addition to these symptoms, this disease can be recognized by the production of small raised, black fungal reproductive structures on infected kernels and stalks giving it a rough feeling when touched, similar to sandpaper.

Penicillium Ear Rot

The fungus causing Penicillium ear rot can produce green to blue-green spores where it infects, especially on wounded kernels, such as on ear tips. This disease is particularly a storage problem and is favored by high moisture levels in grain bins. Management of the disease is by reducing wounding of ears in the field by insects and maintaining low moisture while the grain is in storage. Because of their similarities in appearance, it may be misdiagnosed as Aspergillus ear rot.

Aspergillus Ear Rot

Aflatoxin is the best-known mycotoxin and is produced by the fungus that causes Aspergillus ear rot. There were no reports of alfatoxin in corn in Nebraska this year nor the Aspergillus ear rot disease. Hot, dry weather during the latter half of the growing season after pollination especially favors aflatoxin production. Drought-stressed corn, such as that in non-irrigated fields and the corners of irrigated pivots that are out of range of water from center pivots are especially vulnerable to the accumulation of aflatoxin. Aspergillus ear rot is caused by a fungus that may infect wounded kernels and produces green-yellow spores. Aflatoxin is toxic and carcinogenic to humans and livestock. The FDA has suggested action levels for aflatoxin concentrations, ranging from 0.5 – 300 parts per billion (ppb) depending upon its intended use, such as the species and age of the animal.

Literature Cited

Coutinho, T. A., and Wallis, F. M. 1991. Bacterial streak disease of maize (Zea mays L.) in South Africa. J. Phytopathol. 133:112-120.

Wheat Disease Update

Stephen Wegulo, Extension Plant Pathologist

Because of its widespread occurrence and severe epidemics in Nebraska in the last two years, this wheat disease update is devoted to stripe rust. Weather conditions in 2016 again favored its development. However, except in the Panhandle, stripe rust in 2016 was not as severe statewide as it was in 2015. This was partly due to a dry period in April that considerably reduced the risk of disease development. Conditions (cool temperatures and moisture) became more favorable to stripe rust in May and June, leading to significant levels of the disease in fields that were not sprayed preventively.

Stripe rust is caused by the fungus *Puccinia striiformis* f. sp. *tritici*. It has become increasingly common in the south central and central Great Plains. The most recent notable epidemics of the disease in Nebraska occurred in 2010, 2012, 2015, and 2016. Yield losses often exceed 40%. Signs of the disease are yellow stripes on leaves. The stripes consist of yellow to orange uredinia (fruiting bodies that produce repeating spores known as urediniospores). Localized or widespread epidemics result from infections caused by urediniospores. Rapid desiccation of entire plants can occur when infections are severe. Later in the growing season, dark brown to black telia develop under the epidermis and form streaks on the leaves and leaf sheaths. Telia are fruiting bodies that produce overwintering spores known as teliospores. Because they do not infect wheat, teliospores are not epidemiologically important.

The stripe rust fungus overwinters as mycelium and/or urediniospores on volunteer wheat or overwintering wheat crops in regions with mild winters. In the central and northern Great Plains of the U.S., urediniospores originate mainly from the southern states and Mexico and are blown northward by wind.

In Nebraska, stripe rust is usually first detected in April. Disease development is favored by cool temperatures and moisture. Infection occurs optimally when temperatures are between 45 and 54°F and free moisture on the leaf surface is present continuously for at least eight hours. Optimal conditions for disease development are a temperature range of 50-59°F and intermittent rain or dew. Under these conditions, new uredinia are formed within a period of 7 to 10 days after infection. Several cycles of urediniospore production occur during the growing season. The urediniospores are blown within the field and from field to field by wind and cause new infections.

Due to milder fall and winter temperatures in Nebraska, the risk of stripe rust overwintering in the state has increased during the last 10 to 15 years. In the fall of 2014 and 2015, stripe rust infected newly emerged wheat in the Nebraska Panhandle. Appearance of stripe rust in the Panhandle very early in the 2016 growing season indicated that it had overwintered from the infections that occurred in the fall of 2015. Because of the very early appearance, inoculum (spores) built up over a longer period of time, and the combination of local and blown in inoculum led to the very severe epidemics that were observed in the Panhandle in late May to early June.

In 2016, stripe rust was found on jointed goatgrass in Perkins County in southwest Nebraska. Although the epidemiological importance of this finding has not been investigated, the observation implies a greater risk for stripe rust occurrence and its overwintering in the state because the previously unknown host (jointed goatgrass) can serve both as a source of inoculum during the growing season and an overwintering host for the pathogen.

The higher frequency of occurrence of stripe rust and the elevated risk of its overwintering in Nebraska in recent years warrant a fresh look at management strategies. Management tactics that have routinely been practiced include planting resistant cultivars, fungicide application timed to protect the flag leaf, and cultural practices such as controlling volunteer wheat and avoiding excessive fertilization and irrigation.

It is not recommended to spray wheat for stripe in the fall. Instead, start scouting early in the spring and if you see stripe rust, be prepared to apply a fungicide to prevent its spread. Occurrence of stripe rust on newly emerged wheat in the fall increases the risk of overwintering and causing damage starting early in the spring.

A fungicide application program should be in place well in advance of the spring growing season. If stripe rust is observed in the fall, start scouting fields as early in the spring as possible. If stripe rust is observed early in the spring – an indication that it may have overwintered, a pre-flag leaf fungicide application will be warranted if wet weather is prevalent or forecast. The fungicide application decision should be timely and decisive. Fungicides work best when applied preventively. Waiting until a significant amount of stripe rust is visible on the leaves significantly diminishes fungicide efficacy. A second spray should be timed to protect the flag leaf. Follow label instructions and restrictions.

The following factors increase the risk of occurrence and development of stripe rust: a susceptible variety planted; mild fall and winter temperatures which favor overwintering; cool, wet conditions in the spring; occurrence of stripe rust in southern states in January, February and March; and strong southerly winds early in the spring. Scouting, keeping abreast of weather conditions and information on stripe rust in states south of Nebraska, and readiness to implement management tactics will help you to minimize damage caused by the disease and thereby reduce yield loss.

Soybean Disease Update

Loren J. Giesler, Extension Plant Pathologist

Once again we had a different weather pattern in 2016 that affected our common soybean diseases. While overall production was good there were some disease problems that occurred more commonly due to the wet conditions with warmer temperatures. Excessive early season moisture and heavy rains during the season resulted in many fields being affected by *Pythium* and Phytophthora. Another year with cool conditions during flowering resulted in White Mold being a common problem in the northern half of the state. Sudden Death Syndrome was also present in several fields. Frog eye leaf spot continued to be more common in 2016 and several areas had more bacterial pustule than normally observed. This article will help to identify, differentiate and manage these diseases that occurred in 2016. Additional information on disease identification can be found at the UNL Crop Watch Web Site.

Early Season Seedling Diseases

There are several pathogens involved in damping off seedling diseases. The most common in Nebraska are Fusarium, Phytophthora, Pythium, and Rhizoctonia. All four are capable of killing the developing soybean seedling or causing damage that affects the ability of the plant to achieve its full yield potential. In 2016, Pythium was the most common seedling disease problem due to wet conditions early in the season.

Seed and seedling diseases caused by Pythium develop early in the season under cool soil temperatures (50 to 60ºF) and wet soil conditions.

Products and ratings for all the common seedling disease pathogens are in the "Guide for Weed, Insect and Disease Management".

Criteria for assessing the use of seed treatment fungicides to manage seedling disease problems: (If these conditions are part of your production system your risk is greater)

- History of a stand problem
- No-till
- Early planting date when soils are cool
- Poor seed quality

Phytophthora Root and Stem Rot (*Phytophthora sojae*)

Warmer soil temperatures earlier in the year resulted in more seedling Phytophthora problems. Phytophthora root and stem rot of soybean, is caused by, a soilborne fungus that is present in many Nebraska soybean fields. The pathogen survives primarily as "resting" spores in the soil or in association with infested crop debris. Disease development is favored at soil temperatures of 60ºF and high soil moisture. We have observed in the past that dry conditions followed by heavy rain events can result in higher amounts of Phytophthora. This is most likely due to the plants being slightly stressed and the higher soil temperature. It is most common in low areas of a field, on poorly drained or compacted soils, and in soils with high clay content, although it is not limited only to these sites or conditions. It may also occur on well-drained hillsides during wet growing seasons.

Occurrence of Phytophthora should be documented in the field record book and the genetics used in the field should be checked. This disease is best managed with resistance, but there are over 70 races of the pathogen and several races are not impacted by any resistance genes currently deployed in commercial varieties. In Nebraska surveys conducted in 2000-02, Race 25 was found in several fields. Race 25 infested fields should be planted to *Rps3a* resistant varieties. The most common gene deployed in resistant varieties (*Rps1k*) is not effective against Race 25.

Symptoms

Symptoms associated with *P. sojae* infections include seed rots, pre- and post-emergence damping off of seedlings and stem rot of plants at various growth stages. The stem rot phase is easily identified by the dark brown color on the exterior surface of the stem and lower branches. Discoloration of the stem extends from below the soil to 6 inches or more above the soil line. The taproot turns dark brown and the entire root system may be rotted. Leaves on older infected plants become chlorotic between the veins followed by general wilting and death. Leaves will remain attached.

Management of Phytophthora Root and Stem Rot

Genetic Resistance.

Using resistant varieties is the most effective way to manage Phytophthora root and stem rot of soybean. Genetic resistance in the host is expressed in terms of Rps ("resistant to *Phytophthora sojae*") genes. The race-specific genes are complete resistance to a specific race of *P. sojae* and genes are denoted as Rps 1a, 1b, 1c, 1d, 1k, 3, 6, and 7. The pathogen exists in races or biotypes that interact with these genes. In a resistant reaction, the plant survives infection; susceptible varieties are killed when infection occurs. Race-specific resistance is effective in the early stages of germination.

The other parameter on which soybean varieties are rated for *P. sojae* is partial resistance (also called field resistance or tolerance). Soybean varieties with high levels of partial resistance can become infected with Phytophthora but the symptoms are not as severe as highly susceptible varieties. In field research trials conducted in Nebraska, good partial resistance performed as well as varieties with resistance genes and partial resistance. In fields where the *P. sojae* biotype is aggressive against the resistance genes available in commercial varieties, this is the only choice for management with genetics. If possible, a combination of good partial resistance and an Rps gene are recommended. Partial resistance alone will not be as effective during early growth stages or under high disease pressure.

Cultural Practices.

Anything which can be done to improve soil drainage and structure will reduce disease potential. Soil drainage can be improved through tilling in many cases. Compacted soils will also result in increased disease levels. Crop rotation should also be done, as continuous soybean production will increase fungal inoculum and promote development of new biotypes.

Fungicide application.

Seed treatment fungicides containing mefenoxam or metalaxyl should be used in fields with a history of this disease. Note that many products require increased rates for activity against Phytophthora. Check with your seed company representative to determine if their product has what is needed for Phytophthora management.

Sudden Death Syndrome
(*Fusarium virguliforme* syn. *Fusarium solani* f. sp. *glycines*)

The sudden death syndrome (SDS) pathogen is spread with soil; thus, the methods used to prevent soybean cyst nematode spread are also applicable to preventing spread of SDS. For symptoms to develop there needs to be high soil moisture available at flowering. As this is a soilborne disease, it will not spread rapidly across the field from individual spots that show up. Infected areas in a field can also have an oblong distribution in the direction of tillage or equipment traffic.

Symptoms

The first signs of SDS appear as scattered yellow or white spots on the leaves in the upper portion of the canopy. In the intermediate stage, these spots eventually coalesce to form brown streaks between the veins (interveinal necrosis). On these leaves only the midvein and major lateral veins remain green. As the disease reaches the more advanced stages, premature defoliation occurs with petioles (leaf stems) remaining on the plant. The progression from early symptoms to defoliation will occur rapidly (less than 14 days in most cases). Symptoms of SDS can be confused with brown stem rot symptoms. To differentiate the two, split the stems of infected plants and check for discoloration. If the pith (center stem) is discolored, this is a symptom of brown stem rot. Stem discoloration will be confined to the outer stem layers (vascular tissue) with SDS and can extend up the stem of infected plants.

Favorable Environmental Conditions

Sudden death syndrome is favored in high-yield environments. The disease is more prevalent during cool, wet growing seasons and is favored by early planting in cool soils. Hot, dry weather appears to slow disease development, but depending on the stage and infections which may have occurred prior to dry weather it can become severe under these conditions. Heavy rains around flowering time promote foliar symptom development.

Management of Sudden Death Syndrome

Resistance.

Different varieties will vary in their susceptibility to this disease. Ratings for SDS are not common in Nebraska seed catalogs.

Cultural Practices.

In fields with a history of this disease avoid early planting as it favors SDS infection with cool soil temperatures.

Fungicide application.

In 2015 ILeVo© was launched by Bayer Crop Science. Management trials with the on-farm research program in 2015 showed benefits of using ILeVo when SDS was present in the field at higher levels. There is still a question of how much SDS needs to be present in the field to justify the added application cost.

Sclerotinia Stem Rot (White Mold)
(*Sclerotinia sclerotiorum*)

Sclerotinia stem rot, also referred to as white mold, is caused by a fungal pathogen that can reside in soybean fields an indefinite amount of time. 2016 was the fourth year in a row that white mold has shown up in northern Nebraska. The fungus survives from year to year as hard dark structures called sclerotia. Sclerotia are variously shaped bodies of tightly packed white mycelium covered with a dark, melanized protective coat. Saturated soils and a full canopy favor the emergence of apothecia from the sclerotia, which are mushroom-like bodies that produce millions of airborne spores almost daily over a 7 to 10 day period. These spores are released during favorable weather conditions and can travel to other fields in air currents.

Spores infect plants like soybean primarily through colonized blossoms that are senescing but they can also infect through injured plant tissue. Free moisture must be present on the plant surface for infection to occur. Flowers on the tips of small pods provide a common entrance for the fungus. Invasion of the pod and eventually the stem may lead to lesions covered with sclerotia. During harvest these survival structures are scattered back onto the soil. Thus, inoculum for the next three or more seasons has been distributed.

Symptoms

Initial symptoms are visible during pod development. Leaves will wilt and turn gray-green before turning brown, curling and dying. It is important to observe stems and pods for white mycelium and sclerotia to differentiate Sclerotinia stem rot from other stem and root rot diseases. Since blossoms are infected first, early stem or pod water-soaked symptoms often initiate near colonized flowers. In a few days diseased stem areas are killed and become tan and eventually bleached. This bleached stem will have a pithy texture and will shred easily. Infected plant parts generally will have signs of the fungal pathogen as white, fluffy mycelium during humid conditions and sclerotia on the surface of or embedded in the stem tissue. Although stem and pod infection usually occurs about 6 to 14 inches above the soil line, some basal infection also may be found. Infections will occur after flowering has initiated in the crop.

Favorable Environmental Conditions

Disease development and spread will occur from flowering until pod formation. As the flower is directly related to disease development, this disease will only develop if we have wet, humid conditions at flowering with moderate temperatures (<85°F). This is why this is not a consistent problem in most of the Nebraska soybean crop acres. This is also why the disease was more severe in 2015 as we had cool, wet conditions during flowering.

Management of Sclerotinia Stem Rot

Resistance.

Soybean varieties vary in their response to Sclerotinia and most companies have ratings in the seed catalog. Avoid planting highly susceptible varieties in fields with a history of this disease. In addition, planting varieties which are short and do not lodge will reduce disease potential.

Cultural Practices.

Row spacing has been shown to influence this disease, with narrow rows resulting in more Sclerotinia stem rot. Fields with a history of Sclerotinia should not be planted in narrow rows. Avoid irrigation during flowering. The common corn-soybean rotation will not reduce the potential for disease development. Utilizing a longer rotation with corn and wheat has been shown to reduce pathogen buildup and disease risk. As several weeds can be a host for this fungus, it is important to maintain good weed control during rotation years.

Fungicide application.

Foliar fungicide applications are typically only recommended to be considered in seed fields or fields with a history of severe disease development. Sclerotinia suppressive herbicides may also be considered. Fungicides applied at the R1 growth stage (beginning bloom) have been shown to provide better control than applications at R3 (beginning pod).

Bacterial Pustule
(*Xanthomonas axonopodis pv. glycines*)

Bacterial pustule is a bacterial disease of soybean that typically occurs sporadically and at very low severity. In 2016, very warm temperatures with wet conditions resulted in this disease being more common in many soybean fields. As the disease was more common and at higher levels of development than normal it did create some diagnostic issues in some cases.

Symptoms

Bacterial pustule initially appears as small green to yellow lesions. The lesions turn brown with the center of the lesion having a raised area. The raised area develops into a pustule and the entire lesion is often surrounded by a yellow halo. The pustule will crack open and release bacteria to spread the disease.

The raised pustule is of the most common look-alikes to soybean rust pustules. This appearance and the presence of an abundance of rust spores from corn rust resulted in a few scares of observers thinking they could have had soybean rust.

Management of Bacterial Pustule

Resistance.

Varieties vary in resistance and selection of varieties with bacterial pustule resistance can be used in fields with a history of the disease.

Cultural Practices.

Bacteria overwinter in crop residue primarily. Rotation and tillage will help break down residue and reduce the disease. Avoiding traffic in wet fields to avoid spreading the disease.

Frogeye Leaf Spot (*Cercospora sojina*)

Frogeye leaf spot is a fungal disease that is becoming more common in Nebraska and occurs from the southern to northern state boarders mostly on the eastern third of the state. Yield loss estimates due to frogeye leaf spot have been reported as high as 30% nationally with extensive leaf blighting, but for Nebraska I would estimate less than 20% in highly susceptible varieties. The disease is most severe when soybean is grown continuously in the same field, particularly in fields where tillage is reduced, since this is a residue-borne disease. The primary source for this disease is infested residue, infected seed and airborne spores. In areas where this disease has been observed in past years it will typically show up again if weather conditions are favorable.

Symptoms

Infection can occur at any stage of soybean development, but most often occurs after flowering and is typically in the upper canopy. Initial symptoms are small, dark spots on the leaves. Spots eventually enlarge to a diameter of about ¼ inch and the centers of the lesions become gray to brown and have a reddish purple margin. Individual leaf spots can coalesce to create irregular patterns of blighting on the leaf. In addition, stems and pods can also be affected. Stem infections appear later in the season and will be long, narrow, dark lesions with flattened centers. Pod lesions will be circular to elongate, slightly sunken and reddish-brown in color.

Management of Frogeye Leaf Spot

Resistance.

Soybean varieties vary in their resistance to frogeye leaf spot and there are several genes commonly used for resistance.

Cultural Practices.

Frogeye leaf spot is more severe in continuously cropped soybean fields. Reduced tillage systems will tend to have more as the pathogen overwinters in residue.

*Fungicide application***.**

Application of fungicides to manage frogeye leaf spot in Nebraska is typically not warranted in most fields. Fields with a history of frogeye should be watched carefully and if disease develops application of a strobilurin fungicide at the R3 (pod set) – early R4 growth stage is considered the most effective. In 2010, resistance to strobilurin fungicides was reported for the first time to this pathogen in Tennessee. Since this time, there has been a significant spread in the Mississippi valley but we have not observed this in Nebraska yet. If an application is made and control is not as expected, it is possible that resistance has spread. It will most likely not be an issue for us in Nebraska for several years. In addition, most fungicide products on the market today are combinations with different modes of action that have activity against this fungus.

Root Disease Update

Anthony O. Adesemoye, Nebraska Extension Plant Pathologist

The cool wet conditions early in the 2016 season provided the needed environment for root pathogens to thrive. We monitored multiple crops across the state during the year and found many fields with root diseases. Patches without plants were observed in certain fields. In other fields, we noticed symptoms that included lesions in the crown and root, reduced crop development and stunting, very small root growth, and root rot. In fields where root diseases were severe, stand establishment was noticeably, poor. In this report, three important root pathogens monitored in 2016 are highlighted.

Fusarium Species

Fusarium is a fungus genus (group) that contains many species, which are pathogens on many crops. It is one of the major concerns in the production of row crops. Symptoms of Fusarium disease included dark and swollen roots, death of lateral roots, and development of secondary roots on the upper tap roots. Stunting and yellowing of shoot and leaf margins and reddish brown discoloration of shoot are common. Usually, more than one Fusarium species infect plants in the field at the same time and this can complicate management and make the disease to cause great yield losses. Some of the species can produce mycotoxins that are harmful to humans and animals. During the 2016 survey, multiple species of pathogenic Fusarium were recovered from plants collected from different locations across the state. Among these, F. graminearum, and F. oxysporum were the most common and most pathogenic, causing diseases in corn, soybean and wheat.

Macrophomina phaseolina

Macrophomina phaseolina causes charcoal rot in soybean and corn and ashy stem blight in dry beans. In 2016, the pathogen was recovered from plants collected in non-irrigated fields located in four countries in the eastern part of the state. It appears that the pathogen is more spread than previously anticipated, so we will continue to monitor it in the years ahead.

Rhizoctonia Species

Rhizoctonia solani is a pathogen to most crops that are produced in Nebraska and causes root rot diseases. The pathogen is a species complex, containing at least 14 anastamosis groups. Host preferences and environmental conditions that support disease establishment vary among anastomosis groups. In soybean, wheat, and dry bean fields this past year, patches of where plants did not grow or had died were seen. In those fields, samples showing symptoms typical of Rhizoctonia were collected and isolates were recovered and identified. The *Rhizoctonia solani* anastomosis groups identified were AG-F, AG-5, AG-A and *Rhizoctonia zeae* was also recovered. These isolates are being further studied.

Management of Root Diseases

The impact of each of these three pathogens can vary from minimal to significant yield losses depending on (1) the presence of suitable environmental conditions and (2) the practices adopted by growers, including pre- and post-planting operations. Methods of disease management have varying levels of efficacy for each pathogen. However, integrating different methods or factors together will lead to better efficacy in managing these diseases. Among factors that could be integrated are – crop rotation, planting fungicide treated seeds, use of organic fertilizer, planting resistant lines which is rarely available, and the use of biological control agents. Although, tillage is effective, it is not recommended for most parts of Nebraska.

The long view of nitrogen recommendations from Nebraska Extension

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Introduction:

Nitrogen use for corn production is under continuous scrutiny. The farmer seeks to optimize its use for profit and efficiency. Many of our Natural Resource Districts have had Nitrogen Management Plans for 25 or more years requiring periodic certification and reporting of soil N, fertilizer N application, irrigation water N content, N application, and yield. Concern about surface water is highlighted by the recent lawsuit over nitrate-N in the Des Moines IA water supply. Several ag corporations have launched on-line tools to manage N throughout the season such as Climate Corp and Pioneer. Some consultants advise on N management using Adapt-N or similar tool. Not all these private tools are completely documented, meaning that they do not publish the underlying models used to make estimates of N use or loss.

The NRCS uses UNL recommendations as published in our NebGuides and Extension Circulars, as well as our experience and research data base to inform their recommendation and procedures. These publications are revised at least every five years with reinterpretation of past and new information although the history and rationale for changes are not documented in the Extension resources. This paper is an attempt to fill in some of the gaps about how and why UNL recommendations have changed over the years.

This paper is authored by current UNL nutrient management Extension faculty but this is an ever changing group. In 2015 Dr. Gary Hergert retired, at least two others intend to retire before mid-2018, and Dr. Ferguson will assume the role of Interim Department Head for the Department of Agronomy and Horticulture. Dr.'s Shaver, Maharjan and Krienke are relatively recent to our group and plan to continue as UNL specialists on N and nutrient management. Contributions of Agricultural Research Service and other UNL scientists have been and continue to be a valuable part of information supply for developing and refining recommendations.

The objective of this paper and the talk that will accompany it is a look back at how we have arrived at our present nitrogen recommendation procedures and also a glimpse forward to where we think it might go. In addition, we have compiled a bibliography of N related publications from UNL soils faculty. At the time of this writing we do not have a link, but it will be highlighted at http://cropwatch.unl.edu/soils for a while after these clinics.

History:

The longest serving soil fertility specialist of the above authors is Dr. Shapiro (1984), followed closely by Dr. Ferguson. Dr. Wortmann is a native Nebraskan and did graduate study in Nebraska, left for positions in Africa, and returned to Nebraska in 2001. When Drs. Shapiro and Ferguson started, the corn fertilizer N algorithm or formula considered yield goal and residual soil nitrate-N based on available research at the time to achieve profitable yield. Residual soil nitrate-N was inputted as pounds of N with an adjustment for sampling depth to estimate a credit for crop available N from the residual nitrate-N in the top 6 ft of soil. In addition to yield goal and residual soil nitrate-N, the formula accounted for the effects of previous crop, applied manure, and nitrate-N in irrigation water.

Recommended N in lbs/ac: $[(0.9 \times YG)/(1-0.0008*YG)] + 50 - \text{SoilN-lbs}$

with YG = Yield Goal and SoilN-lbs = soil nitrate in lbs N/6 ft depth

Before Dr. Shapiro came on board, the soil fertility position at the Northeast Station, as the Haskell Ag Lab was called back then was filled by Dr. George Rehm. Other soil fertility faculty at that time were Drs. Anderson (Scottsbluff), Gary Hergert (North Platte), Ken Frank (Clay Center), and Ed Penas (Southeast) , Richard Wiese and Don Sander (Lincoln). This group generated a large dataset from 81 site years of N rate trials over several years which was analyzed by Gary Hergert who then proposed revisions of the corn N algorithm. These included:

1. The use of the weighted average for residual soil nitrate-N concentration for a soil sample depth of at least two feet;

2. Consideration of soil organic matter level with a formula for estimating the release of N from soil organic matter;

3. Revision of the soybean N credit.

The new formula, which is what we are currently using is the following:

N rate (lb N/acre) = [35 + (1.2 x EY) - (0.14 x EY x OM) - 8 x SoilN-ppm - Other credits] x f_A x f_R

EY = expected yield (yield goal, bu/acre)
OM = organic matter (%)
SoilN-ppm = weighted average soil nitrate test (min 2-ft) ideally before planting in spring
Other credits: legumes, manure, irrigation

Added after NSFP Project, see below points
f_A = application timing adjustment factor
f_R = price ratio adjustment factor

These changes were accepted and the new formula was published in our corn NebGuide in the early 1990s. The credits for irrigation water N, manure N, and other previous crops remained with some revision over time. Default values for when measured values are not available are used for residual soil nitrate-N and for the amount of irrigation water applied when records of past years are inadequate.

Between 2002-2004, 34 site-years of research were conducted across Nebraska to evaluate high yield corn responses to N, P, K, and S through the project called the Nebraska Soil Fertility Project (NSFP). Drs. Doberman, Blumenthal, and Tarkalson also participated in NSFP. Results of NSFP were used to validate or update our recommendations for irrigated high yield situations. The earlier 81 site-years included both irrigated and rainfed sites, but NSFP sites were all irrigated. Three published papers report NSFP results while results were also used in other papers. These papers detail the experimental procedures and report the major findings. These findings included:

1. The corn N formula estimated fertilizer N need very well on average but the results found much year-to-year variation in the economically optimal N rate (EONR). The NSFP results did not indicate an opportunity to improve the predictive power of the corn N formula to better account these variations in EONR.

2. The corn N response curve differed for continuous corn compared with corn following soybean and the response to fertilizer N was less variable for corn following soybean (Figure 1). We have discussed using two procedures, one for corn on corn and one for corn on soybean ground, but this has not been developed.

1. 3. Dr. Doberman revised our corn nitrogen recommendations to account for the price of nitrogen and value of corn, so that our initial recommendation can be adjusted based on the corn price: nitrogen price ratio. Therefore the recommended corn N rates are higher with low N cost relative to corn price, but lower when nitrogen is relatively more expensive. Factor Fr above.

2. 4. The corn N formula was revised to consider whether the time of N application adjusting fall, spring/preplant, or predominantly in-season with respective N rate adjustments of 105, 100, and 95% of the predicted N. Factor Fa above.

The corn N calculator is an Excel spreadsheet tool that allows the user to enter data to calculate an N rate with and without the economic analysis http://cropwatch.unl.edu/soils/software (download the Excel Spreadsheet 'Corn Nitrogen Recommendations Calculator' link found on that page). In the spreadsheet the details of the calculations are listed and the assumptions used.

3. 5. The corn N calculator considers more information and does more detailed calculations compared with the published corn N formula in Extension Circulars EC117 and EC155. The main difference is it assumes different bulk density values for sandy and fine textured soil when converting soil nitrate from a concentration to weight. The corn N calculator differentiates the soybean N credit for soybeans based on soil texture.

6. The corn N calculator does not calculate environmental implications.

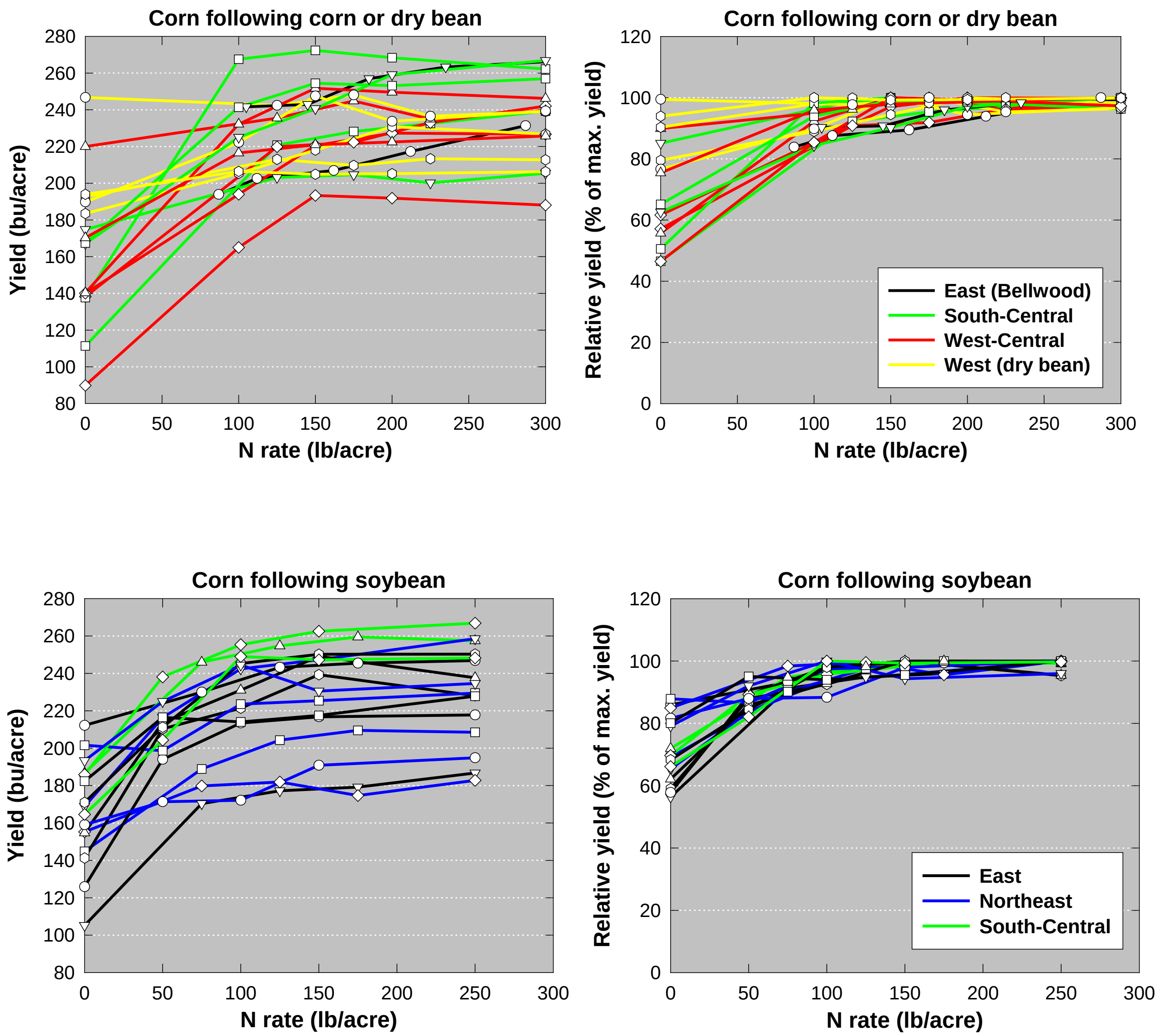

Figure 1. Corn yields response to N in absolute yield and relative yield for continuous corn and corn following soybeans. From the NSFP project 2002-2004.

The above discussion is focused on the N rate determination and a bit on the timing. However, critical to the N rate determination is having a soil nitrate assessment of the field that is representative of the area of the field that is to be fertilized. In the mid to late 1980s research was conducted to assess deep nitrate variability.

More recent corn N research has addressed improvement of N use efficiency such as by determining effects of: use of fertilizer N use efficiency products such as inhibitors and controlled release products; in-season N application guided by leaf canopy color; N recovery from applied manure and other organic products; and crop residue harvest.

The first NebGuide addressing use of crop canopy color to guide in-season N application addressed the use of a chlorophyll meter (Minolta SPAD 502), the precursor to the crop sensors that are more popular today. This work was conducted by the Agricultural Research Service division located at the University of Nebraska and was led by Dr. Schepers with help from Dr. Varvel and Dennis Francis. Another proceedings article could be written on the development of sensor technology and development of its use in corn nitrogen decisions.

This article was intended to just focus on the work related to N rate development, and we recognize it is related to other aspects of N management. The bibliography cited in beginning will be more comprehensive than just the N reate decision.

Selected publications of interest:

Dobermann, A., C.S. Wortmann, R.B. Ferguson, G.W. Hergert, C.A. Shapiro, D.D. Tarkalson, D. Walters. 2011. Nitrogen Response and Economics for Irrigated Corn in Nebraska. Agron. J. 103:67-75.

Ferguson, R.B., C.A. Shapiro, G.W. Hergert, W.L. Kranz, N.L. Klocke, and D.H. Krull. 1991. Nitrogen and irrigation management practices to minimize nitrate leaching from irrigated corn. J. Prod. Agric. 4:186-192.

Hergert, G.W., R.B. Ferguson, C.A. Shapiro, E.J. Penas, F.B. Anderson. 1995. Classical statistical and geostatistical analysis of soil nitrate-N spatial variability. Chapter 13. P. 175-186. *In* P.C. Robert, R.H. Rust, and W.E. Larson, (eds.). Site-specific management for agricultural systems. ASA. Madison WI.

Kranz, W.L., C. Burr, B.S. Farmaha, P. Grassini, G.W. Hergert, S. Irmak, D. Martin, A. Nygren, C.A. Shapiro, T. Shaver, and G. Zoubek. 2015. Irrigation and Nitrogen Management: User Education/Certification Program. EC2008. University of Nebraska–Lincoln Extension Division. http://extensionpublications.unl.edu/assets/pdf/ec2008.pdf (http://water.unl.edu/waternmgt)

Olson, R.A., F. N. Anderson, K. D. Frank, P. H. Grabouski, G. W. Rehm and C. A. Shapiro. 1987. Soil Testing Interpretations: Sufficiency vs. Build-up and Maintenance. In SSSA Spec. Pub 21. Soil Testing: Sampling, Correlation, Calibration, and Interpretation. p.41-52.

Wortmann, C., C. Shapiro, A. Dobermann, R. Ferguson, G. Hergert, D. Walters, and D. Tarkalson. 2012. High yield corn production can result in high nitrogen use efficiency. Better Crops 4:14-15.

Shapiro, Charles A., Richard B. Ferguson, Gary W. Hergert, Charles Wortmann, and Daniel T. Walters. 2009. Fertilizer Suggestions for Corn. EC117. University of Nebraska Extension Division. http://extensionpublications.unl.edu/assets/pdf/ec117.pdf

Shapiro, C.A., J.S. Schepers, D.D. Francis, and J. F. Shanahan. 2006. Using a chlorophyll meter to improve N management. NebGuide G1632 (Revised, October 2006).

Shaver, T., Brand, J. I., Hergert, G. W., Krienke, B., Shapiro, C., Wortmann, C. Nutrient Management for Agronomic Crops in NE (EC155). Tim Shaver (Ed.), Lincoln, NE: EC155. UNL Extension. http://extensionpublications.unl.edu/assets/pdf/ec155.pdf

Wortmann, C., Jansen, J., Van Liew, M., Ferguson, R., Hergert, G. W., Shaver, T., Shapiro, C. Nitrogen Loss Assessment Tool (N-LAT) for Nebraska: Background and Users Guide. http://extensionpubs.unl.edu/publication/9000016369584/nitrogen-loss-assessment-tool-n-lat-for-nebraska/

Herbicide Update 2017

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Corn Herbicides

Acuron® Flexi [Bicyclopyrone (0.87%) + Mesotrione (3.47%) + S-metolachlor (31.24%)]. Acuron may be used pre-emergence or post-emergence (up to 30 inches tall or 8-leaf stage) in field corn, seed corn, silage corn. It can be used in sweet corn and yellow popcorn, but only pre-plant or pre-emergence. Acuron Flexi contains the safener benoxacor. If organic matter content of the field is less than 3%, apply at 2.0 qt/Acre, and if ≥ 3% then at 2.25 qt/Acre. Do not exceed 2.25 qt/Acre of this product per year. Do not make more than one post-emergence application and not more than two total applications of Acuron Flexi per year. EPA Reg. No. 100-1568. **Modes of Action: 27 + 27 + 15.**

Armezon PRO [Topramezone (1.12% + Dimethenamid-P (56.25%)]. It is an emulsifible concentrate (EC) that provides systemic post-emergence control of emerged broadleaf and grass weeds followed by residual control in all corn types. Application rates depend on soil texture and organic matter content. It may be applied from corn emergence to V8 stage or 30 inches tall field corn and popcorn. For applications when corn is more than 12-inches tall but before 30 inches in height, applications should be directed beneath the crop canopy using drop nozzles and appropriate nozzle spacing for best performance. EPA Reg. No. 7969-372. **Modes of Action: 15 + 27.**

DiFlexx® DUO [Dicamba (19.73%) + Tembotrione (2.83%)]. DiFlexx DUO can be used for post-emergence selective control of broadleaf and grass weeds in corn and postharvest burndown weed control. DiFlexx DUO includes exclusive CSI™ safener technology which enables corn plants to better withstand herbicidal activity and provides better crop safety. It can be applied from emergence up to, but not including, the V7 stage of growth or 36 inch tall corn or 15 days prior to tassel, whichever occurs first. The application rates of DiFlexx vary from 24 to 40 fl oz/Acre depending on weed type and growth stage. Apply maximum of two applications per growing season, separated by two weeks or more. EPA Reg. No. 264-1184. **Modes of Action: 4 + 27.**

Incinerate™ [Mesotrione (40%)]. Incinerate is for control of annual broadleaf weeds in field corn, seed corn, yellow popcorn, and sweet corn. EPA Reg. No. 100-1131-1381. **Mode of Acton: 27.**

Resicore™ [Acetochlor (31%) + Mesotrione (3.3%) + Clopyralid (2.7%)]. Resicore is for control of annual grasses and broadleaf weeds in field corn, seed corn, and silage corn with preplant, pre-emergence, and post-emergence application. Resicore can only be applied preplant or pre-emergence in yellow popcorn. The application rate of Resicore is in the range of 2.25 to 3.0 qts/Acre based on soil texture and organic matter content. EPA Reg. No. 62719-693. **Modes of Action: 15 + 27 + 4**.

Soybean Herbicides

Authority®Elite [Sulfentrazone (7.55) + S-metolachlor (68.25)]. It is soil applied herbicide for control of broadleaf, grass and sedge weeds in soybeans. The crop rotation restriction for corn and sorghum is 10 months. It should not be applied more than 38.7 fl oz/A per year. EPA Reg. No. 279-3442. **BroadAxe XC** EPA Reg. No. 279-3442-100. **Modes of Acton: 14 + 15.**

Authority®Maxx [Sulfentrazone (62.12) + Clorimuron-ethyl (3.88)]. It can be applied pre-plant or pre-emergence in soybean for broadleaf and partial grass weed control. The application rate is 6 to 9 oz/A depending on soil texture and organic matter content. EPA Reg. No. 279-9560. **Modes of Acton: 14 + 2.**

Fierce® XLT [Flumioxazin (24.57%) + Pyroxasulfone (31.17%) + Chlorimuron (6.67%)]. Fierce XLT in Nebraska can only be used in the fields south of route 30 and east of route 281. This herbicide provides residual control of broadleaf and grass weeds in soybean. It also provides additional burndown activity when used as part of a burndown program. Moisture is necessary to activate this herbicide in soil for residual weed control. Do not apply more than 5.25 oz/Acre per growing season. Do not apply additional chlorimuron containing herbicides to fields treated with Fierce XLT. EPA Reg. No. 59639-194. **Modes of Acton: 14 + 15 + 2.**

Marvel™ [Fluthiacet-methyl (1.2%) + Fomesafen (30.08%)]. It is a new premix herbicide from FMC for post-emergence weed control in soybean. It can be applied at 5 to 7.25 fl oz/A from pre-plant through full flowering stage (prior to R3). It is a contact herbicide therefore, a good coverage is essential for optimum weed control. Do not apply more than 7.25 fl oz/A per application and 9.75 fl oz/A per year. EPA Reg. No. 279-3455. **Modes of Acton: 14 + 14.**

Presidual™ [*S*-metolachlor (58.2%) + Metribuzin (13.8%)]. Presidul is for control of certain grasses and broadleaf weeds in soybean. The application rate of this herbicide is 2.0 to 2.9 pt/Acre depending on soil texture and organic matter content. EPA Reg. No. 1001162-1381. **Modes of Acton: 15 + 6.**

Warrant® Ultra [Acetochlor (30.2%) + Fomesafen (7.1%)]. It can be applied as a preplant surface, pre-emergence, or post-emergence treatment in soybean. A maximum of 48 fl oz/Acre of this herbicide can be applied in alternate years in Nebraska. It can provide residual as well as burndown activity. This herbicide can be applied only once per growing season. EPA Reg. No. 524-620. **Modes of Acton: 15 + 14.**

XtendiMax [Dicamba (42.8%)]. XtendiMax is a new dicamba product to be used on dicamba-tolerant (Roundup Ready 2 Xtend) soybean. The formulation contains Vapor Grip, which reduces the volatility of this product. This product has 2.9 lb/gallon of DGA salt of dicamba in liquid, so 22 fl oz provides 0.5 lb of dicamba, which is equivalent to 16 oz of Clarity and other 4 lb/gallon dicamba products. Minimum application rate for any use is 22 fl oz/Acre. The maximum rate per application prior to soybean emergence is 44 fl oz/Acre, which is also the total maximum allowed for all applications prior to soybean emergence. The maximum rate per application after soybean emergence is 22 fl oz/Acre, and the total of all POST applications cannot exceed 44 fl oz/Acre. The cumulative application rate per year cannot exceed 88 fl oz/Acre. Use of ammonium sulfate, UAN, etc. is not allowed due to their potential to increase the volatility of dicamba. We assume that there will be approved AMS replacement products listed on xtendimaxapplicationrequirements.com eventually, to mitigate hard water issues. Post-emergence application of XtendiMax can be made from emergence up to and including the R1 stage of soybean growth. Weeds should be less than 4 inches tall at time of post-emergence application. **Modes of Acton: 4.**

Zidua® PRO [Imazethapyr (13.45%) + pyroxasulfone (23.06%) + saflufenacil (4.81%)]. Zidua PRO provides contact burndown and residual pre-emergence control of annual grass and broadleaf weeds in soybean. It can be applied from 4.5 to 6.0 fl oz/Acre depending on tillage system. EPA Reg. No. 7969-365. **Modes of Action: 2 + 15 + 14.**

Wheat Herbicides

Finesse® Grass and Broadleaf [Chlorsulfuron (25%) + Flucarbazone-sodium (46.7%)]. Finesse Grass and Broadleaf is for use in wheat. The use rate ranges from 0.6 to 0.9 oz/a depending on the target weed. Consult the label for wheat appropriate wheat growth stage for application and rotational crop restrictions. EPA Reg. No. 352-718. **Modes of Action: 2 + 2.**

Cody [Clopyralid (5.1%) + 2,4-D (39.0%)]. For selective control of broadleaf weeds in wheat and barley not under seeded with a legume, corn, fallow cropland, grasses grown for seed, rangeland and permanent grass pastures, conservation reserve program (CRP) acres, and non-cropland. Alligare. EPA Reg. No. 81927-28. **Modes of Action: 4 + 4.**

Herbicides Labeled for Use in Multiple Crops

Anthem® MAXX [Pyroxasulfone (45.22%) + Fluthiacet (1.38%)]. Anthem MAXX is a new formulation of Anthem, a premix for pre-emergence or early post-emergence control of annual grasses and some small seeded broadleaf weeds in corn and soybean. EPA Reg. No.279-3468. **Modes of Action: 14, 15.**

Enlist™ Duo [2,4-D choline (24.4%) + Glyphosate (22.1%)]. For control of annual and perennial weeds in Enlist corn and soybeans. This herbicide is based on Colex-D technology. 2,4-D products that do not contain Colex-D technology are not authorized for use in conjunction with Enlist corn and soybeans. It is a systemic herbicide intended for control of annual and perennial weeds. Apply 3.5 to 4.75 pints of Enlist Duo per acre. Apply when weeds are small and corn is no larger than V8 growth stage or 30 inches (free standing) tall, whichever occurs first. For corn heights 30 to 48 inches (free standing), apply only using ground application equipment using drop nozzles aligned to avoid spraying into the whorl of corn plants. Make one to two applications with a minimum of 12 days between applications. In Enlist Soybean, Apply 3.5 to 4.75 pints of Enlist Duo per acre. Apply when weeds are small and any time after soybean emergence but no later than R2 (full flowering stage). Do not apply more than 4.75 pints of Enlist Duo per acre per application. Do not apply more than 14.25 pints/Acre of Enlist Duo per use season. EPA Reg. No. 62719-649. **Modes of Action: 4 + 9.**

Fierce™ [Flumioxazin (33.5%) + Pyroxasulfone (42.5%)]. Fierce is a new premix from Valent for pre-emergence control of broadleaf and grass weeds. It will be labeled for use in soybeans and no-till & minimum till corn. The use of residual herbicides can help manage or prevent the development of glyphosate-resistant weed biotypes and reduce early season weed competition. MOA: flumioxazin is a PPO inhibitor and pyroxasulfone is a seedling growth inhibitor. EPA Reg. No. 63588-93-59639. **Modes of Action: 14 + 15.**

Kochiavore™ [2,4-D (25.93%) + Bromoxynil (25.13) + Fluroxypyr (10%)]. Kochiavore is for post-emergence control of broadleaf weeds in wheat, barley, corn, sorghum, non-cropland areas, conservation reserve program land and fallow land. EPA Reg. No.1381-258. **Modes of Action: 4 + 6 + 4.**

Always refer to herbicide product labels for complete details and directions for use.

Improving Pesticide Efficacy and Management of Spray Drift by Using the Guide (EC130)

Robert N. Klein, Western Nebraska Crops Specialist

The best decisions are made by understanding the factors involved.

In pesticide application, two important factors are pesticide efficacy and spray drift management. The goal is 100% pest control and 0% spray drift. As with most situations where one cannot control all the variables, achieving goals such as these is a real challenge.

The following is a quote from Kirk A. Howatt, Associate Professor, Department of Plant Sciences, North Dakota State University:

> "Increasing spray droplet size to reduce drift has reduced weed control by 10 to 50% for some herbicides used in cereals. Research continues to evaluate the extent of impact as well as the cause of this effect and corrective measures."

Dr. Howatt's quote explains what the results are when one is only concerned about spray drift and forgets about pesticide efficacy. One always needs to be concerned about spray drift and the effect of our pesticide application on the environment. With knowledge of the factors that affect spray drift and pesticide efficacy, one is able to make the pesticide application and accomplish both goals.

Pesticide efficacy is when the product, used according to label directions, will be effective as per the label claims and that its application to the target crop (or other situation) will not cause any unintended adverse effect.

Spray drift of pesticides away from the target is an important and costly problem facing both commercial and private applicators. Drift causes many problems including: 1) damage to susceptible off-target sites; 2) a lower rate than intended, which can reduce the effectiveness of the pesticide and waste pesticide and money; and 3) environmental contamination, such as water pollution and illegal pesticide residues. Drift occurs by two methods: vapor drift and particle drift.

Factors that affect pesticide efficacy and spray drift management:

- Pre or post application
- Contact or systemic pesticide
- Material being applied
- Nozzle tip size
- Spray particle size
- Nozzle tip spray angle
- Spray pressure
- Discharge height
- Discharge spray angle
- Sprayer speed
- Weather conditions
    - o Wind velocity, temperature, humidity, and atmospheric stability

Let's examine some of these factors that affect pesticide efficacy and spray drift management in more detail.

Spray particle size is of the utmost importance in both pesticide efficacy and spray drift management. Table 1 compares micron sizes to familiar items.

Table 1. Comparison of micron sizes (approximate values).	
Pencil lead	2,000 μm
Paper clip	850 μm
Staple	420 μm
Toothbrush bristle	300 μm
Sewing thread	150 μm
Human hair	100 μm

Figure 1 illustrates what happens to the number of drops when the droplet size is cut in half.

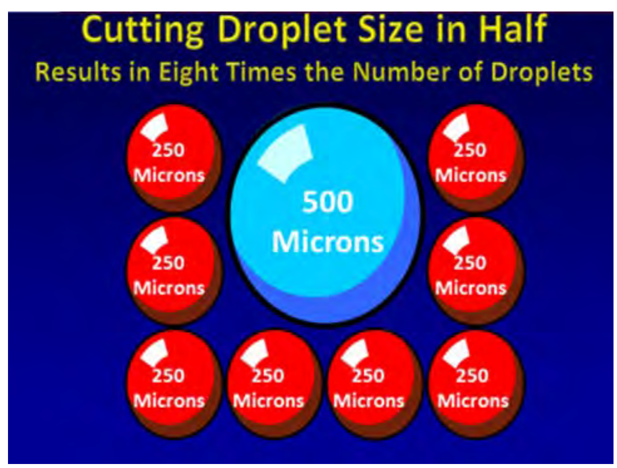

Figure 1. Cutting droplet size in half results in eight times the number of droplets.

Table 2 lists the average number of droplets per square inch for three droplet sizes (VMD) and three application rates (GPA).

Table 2. Coverage/drift potential (average drops per square inch) with change in VMD and GPA.

VMD	5 GPA	10 GPA	20 GPA
250	369	738	1,475
500	46	92	184
1,000	6	12	23

Table 3 illustrates that the larger droplet sizes are not greatly affected by wind speed and temperature with a low boom height. Also, small droplet sizes evaporate in higher temperatures.

Table 3. Effect of temperature and wind velocity on droplet size at the end of flight of various size water droplets discharged downward at 65 ft/second toward a target 18 inches below point of discharge (relative humidity = 50%) (H. E. Ozkan, Ohio State University).

Initial Droplet Size (Micron, μm)	Wind Velocity (mph)	Final Droplet Size (DS) and Drift Distance (DD) with varying Temperature (degrees F)					
		50°F		68 °F		86 °F	
		DS (μm)	DD (ft)	DS (μm)	DD (ft)	DS(μm)	DD (ft)
70	1.1	59.4	5.18	43.6	6.30	0.0	12.50*
70	5.6	59.2	26.14	42.7	32.14	0.0	38.70*
70	11.1	59.0	52.48	41.9	64.61	0.0	70.19*
70	22.4	58.8	105.94	40.4	132.18	0.0	132.51*
150	1.1	149	0.59	148	0.59	147	0.59
150	5.6	149	2.72	148	2.85	147	2.98
150	11.1	149	5.58	148	5.74	147	6.04
150	22.4	149	11.97	148	12.27	147	12.82
300	1.1	300	0.03	300	0.03	299	0.03
300	11.1	300	0.33	300	0.33	299	0.33
300	22.4	300	0.69	300	0.69	299	0.69

* Droplet completely evaporated before deposition.

Table 4 illustrates that with larger droplet sizes, temperature and relative humidity have little effect on spray drift distance.

Table 4. Effect of relative humidity (RH) and ambient temperature on average drift distances of various size water droplets directed downward at 65 ft/second toward a target 18 inches below point of discharge (wind velocity = 10 mph) (H. E. Ozkan, Ohio State University).

Droplet Size (Micron, μm)	Ambient Temp. (Degrees F)	Drift Distances (ft) with varying RH		
		RH 20%	RH 60%	RH 100%
50	55	63.32*	60.87*	76.78
50	85	30.81*	44.81*	80.34
150	55	4.65	4.62	4.59
150	85	4.76	4.70	4.58
300	55	0.98	0.95	0.95
300	85	0.93	0.93	0.93

* Droplet completely evaporated before deposition.

Table 5 illustrates that spray drift can be managed with lower boom heights and larger droplet sizes.

Table 5. Effect of droplet discharge height (nozzle height) and wind velocity on drift distances of various size droplets discharged downward at 65 ft/second toward a target (temperature: 70 degrees F; relative humidity: 50%) (adapted from H. E. Ozkan, Ohio State University).

Initial Droplet Size (micron)	Wind Velocity (mph)	Drift Distances (ft) with varying Nozzle Height (Noz Ht)			
		Noz Ht 1 ft	Noz Ht 1.5 ft	Noz Ht 2 ft	Noz Ht 3 ft
50	4	23.51*	23.72*	23.80*	23.98*
50	10	51.48*	52.29*	52.89*	53.43*
150	4	0.57	1.82	3.57	7.49
150	10	1.43	4.55	8.92	18.75
300	4	0.05	0.10	0.24	0.79
300	10	0.12	0.26	1.04	1.97

* Droplet completely evaporated before deposition.

Let's review the status of the Drift Reduction Technology (DRT) Program:

Agricultural Pesticide Spray Drift Reduction Technologies Voluntary Program, Federal Register Volume 79, Number 199 (Wednesday, October 15, 2014), includes the following comments:

The drift reduction suggested by the study results will be used to assign the tested DRT a drift reduction rating. The four DRT ratings represented by one, two, three or four stars are awarded for technologies that demonstrate at least 25% reduction in potential spray drift as compared to the test standard nozzle. The greater the number of stars, the greater the potential reduction of spray drift.

★ – 25-49% reduction
★★ – 50-74% reduction
★★★ – 75-89% reduction
★★★★ – 90+% reduction

EPA on Adding DRT Instructions to Pesticide Labels

We encourage pesticide registrants to submit applications for including the use of verified drift reduction technologies to their product label use directions. Applications for this label claim must be submitted according to standard requirements and procedures for applications for registration.

Pesticide registration applicants and registrants can choose to label their products for use with both standard application equipment (non-DRT) and DRT-related equipment or technologies, thus giving the applicator a choice. In this case, labels would have two sets of application restrictions:

- One set of restrictions if the product is applied without DRT.
- Another set of restrictions if the product is applied using a DRT.

Drift reduction ratings could appear soon on pesticide labels. Look for information about use of DRT in the Directions for Use.

Some new pesticides like Dow Agro Sciences Enlist Duo have a chart that details nozzles and pressures that are allowable when applying Enlist Duo herbicide. It goes on to state "do not use any nozzle and pressure combination not specifically allowed in the chart." Some examples in the chart are:

ABJ Agri	ABJ11004	MAX 40 PSI
GreenLeaf	TDXL11004	MAX 45 PSI
Hypro	ULD12004	MAX 70 PSI
Lechler	ID11004	MAX 40 PSI
TeeJet	AIXR11004	MAX 40 PSI
Wilger	MR11006	MAX 60 PSI

2017 Guide for Weed, Disease, and Insect Management in Nebraska EC130

Many pesticide labels now list recommended or required spray droplet size(s) for application. Follow the label guides to increase pesticide efficacy and help manage spray drift. Droplet size classes are based on British Crop Production Council (BCPC) specifications and in accordance with American Society of Agricultural and Biological Engineering (ASABE) standard S572.1. Following are examples of charts in the Guide.

Top of first Page of 4 in Guide (EC 130)

Pesticides listing the recommended or required spray droplet size and carrier rate on the label. Always check the label before applying.

Herbicides

Herbicides	*Drop Size Classification*	*Ground Application GPA*	*Herbicides*	*Drop Size Classification*	*Ground Application GPA*
2,4-D amine	C	8 to 20+	Ally Extra SGW/TOTSOL	Largest Droplet Size	Minimum 5 to 20
2,4-D ester #4	C	10+	Ally 60XP	Largest Droplet Size	Minimum 3 - 20
2,4-D ester #6	C	10+	Broadaxe SE	Minimal Amts of Fine Spray	Minimum 10
AAtrex 4L	C	Minimum 10	Butyrac 200	C-but nozzle types that will provide adequate coverage	Minimum 10
AAtrex Nine-O	C	Minimum 10	Cadet	M – C	Min 15; up to 40 for dense canopy or weeds
Accent Q	M - C	Minimum 15	Callisto 4SC	M to C	PRE: 10 to 60 & POST: 10 to 30
Acuron	M to C	Pre-Emergence 10 - 80 & Post Emergence 10 - 30	Calisto XTRA	M to C	10 to 30
Affinity BroadSpec	Largest Droplet Size	Minimum 5 to 20	Canopy DF	C to VC	Minimum 10
Agility SG	Largest Droplet Size	Minimum 5 to 20	Canopy EX	M, C	Minimum 20
Aim EC	Min. Amt of Fine Spray Droplets	Minimum 10	Capreno	M to C	Minimum 10

2 Nozzle Charts of 12 in Guide (EC130)

For Medium (M) Spray Quality 10 GPA				
	Nozzle Spacing			
Speed mph	**Rate gpm**	**20-inch**	**Rate gpm**	**30-inch**
6	0.202	TT11002@41psi	0.303	TT11003@41psi*
7	0.236	TT110025@36psi**	0.354	XRC11004-VK@31psi or TT11003@56psi
8	0.269	TT110025@ 46psi	0.404	XRC11005-VK@26psi or TT11004@41psi*
10	0.337	XRC11004-VK@28psi or TT11003@50psi**	0.505	XRC11006-VK@28psi
12	0.404	XRC11005-VK@26psi	0.606	XRC11006-VK@41psi
14	0.471	XRC11006-VK@25psi	0.707	XRC11008-VK@31psi*

*Just into the next larger spray drop size with water-many pesticides and additives reduce the spray drop size
**Just into spray drop size

TT110025

XRC11004-VK

For Ultra Coarse (UC) Spray Quality 15 GPA						
		Nozzle Spacing				
Speed mph	**Rate gpm**	**20-inch**	**Rate gpm**	**15-inch**	**Rate gpm**	**30-inch**
6	0.303	TTI11003@41psi	0.227	TTI110025@33psi	0.455	TTI11005@33psi
7	0.354	TTI11004@31psi	0.265	TTI11003@31psi	0.530	TTI11006@31psi
8	0.404	TTI11004@41psi	0.303	TTI11003@41psi	0.606	TTI11006@41psi
10	0.505	TTI11005@41psi	0.379	TTI11004@36psi	0.758	AIC11008-VK@36psi
12	0.606	TTI11006@41psi	0.455	TTI11005@33psi	0.909	AIC11010-VK@33psi
14	0.707	TTI11006@56psi	0.530	TTI11006@31psi	1.061	TF-VS7.5@20psi

TTI11004

TF-VS7.5

Management of Glyphosate (Group 9) and ALS-Resistant (Group 2) Kochia (*Kochia scoparia*) in the Panhandle

Nevin Lawrence, Weed Management Specialist for the Panhandle of Nebraska
Cody Creech, Dryland Cropping Systems Specialist

Kochia has been a problem weed in the panhandle for decades. Before the arrival of RoundUp® Ready crops, kochia became resistant to the triazine class of herbicides (group 5) as atrazine was commonly used in both corn and in dryland fallow rotations. Following the development of sulfonylurea chemistries, kochia quickly became resistant to the ALS-inhibiting herbicides as well. In 2011 glyphosate resistant-kochia was confirmed in Nebraska for first time. In hindsight, the arrival of glyphosate-resistant kochia populations in Nebraska should not have come as a surprise. Glyphosate is used in virtually every crop in the Panhandle, as a burn-down treatment before planting, as a POST applied herbicide in RoundUp Ready® crops, or to control weeds in fallow systems. Depending on the crop rotation, a particular field can easily see 2-3 applications of glyphosate every year, often without any other herbicide being used in the system. As the use of atrazine has decreased, so has the incidence of triazine-resistant kochia. This is because kochia resistant to triazine herbicides produces less seed and grows more slowly than a "normal" kochia biotype. This isn't the case with ALS or glyphosate-resistance, which do not subside once they are present in a population.

Dryland Cropping Systems

Kochia can be outcompeted by a competitive winter wheat stand, and tends to be more prevalent in areas where the stand is thinner. Kochia will typically become noticeable in healthy wheat stands near harvest or soon after harvest when little crop competition remains. This period post-harvest, or during the fallow period where no crop is grown for a year, kochia can be more difficult to control. To complicate control in fallow, most herbicide programs rely on glyphosate applied multiple times a year to control weeds. As a burndown or in fallow, simply adding 2,4-D or dicamba as a tank mix partner with glyphosate is often not effective enough to achieve consistent control of glyphosate resistant-kochia especially when not used at higher rates. Using glyphosate tank-mixtures with 2,4-D, dicamba, fluroxypyr containing products, or MCPA at sufficiently high rates with appropriate adjuvants per label instructions is the best method to obtain satisfactory chemical control. Gone are the days of using partial or lower herbicide rates and still be able to achieve good results. Timely applications when weeds are small and with appropriate adjuvants cannot be emphasized enough. Kochia growing in hot and dry environments uses different biological methods to protect itself. Adjuvants help the herbicides to get through these barriers and into the plants. In some cases, tillage could be used to limit seed going back into the seed bank.

Irrigated Cropping Systems

Kochia is among the earliest emerging summer annual weeds, with germination starting in early March. However, the bulk of kochia emergence occurs in early April. What this means for corn and sugarbeet production is that a competitive population of kochia can be well established before planting. Early weed control is essential to prevent yield loss in both corn and sugarbeet. In corn, multiple herbicides are available that can provide control of glyphosate or ALS-resistant kochia both in conventional or limited-till production systems (Table 1). In sugarbeet, PRE or POST emergent herbicides offer limited control of kochia. UpBeet can provide control of populations not resistant to ALS-inhibiting herbicides, but the majority of kochia populations in the Panhandle are resistant to this mode of action. The best option in sugarbeet is adding Norton PRE, which does have activity on both glyphosate and ALS-resistant kochia. However, Nortron only provides around

40-60% control, when applied at rates greater than 24 fl oz per acre.

With limited options to control herbicide-resistant kochia in sugarbeet, it becomes essential to use rotational strategies to prevent new seed from entering the soil seed bank. This is a particularly effective strategy for kochia as kochia seed is only viable for 2-3 years. Corn is a good choice for a rotational crop because of the many herbicide options available to control herbicide-resistant kochia. Winter wheat or dry beans are also good options for rotation with sugarbeet. By the time dry beans are planted, the bulk of kochia emergence has already occurred, which makes it possible to control the weed through tillage or non-selective herbicides before competition or seed production can take place. Winter wheat is likely the best rotation option. Research trials conducted at the Panhandle-REC have demonstrated that wheat can completely suppress the emergence of kochia even when no herbicide was applied. If kochia does emerge within an irrigated wheat canopy, there are several herbicides available to control kochia.

Herbicide options for controlling glyphosate and ALS-resistant kochia.

Herbicide	Timing	Rate (per acre)
———Corn (will allow rotation to dry beans or sugarbeets)———		
Valor + 2,4-D (4 lb)	14 DBP[A]	2 fl oz + 16 fl oz
Verdict[B]	PRE	15 fl oz
Dicamba + 2,4-D	POST	8 fl oz + 4 fl oz
Starane Ultra + 2,4-D	POST	6.4 fl oz + 4 fl oz
———Irrigated or Dryland Small Grains and Fallow ———		
Huskie + 2,4-D (4 lb)	POST	14 fl oz + 8 fl oz
Huskie + MCPA	POST	14 fl oz + 12 fl oz
Widematch	POST	1 pt
Curtail M	POST	2 pts
Curtail	POST	2 pts
Dicamba + 2,4-D	POST	6 fl oz + 8 fl oz

[A] Abbreviations: DBP, Days Before Planting; PRE, pre-emergent herbicide; POST, post-emergent herbicide.

[B] Will require an addition of another herbicide to control emerged weeds.

*See EC-130 and product labels for information regarding required adjuvants and additional use instructions.

Management of ALS-Resistant (Group 2) Palmer Amaranth (*Amaranthus palmeri*) and Waterhemp (*Amaranthus tuberculatus*) in the Panhandle

Nevin Lawrence, Weed Management Specialist for the Panhandle of Nebraska

Palmer and waterhemp are a recent arrival to the Panhandle, only becoming widespread in the past few years. Palmer and waterhemp are thought to have spread from the South and Midwest through contaminated grain and cotton seed used for cattle and dairy feed. Subsequently, Palmer and waterhemp spread into production fields through manure sourced from dairies and feedlots. Both species of Palmer and waterhemp are related to redroot pigweed (*Amaranthus retroflexus*), prostrate pigweed (*Amaranthus blitoides*), and tumble pigweed (*Amaranthus albus*). In the Panhandle, Palmer and waterhemp are only found where irrigation is present. Both species can be characterized by their season-long emergence, and larger size and faster growth compared to other pigweed species. Palmer can be identified by its long petiole length in comparison to other pigweed species. Waterhemp can be identified by its unique lanceolate shaped leaves. Please see EC94-138 for additional information regarding ID.

Biology.

Both species can germinate throughout the growing season, usually starting in late May and extending through July. If uncontrolled, early emerging Palmer and waterhemp can produce over a hundred thousand seeds per plant, and can significantly reduce crop yield or even interfere with harvest equipment. Although both species can emerge even after the last herbicide application is made, late emerging plants produce very little seed and will not impact crop yield. Therefore, it is essential to control Palmer and waterhemp as early as possible. Research has shown the most effective herbicide programs are those using both PRE and POST herbicide applications. Using a PRE treatment extends the time before a POST treatment is necessary as soil applied herbicide can control weeds for several weeks. Compared to a POST only program, PRE/POST herbicide programs do a better job at controlling weeds in the early part of the season where crop yield is most impacted and where weed species are most susceptible to control inputs.

Control in Dry Beans.

Both Palmer and waterhemp in the Panhandle are resistant to ALS-inhibiting herbicides. The resistance likely did not emerge in the Panhandle Rather, already resistant populations were unintentionally brought in from other areas. For corn and sugarbeet production, there are effective herbicide options to control Palmer. In dry beans, effective PRE herbicides are available to control pigweed species. However, Palmer and waterhemp will continue to emerge after PRE herbicides have lost their efficacy. POST herbicide options are extremely limited in dry beans. Palmer and waterhemp are resistant to both Raptor and Pursuit, while Basagran and Varisto do not provide effective control. The only effective POST applied herbicide option in dry beans is Reflex. However, the Reflex label does not allow planting of corn for 10 months following an application. Given the limited options for control in dry beans, controlling Palmer in rotation is paramount. Corn, irrigated small grains, and sugarbeet all make good rotation options for controlling Palmer and waterhemp within the Panhandle.

Pigweed Control in the Near Future.

Palmer and waterhemp resistance issues are likely to get worse in the near future. Although not currently present in the Panhandle, within the state of Nebraska populations of Palmer and waterhemp have confirmed resistance to herbicide mode-of-action groups 4 (synthetic auxins), 5 (triazines), 9 (glyphosate), and 27 (HPPD inhibitors). Although additional cases of resistance are mostly associated with corn and soybean production, in southwest Nebraska a population of glyphosate-resistant Palmer has been found in a sugarbeet field. These resistant populations will continue to spread and become more prevalent with time.

In sugarbeet, glyphosate will currently control Palmer and waterhemp in the Panhandle. Growers should be anticipating the eventual arrival of glyphosate-resistant Palmer in sugarbeet. Nortron applied PRE at 32 fl oz per acre will control pigweed species early in the season. If resistance is suspected after a failed glyphosate application Betamix + Stinger is the most effective treatment to control glyphosate-resistant palmer. However, control will decrease as Palmer exceeds 4” in height.

redroot pigweed prostrate pigweed tumble pigweed Palmer amaranth waterhemp

Common pigweed species found in the Panhandle of Nebraska. Palmer amaranth and waterhemp are ALS-resistant. From right to left: redroot pigweed, prostrate pigweed, tumble pigweed, Palmer amaranth, and waterhemp. Top images are of seed, middle images are of seedlings, and bottom images are of plants in the vegetative phase of growth. Please see EC94-138 for additional information on identification, available at digitalcommons.unl.edu. Photos are taken from EC94-138.

Glyphosate-Resistant Marestail (Horseweed)

Stevan Knezevic, Integrated Weed Management Specialist

Weed resistance to herbicides is not a new thing. It began to occur as soon as man started using chemicals for weed control. One of the earliest cases of weed resistance occurred about 50 years ago in pigweed species showing resistance to atrazine. There is well-documented literature about weed resistance: for example, 40 broadleaf and 15 grassy species are known to have biotypes resistant to triazine herbicides. (www.weedscience.com). Repeated use of the same herbicide was the main reason for weed resistance to herbicides worldwide.

The crop rotation of glyphosate-tolerant soybean with glyphosate-tolerant corn resulted in repeated use of glyphosate-based herbicides creating a single selection pressure on weed populations. Therefore, special attention should be given to proper management of herbicide-tolerant crops to avoid the evolution of glyphosate-resistant weed populations. Prior to the introduction of glyphosate-tolerant crops there were only few weed species known to have evolved resistance to glyphosate worldwide. Resistance resulted from repeated glyphosate applications in species such as rigid ryegrass (*Lolium rigidum*) in Australia and California and goosegrass (*Eleusine indica*) in Malaysia. However, the number of glyphosate-resistant weeds increased to over 25 worldwide, 16 in the US and 6 in Nebraska. It is estimated that over 30 million acres of cropland is affected by glyphosate-resistant marestail across the US.

Current examples of glyphosate-resistant weeds in Nebraska include waterhemp (*Amaranthus rudis* Sauer), horseweed (marestail) (*Conyza canadensis*), giant ragweed (*Ambrosia trifida*), common ragweed (*Ambrosia artemisiifolia*), kochia (*Kochia scoparia*), and palmer amaranth (*Amaranthus palmeri*).

In 2006, horseweed (marestail) was the first weed species confirmed resistant to glyphosate in only one county of Nebraska (Knezevic et al. 2006). Now, 10 years later, there are populations of horseweed with various levels of resistance to glyphosate in almost each county in central and eastern Nebraska as well as 18 other US states. Based on UNL surveys, glyphosate resistance levels ranged from 3-8X the labeled rate, depending on the variability (segregation) within a population. For example, within a given population, some plants are still susceptible and can be controlled by glyphosate, while some have a 2-3X resistance level, or the remaining plants could have as much as a 6-8X resistance level.

What does glyphosate resistance mean to Nebraska producers?

It means that it is time to re-evaluate the weed control strategies in Roundup-Ready crops. Continuous use of a single mode-of-action (e.g., glyphosate) will lead to an increase in populations of other glyphosate-resistant weeds, including the further spread of glyphosate-resistant marestail.

Biology of Marestail

To stop the spread of glyphosate-resistant marestail, it is important to understand its biology and growth habits. As a winter annual (or early germinating summer annual) weed, marestail can germinate in fall and/or spring. The key to successful control of marestail is to control it in the seedling and rosette stages. A rosette is a cluster of circularly arranged leaves, which start forming within a week or two after seedling emergence. Since seeds can germinate in the fall and spring, rosettes can be seen in October-November and March through May. The rosette stage can last for several weeks in spring, followed by stem elongation, the stage known as bolting. Marestail can reach 5-6ft heights, depending on the growing conditions. Seedling and rosette growth stages are the most susceptible to herbicides (or tillage); thus, you should keep that in mind as you plan your weed control program.

Fall Control of Marestail

Marestail seeds can germinate as early as September, and start growing under the corn or soybean canopy. Rosettes can green-up easily under the crop canopy because there is enough light penetrating the crop's canopy as the leaves start senescing in September-October. Therefore, rosettes can be seen during both soybean and corn harvests.

Rosettes are relatively easy to control with fall-applied herbicides. The key is to apply herbicides at least 4-5 days before cold weather. Most POST herbicides require a minimum of 50ºF nights and 60ºF daytime temperatures for 4-5 days in order to effectively translocate within the plant. Several herbicide options are available for fall burndown in both corn and soybean: for example, 2,4-D+dicamba can provide 80-90% control of rosettes with no crop rotational restrictions. Check the "Weed Response to Fall Burndown Herbicides" tables in the corn and soybean sections of the 2016 Weed Guide for other herbicide options.

Spring Control of Marestail Before Crop Planting

If not controlled in the fall, rosettes will remain dormant during wintertime and then start greening up as early as March. Marestail seeds can also germinate in spring (even under snow cover), producing new seedlings and rosettes by April. Regardless of whether rosettes are produced in fall or spring, they can be controlled by using spring burndown treatments (before crop planting).

As with fall treatments, follow local weather predictions closely, and avoid applying herbicides when cold fronts are expected. Most POST herbicides require a minimum of 50ºF night and 60ºF daytime temperatures for 4-5 days after application. Cold weather can reduce herbicide activity and efficacy by as much as 50%.

Based on our 2015 studies, about 90% control of marestail rosettes in soybean was achieved with spring burndown application of several herbicide combinations, including Clarity (1pt/acre)+ValorSX (2.5oz/acre); Clarity (1pt/a)+Fierce (3oz/a); Clarity(1pt/a)+Afforia (2.5oz/a); Cadet (0.5oz/a)+2,4-D (12oz); Anthem (8oz/a)+Sharpen (1oz/a); 2,4-D (12oz)+Sharpen(1oz/a), Corvus (5.6oz/a); or Sharpen (1oz/a). Other herbicides are also available: check the "Weed Response to Spring Burndown Herbicides" tables in the corn and soybean sections of the 2016 Weed Guide.

Alternatively, tillage can also be used effectively to control rosettes, either as light disking or field preparation for crop planting. Also, crops should not be planted into an existing stand of marestail unless burndown or pre-emergence herbicides with burndown activity are to be applied soon after crop planting.

Post-Emergence Control of Marestail

Post-emergent control (control after crop emergence) of marestail can be challenging due to its rapid stem elongation and the limited number of effective herbicide options, especially when the plants reach 6-12" in height. Taller marestail plants are even harder to control, especially those that are 2-3' tall. For example, there was only 50-60% control of 8" tall marestail in corn with 8oz or 16oz of 2,4-D LV ester, and about 70% with 8oz of Clarity.

Marestail control in soybean can be harder yet. Most herbicides listed in the Weed Guide have ratings between 5 and 8, which means 50-80% control. For more details, check the "Broadleaf Weed Response to Foliar-Applied Herbicides" tables in the 2016 Weed Guide for other options in both corn and soybean.

General Guidelines for Resistance Management

Regardless of the type of weed resistance, growers can use these guidelines for reducing the chance for glyphosate resistance at any farm:

1. Scout fields prior to the application of any herbicide to determine the weed species.
2. Scout your field after herbicide application to look for weed survivors. It takes 10-15 days for glyphosate to kill a weed. It is important to note that many glyphosate resistant weeds may show initial susceptibility to glyphosate (e.g., exhibit the appearance of a "dead weed"). However, the weed that appeared to be dead can regrow a week or two later from the top of the plant (meristematic growth) or the side (secondary buds, in the form of branches). A branch will take over as a new stem, producing a new plant with resistant seeds for future infestations.
3. Rotate herbicides, and avoid using the same herbicide mode-of-action in the same field in sequential growing seasons or more than once per year.
4. Limit the number of applications of glyphosate, or any other single herbicide, in a single growing season.
5. Use mixtures of POST herbicides that each control the weeds in question, but have a different site-of-action. Some POST broadleaf herbicides will also provide additional soil residual activity for prolonged weed control. Use residual-based herbicides when possible.
6. Plant into a weed-free field. Use other herbicides alone or with glyphosate as burndown treatments for winter annuals including horseweed either in the fall or spring before crop planting, as it is easier to control those species while they are small.
7. In glyphosate-resistant crops, use soil-applied herbicides followed by a single application of glyphosate. This will provide additional modes-of-action for weed control, thus reducing the chance of weed resistance. Soil-applied herbicides will also provide a longer "comfort zone" for weed control early in the season by delaying the critical time for weed removal and reducing the need for multiple glyphosate applications later in the season.
8. Scout fields after application to detect weed escapes or changes in weed species composition (weed shifts). If a potentially resistant weed has been detected, use alternative control methods to prevent the weed from producing seeds.
9. Use alternative weed management practices, such as mechanical cultivation, spot spraying with different herbicides, delayed planting, and weed-free crop seeds.
10. Clean equipment before leaving fields infested with or suspected to have resistant weeds.

It is easy to fall into a trap of overusing glyphosate, versus combinations of pre-emergence herbicides or tank-mix partners, especially when one glyphosate-resistant crop is grown after another. Therefore, proper stewardship of herbicides in herbicide-tolerant crops, as a component of an integrated weed management program, is the key to preventing further spread of resistance.

Control of Glyphosate-Resistant Giant Ragweed in Soybean and Corn

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Glyphosate-Resistant Giant Ragweed

Giant ragweed (*Ambrosia trifida* L.), a member of Asteraceae family, is an annual, broadleaf species that is native to the United States and it is found throughout North America and several other continents. Giant ragweed has been common throughout the eastern United States, and in recent years the weed has become more problematic in Illinois, Iowa, Minnesota, and Nebraska.

Repeated use of herbicides with the same mode-of-action can impose selection pressure for resistance within or among weed species that have previously been susceptible. For example, a widespread and repeated use of the acetolactate synthase (ALS)-inhibiting herbicides resulted in the evolution of ALS inhibitors-resistant giant ragweed. In 2005, a giant ragweed biotype in Ohio was reported to have reduced sensitivity to glyphosate. In 2007, glyphosate-resistant giant ragweed was confirmed in Tennessee, and now it has been confirmed in several states including Arkansas, Indiana, Iowa, Kansas, Minnesota, Mississippi, Missouri, Nebraska, Ohio, and Wisconsin. Therefore, management of glyphosate-resistant giant ragweed is not only a challenge in soybean fields in Nebraska, but also in several other states and crops.

Control of giant ragweed in Roundup Ready Soybean

Field experiments were conducted at David City, NE for control of glyphosate-resistant giant ragweed in Roundup Ready soybean in 2012 and 2013. Burndown applications of 2,4-D followed by PRE or POST herbicide treatments were effective for control of glyphosate-resistant giant ragweed. PRE or POST herbicides prevented regrowth of the partially controlled giant ragweed plants that survived the burndown treatments. For example, OpTill, Boundry, or Authority First applied PRE resulted in 99% control of giant ragweed (Table 1). Similarly, FirstRate, Classic, Flexstar, Pursuit, or Cobra tank-mixed with Warrant resulted in 85 to 97% control of giant ragweed at 7 days after POST treatment (DAPT) with no difference between them. Poor control of giant ragweed (≤ 68%) was usually observed when the burndown-only treatments were not followed by PRE or POST herbicides at 30 DAPT (Table 1).

Control of giant ragweed in Liberty Link Soybean

Field experiments were conducted at David City, NE for control of glyphosate-resistant giant ragweed in Roundup Ready soybean in 2012 and 2013. Treatments including Liberty, Gramoxone, or Sharpen applied alone or in tank mixes resulted in 91 to 97% giant ragweed control at 7 days after burndown treatment (DABT) (Table 2). Although comparable with several other treatments, 2,4-D and Sharpen alone or in tank mixes resulted in 88 to 99% giant ragweed control at 21 DABT. Liberty applied alone or in tank mixes was effective for control of giant ragweed and prevented regrowth from any partially controlled plants that were not completely eliminated with the burndown treatment. Preplant herbicides followed by early POST application of Liberty usually resulted in 88 to 100% giant ragweed control at 7 days after treatment. Although comparable with several other treatments, 2,4-D applied alone or with Sharpen resulted in 99% giant ragweed control. This indicated that preplant program was critical for early season control of giant ragweed (Table 2).

Control of giant ragweed in Roundup Ready Corn

Field studies were conducted at David City, NE to evaluate commonly used PRE and POST herbicides to control glyphosate-resistant giant ragweed in Roundup Ready corn in 2012 and 2013. Visual estimates recorded 30 days after treatment (DAT) indicated that applications of any of the 12 treatments provided at least 90% control (Table 3). For example, PRE application of 2 qt of atrazine followed by 16 oz/A of 2,4-D at V4 corn provided 100% control at 60 DAT.

Conclusion

Glyphosate-resistant giant ragweed can be effectively controlled in Roundup Ready and Liberty Link soybean. Preplant application of several herbicides, including 2,4-D, Valor, Liberty, Gramoxone, Sharpen, and Authority alone or in tank mixes followed by PRE and POST herbicides resulted in season-long giant ragweed control and greater soybean yields. Several herbicides have been tested for control of giant ragweed in corn. An integrated management approach should be adopted that may include tillage, use of herbicides with different site-of-action, rotation of herbicide-resistant trait, and crop rotation for control of glyphosate-resistant weeds.

Table 1. Control of glyphosate-resistant giant ragweed in Roundup Ready soybean (Abbreviations: DABT, days after burndown treatment; *fb*, followed by; DAPOST, days after post-emergence treatment).

Herbicide Treatment[a]	Application timing	Rate	Giant ragweed control after burndown treatments[b,c]			Giant ragweed control after POST herbicide treatments[b,c]		
			7 DABT	14 DABT	21 DABT	7 DAPOST	30 DAPOST	At harvest
		Oz/Acre	%					
Nontreated Control	-	-	0	0	0	0	0	0
Roundup PowerMax *fb*	Burndown	22	36 d	54 b	56 b	43 c	46 b	10 c
Roundup PowerMax	POST	22						
2,4-D Amine 4 *fb*	Burndown	16	63 b	87 a	92 a	93 a	92 a	89 ab
Roundup PowerMax	POST	22						
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	64 b	98 a	99 a	99 a	99 a	99 a
fb OpTill	PRE	2						
OpTill + Roundup PowerMax	Burndown	2 + 22	93 a	94 a	89 a	85 a	68 b	63 b
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	66 b	98 a	99 a	99 a	99 a	99 a
fb Boundary	PRE	36						
Boundary + Roundup PowerMax	Burndown	36 + 22	28 d	48 b	51 b	41 c	23 c	5 c
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	64 b	94 a	99 a	99 a	97 a	96 a
fb Authority First	PRE	6						
Authority First + Roundup PowerMax	Burndown	6 + 22	51 c	64 b	65 b	50 c	47 b	25 c
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	64 b	86 a	87 a	85 a	89 a	87 ab
fb FirstRate+ Warrant	POST	0.3 + 68						
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	65 b	92 a	95 a	97 a	93 a	90 ab
fb Classic + Warrant	POST	0.33 + 68						
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	65 b	94 a	96 a	96 a	95 a	95 a
fb Pursuit + Warrant	POST	4 + 68						
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	65 b	94 a	93 a	97 a	90 a	89 ab
fb Cobra + Warrant	POST	12.5 + 68						
2,4-D Amine 4 + Roundup PowerMax	Burndown	16 + 22	65 b	91 a	92 a	94 a	95 a	94 a
fb Flexstar + Warrant	POST	16 + 68						

[a] Roundup PowerMax was applied at 22 fl oz/A + 17 lb/100 gal of AMS late-POST for control of late emerging weeds

[b] Data were arc-sine square-root transformed before analysis; however, data presented are the means of actual values for comparison based on interpretation from the transformed data.

[c] Means within columns with no common letter(s) are significantly different according to Tukey-Kramer's pairwise comparison test at $P \leq 0.05$.

Table 2. Control of glyphosate-resistant giant ragweed at 7, 14, and 21 days after burndown treatment (DABT) and 7 and 21 days after early POST (DAEP) treatment, and at harvest in Liberty Link soybean at David City, NE.

Herbicide[a]	Application timing	Rate	Giant ragweed control after preplant treatments[b,c]			Giant ragweed control after POST herbicide treatments[b,c]		
			7 DABT	14 DABT	21 DABT	7 DAEP	21 DAEP	At harvest
		Oz/Acre	%					
Nontreated control[e]	-	-	0	0	0	0	0	0
OpTill + Outlook *fb*	Preplant	2 + 10	91 ab	93 a	97 a	97 ab	99 a	99 a
Liberty	Early POST	29						
Authority First *fb*	Preplant	7	68 c	75 ab	88 ab	95 abc	95 a	92 ab
Liberty	Early POST	29						
Valor XLT *fb*	Preplant	3	70 bc	79 ab	79 ab	91 c	94 a	70 abc
Liberty	Early POST	29						
Boundary *fb*	Preplant	36	21 d	31 c	35 d	79 c	53 b	25 c
Liberty	Early POST	29						
Enlite *fb*	Preplant	2.8	69 bc	58 b	50 cd	80 bc	60 b	32 bc
Liberty	Early POST	29						
2,4-D Amine *fb*	Preplant	16	66 c	90 a	98 a	99 a	99 a	99 a
Liberty + Pursuit	EarlyPOST	29 + 4						
Roundup PowerMax *fb*	Preplant	22	41 d	32 c	33 d	94 abc	94 a	89 abc
Liberty + FirstRate + Warrant	EarlyPOST	29 + 0.3 + 68						
Gramoxone SL *fb*	Preplant	32	91 ab	77 ab	80 ab	88 abc	90 a	76 abc
Liberty + Classic + Warrant	EarlyPOST	29 + 0.33 + 68						
Liberty 280 *fb*	Preplant	29	91 ab	94 a	91 ab	93 abc	96 a	90 abc
Liberty *fb*	EarlyPOST	29						
Cobra	LatePOST	12.5						
Sharpen *fb*	Preplant	1	97 a	96 a	93 ab	91 abc	90 a	80 abc
Liberty + Warrant	EarlyPOST	29 + 68						
Sharpen + 2,4-D Amine *fb*	Preplant	1 + 16	95 a	99 a	99 a	100 a	99 a	99 a
Liberty + Warrant	EarlyPOST	29 + 68						
Sharpen + Roundup PowerMax *fb*	Preplant	1 + 22	91 ab	96 a	94 a	97 abc	98 a	97 ab
Liberty + Warrant + Pursuit	EarlyPOST	29 +68 + 4						

[a] All herbicide treatments were followed by late POST application of Liberty at 29 fl oz/A + ammonium sulfate 17 lb/100 gal.
[b] Data were arc-sine square-root transformed before analysis; however, data presented are the means of actual values for comparison based on interpretation from the transformed data.
[c] Means within columns with no common letter(s) are significantly different according to Tukey-Kramer's pairwise comparison test at $P \leq 0.05$.

Table 3. Control of glyphosate-resistant giant ragweed in Roundup Ready corn.

Product (PRE)	Rate/Acre	Growth Stage	Product (POST)	Rate Oz/Acre	Growth Stage	~30 DAT	~60 DAT
Nontreated Check	-	-	-	-	-	0	0
Atrazine	2 qt	PRE	2,4-D	16 oz	POST	93	100
Balance Flexx	6 oz	PRE	2,4-D	16 oz	POST	94	100
Balance Flexx + Atrazine	6 oz+1 qt	PRE	2,4-D	16 oz	POST	95	100
Callisto	6 oz	PRE	Hornet	5 oz	POST	88	100
Corvus	5.6 oz	PRE	2,4-D	16 oz	POST	95	100
-	-	-	2,4-D	16 oz	POST	0	91
Guardsman Max	4 pt	PRE	2,4-D	16 oz	POST	93	100
Lumax EZ	2.7 qt	PRE	2,4-D	16 oz	POST	94	100
Sharpen	3 oz	PRE	Distinct	6 oz	POST	69	100
Verdict	16 oz	PRE	Status	5 oz	POST	87	100
Zemax	2 qt	PRE	Status	5 oz	POST	89	100

All post-emergence treatments included NIS and AMS; results averaged from 2 studies

Control of Glyphosate-Resistant Common Waterhemp in Roundup Ready and Liberty Link Soybean

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Glyphosate-Resistant common waterhemp

Common waterhemp is a summer annual weed and it is one of the difficult-to-control weeds in the Midwestern United States. Widespread adoption of conservation tillage and evolution of herbicide-resistance resulted in dominance of small-seeded broadleaf weed species such as common waterhemp in corn-soybean production system.

Common waterhemp has a rapid growth habit, extended germination window (May to August), and potential for producing over a million seeds per plant, that have contributed to the success of this weed species. It is a highly competitive weed that reduces corn and soybean yield significantly. Furthermore, common waterhemp is a dioecious species, which means male and female flowers occur on two different plants, that requires the movement of pollen for successful reproduction. So the herbicide-resistant traits can travel a long distance via pollen-movement and outcrossing.

Glyphosate, a broad-spectrum nonselective POST herbicide, was first commercialized in 1974. The label of Roundup PowerMax (glyphosate) herbicide lists over 100 annual broadleaf and grass weeds and almost 60 perennial weed species that can be controlled. The use of glyphosate changed dramatically after 1996 with the commercialization of glyphosate-tolerant crops. According to the recent report of USDA, 94% of soybean and 89% of corn grown in 2014 were herbicide-tolerant; and primarily glyphosate-tolerant. Wide-spread adoption of glyphosate-tolerant crops has increased farmers' reliance on glyphosate in weed management programs by replacing residual soil-applied herbicides and other POST herbicides.

Over-reliance on any particular herbicide may create a selective advantage for a specific resistant weed species. In Nebraska, eight weed species (common waterhemp, common ragweed, giant ragweed, kochia, marestail, Palmer amaranth, redroot pigweed, and shattercane) have been confirmed resistance to at least one mode-of-action of herbicide and six of them are resistant to glyphosate. The first glyphosate-resistant common waterhemp in the United States was confirmed in Missouri in 2005, but by 2014 glyphosate-resistant common waterhemp has been confirmed in 13 states.

Glyphosate-Resistant Common Waterhemp Confirmed in Nebraska

In the fall of 2012, seedheads of common waterhemp plants that survived repeated glyphosate applications were collected from fields of seven eastern Nebraska Counties (Antelope, Dodge, Fillmore, Lancaster, Pawnee, Seward, and Washington) and were suspected to be glyphosate-resistant biotypes. Greenhouse dose-response experiments were conducted at the University of Nebraska- Lincoln and common waterhemp biotypes were treated with 9 rates (0 to 16×, where ×= recommended rate of glyphosate i.e. 24 fl oz/ac) of Touchdown HiTech (glyphosate). Dose response study has shown that common waterhemp biotypes were 3- to 39-fold resistant to glyphosate depending on the biotype being investigated. The results suggested that 90% control in certain biotype could be achieved by spraying Touchdown HiTech at 900 fl oz/a, which is absolutely impractical for the growers. The confirmation of glyphosate-resistance in common waterhemp biotypes in Nebraska is further evidence of an ever-evolving weed spectrum, and further proof that using only glyphosate for weed control in corn and soybean is not a sustainable approach to weed management. In the face of herbicide selection pressure, common waterhemp has repeatedly proven to be an ecological survivor. As a consequence, common waterhemp biotypes resistant to ALS (Pursuit), triazine (Atrazine), growth regulator (2,4-D), HPPD (Callisto), and now glyphosate (Roundup) have been confirmed in Nebraska.

Glyphosate-Resistant Common Waterhemp Control in Roundup Ready (Glyphosate-Resistant) Soybeans

Field experiments were conducted in the summer of 2013 and 2014 at Fremont, NE in a grower's field infested with glyphosate-resistant common waterhemp. From greenhouse study at the University of Nebraska- Lincoln, we have confirmed that more than 350 fl oz Touchdown Hitech/acre is required to control 90% of the common waterhemp biotypes from that same field. The field was under rain-fed condition throughout the season. The history of the site was a heavy reliance on glyphosate for weed control at least two times per season for the last few years in a glyphosate-resistant corn and soybean rotation. The soil at the experimental site was clay type with pH 6.7, and 4% organic matter. Glyphosate-resistant soybeans (Cv. "Pioneer 93Y12") were planted with 30 inch row spacing. In this study, plot size for each treatment was 10 ft × 30 ft and each treatment was randomly replicated four times.

A total of 18 herbicide programs including pre-emergence herbicide followed by post-emergence were compared for control of glyphosate-resistant common waterhemp. Nontreated control plots were included for comparison. Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 15 gal/ac at 40 psi equipped with a five-nozzle boom and AIXR11015 flat fan TeeJet nozzles. Pre-emergence (PRE) herbicides were applied right after the soybean planting in the field, whereas early post-emergence (Early POST) herbicides were applied at 15 days after soybean planting (DAP) and mid post-emergence (Mid POST) were applied at 30 DAP. Visual estimations of common waterhemp control were recorded on a scale of 0% to 100% (0 equals no common waterhemp control and 100 equals complete control of common waterhemp) at 14, 28, 42, 90 days after soybean planting and at harvest. Middle two rows of soybean were harvested for estimating soybean yield.

Results (Table 1). Control of glyphosate-resistant common waterhemp varied among different treatments. PRE herbicides applied at planting of soybean provided > 80% control of glyphosate-resistant common waterhemp at 14 DAP. The residual activity of Dual II Magnum reduced at 28 DAP that resulted in 66% control, whereas tank-mix of Dual II Magnum with Flexstar (i.e. Prefix) or Sencor (i.e. Boundary) resulted in >90% control of glyphosate-resistant common waterhemp at 28 DAP. Poor control of common waterhemp (< 50% control) was usually observed at 90 DAP with two times application of Roundup PowerMax or Roundup PowerMax applied along with Pursuit (i.e. Extreme). POST treatments Extreme + Flexstar GT + Warrant followed by Cobra + Roundup PowerMax provided 71% control at 90 DAP. In addition, herbicide such as Cobra injured soybean-plant in early season and that delayed the canopy-closure, whereas Flexstar GT did not result in any significant soybean-injury.

Similar results were observed in visual control ratings recorded at soybean harvest. Most of the herbicide treatments containing PRE followed by POST herbicides performed better than POST-only treatments. Few herbicide treatments including, Optill + Outlook followed by Flexstar GT; Sonic followed by Flexstar GT; Prefix followed by Ultra Blazer + Roundup PowerMax; and Boundary followed by Flexstar GT were consistent in common waterhemp control (>90%). Overall, yield of the soybean were slightly lower in 2014 compared to the yield in 2013 because of excess rainfall in 2014.

Glyphosate-Resistant Common Waterhemp Control in LibertyLink (Glufosinate-Resistant) Soybeans

Glufosinate (Liberty) is a non-selective, contact, post-emergence herbicide. It has a different mode-of-action group (group 10) than glyphosate (group 9), so it can be used to control glyphosate-resistant weeds in LibertyLink crops.

Field experiments were conducted at the same site at Fremont, NE as described in previous study. LibertyLink soybeans were planted with 30 inch row spacing. 18 different herbicide treatments including POST treatments of Liberty were randomly replicated four times and were compared in this study. Visual control of common waterhemp and yield of soybeans were recorded as mentioned in the previous study.

Results (Table 2). Herbicide treatments that included pre-emergence herbicide provided ≥ 88% control of glyphosate-resistant common waterhemp except Dual II Magnum and Dual II Magnum plus Pursuit at 14 DAP. Sequential applications of Liberty resulted in 76% control at 42 DAP, whereas all PRE and Early POST treatments followed by Liberty application provided ≥ 80% control of glyphosate-resistant common waterhemp.

The PRE herbicide treatments including Envive, Prefix, Boundary, Authority MTZ, Sharpen + Outlook followed by Liberty provided more than 90% control of glyphosate-resistant common waterhemp throughout the growing season. Additionally, there was no significant soybean injury due to application of Liberty or Flexstar in this study. The similar trend was followed in soybean yield; highest soybean yield (≥ 30 bu/a) were observed in the treatments having highest visual control, whereas untreated control produced only 12 bu/a.

Common Waterhemp Management Considerations

Resistance to any herbicide mode of action is troubling, but multiple resistance (resistance in a weed biotype to more than one herbicide mode of action) is of particular concern. Common waterhemp biotypes with resistance to multiple herbicides have been confirmed in Illinois, Iowa, Kansas, Minnesota and Missouri. This resistance stacking is alarming and limits herbicide options for managing common waterhemp, especially for the soybean growers. Control of glyphosate-resistant common waterhemp will require an integrated approach including:

- Use of soil- residual herbicides
- Use of post-emergence herbicides with different modes-of-action, that will slow down the process herbicide-resistance development
- Rotational use of different herbicide resistant crop technologies (like, Roundup Ready, LibertyLink etc.) and crop rotation
- A combination of tillage system

Table 1. Effect of different herbicide programs on control of glyphosate-resistant common waterhemp at 14, 28, 42, 90 DAP, and at harvest in Roundup Ready soybeans and on the soybean yield

Herbicide[a]	Mode-of-action[a] group	Application timing[a]	Rate	Common waterhemp control after planting[ab] 14 DAP	28 DAP	42 DAP	90 DAP	At harvest	Soybean yield[b] 2013	2014
				%					bu/a	
Nontreated Control	-------	-------	------	0	0	0	0	0	14 g	13 i
Roundup PowerMax *fb* Roundup PowerMax	9 *fb* 9	Early POST *fb* Mid POST	44 oz/a 22 oz/a	0 f	26 i	56 g	31 i	23 i	19 fg	13 i
Extreme *fb* Roundup PowerMax	2 + 9 *fb* 9	Early POST *fb* Mid POST	3 pt/a 22 oz/a	0 f	56 h	59 g	46 h	37 h	21 ef	14 i
Extreme + Warrant *fb* Roundup PowerMax	2 + 9 +15 *fb* 9	Early POST *fb* Mid POST	3 pt/a + 2 qt/a 22 oz/a	0 f	69 fg	61 f	53 h	42 gh	26 de	16 hi
Extreme + Flexstar GT+ Warrant *fb* Roundup PowerMax	2 + 9 + 14 + 15 *fb* 9	Early POST *fb* Mid POST	3 pt/a + 56 oz/a + 2qt/a 22 oz/a	0 f	70 fg	60 g	53 h	49 fg	25 def	15 i
Extreme + Flexstar GT+ Warrant *fb* Cobra + Roundup PowerMax	2 + 9 + 14 + 15 *fb* 14 + 9	Early POST *fb* Mid POST	3 pt/a + 56 oz/a + 2qt/a 12.5 oz/a + 22 oz/a	0 f	64 gh	82 e	71 g	59 f	25 def	20 gh
Valor XLT *fb* Flexstar GT	14 + 2 *fb* 14 + 9	PRE *fb* Mid POST	4 oz/a 56 oz/a	92 bcd	85 cd	90 bcd	86 cde	83 cd	30 cd	29 cde
Optill *fb* Flexstar GT	14 + 2 *fb* 14 + 9	PRE *fb* Mid POST	2 oz/a 56 oz/a	91 cd	87 bcd	89 cde	87 cd	84 bcd	31 bcd	29 cde
Optill + Outlook *fb* Flexstar GT	14 + 2 + 15 *fb* 14 + 9	PRE *fb* Mid POST	2 oz/a + 10 oz/a 56 oz/a	97 a	93 ab	97 a	95 a	96 a	38 a	36 a
Authority Assist *fb* Flexstar GT	14 + 2 *fb* 14 + 9	PRE *fb* Mid POST	12 oz/a 56 oz/a	97 a	94 a	90 bcd	86 cde	83 cd	28 d	28 de
Authority XL *fb* Flexstar GT	14 + 2 *fb* 14 + 9	PRE *fb* Mid POST	8 oz/a 56 oz/a	95 abc	91 abc	94 abc	88 cd	86 bc	29 d	30 cde
Sonic *fb* Flexstar GT	14 + 2 *fb* 14 + 9	PRE *fb* Mid POST	8 oz/a 56 oz/a	96 ab	94 a	95 ab	91 bc	91 ab	35 abc	34 abc
Enlite *fb* Flexstar GT	2 + 2 + 14 *fb* 14 + 9	PRE *fb* Mid POST	2.8 oz/a 56 oz/a	88 de	83 de	86 de	79 f	72 e	26 de	26 ef
Dual II Magnum *fb* Flexstar GT	15 *fb* 14 + 9	PRE *fb* Mid POST	1.33 pt/a 56 oz/a	83 e	66 g	72 f	65 g	61 f	25 def	21 fg
Prefix *fb* Ultra Blazer + Roundup PowerMax	15 + 14 *fb* 14 +9	PRE *fb* Mid POST	2 pt/a 2 pt/a + 22 oz/a	96 ab	93 ab	97 a	96 a	96 a	39 a	35 ab
Fierce *fb* Flexstar GT	14 + 15 *fb* 14 +9	PRE *fb* Mid POST	3.75 oz/a 56 oz/a	94 abc	86 cd	90 bcd	87 cd	88 bc	28 d	31 bcde
Zidua *fb* Flexstar GT	15 *fb* 14 + 9	PRE *fb* Mid POST	3.5 oz/a 56 oz/a	95 abc	83 de	88 de	85 def	83 cd	28 d	27 e
Boundary *fb* Flexstar GT	15 + 5 *fb* 14 + 9	PRE *fb* Mid POST	2.25 pt/a 56 oz/a	97 a	94 a	96 a	93 ab	91 ab	36 ab	33 abcd
Prowl H_2O + Sencor *fb* Flexstar GT	15 + 5 *fb* 14 + 9	PRE *fb* Mid POST	3.6 pt/a + 0.5 lb/a 56 oz/a	92 bcd	77 ef	86 de	80 ef	75 de	26 de	27 e

[a]DAP, days after planting; PRE, preemergence; POST, postemergence; *fb*, followed by.

[b]Means presented within each column with no common letter(s) are significantly different according to Fisher's Protected LSD test where $P \leq 0.05$.

Table 2. Effect of different herbicide programs on control of glyphosate-resistant common waterhemp at 14, 28, 42, 90 DAP, and at harvest in LibertyLink soybeans and on the soybean yield

Herbicide[a]	Mode-of-action[a] group	Application timing[a]	Rate	Common waterhemp control after planting[ab] 14 DAP	28 DAP	42 DAP	90 DAP	At harvest	Soybean yield[b]
				%					bu/a
Nontreated Control	-------	-------	------	0	0	0	0	0	12 i
Liberty *fb* Liberty	10 *fb* 10	Early POST *fb* Mid POST	29 oz/a 29 oz/a	0 e	71 h	76 f	51 f	41 f	17 gh
Liberty + Warrant *fb* Liberty	10 + 15 *fb* 10	Early POST *fb* Mid POST	29 oz/a + 2 qt/a 29 oz/a	0 e	77 efg	81 ef	60 ef	53 e	18 gh
Liberty + Warrant + Pursuit *fb* Liberty	10 + 15 + 2 *fb* 10	Early POST *fb* Mid POST	29 oz/a + 2 qt/a + 4 oz/a 29 oz/a	0 e	77 efg	81 ef	64 de	54 e	19 fg
Liberty + Flexstar *fb* Liberty	10 + 14 *fb* 10	Early POST *fb* Mid POST	29 oz/a + 16 oz/a 29 oz/a	0 e	75 fgh	82 ef	53 f	41 f	18 gh
Liberty + Flexstar + Warrant *fb* Liberty	10 + 14 + 15 *fb* 10	Early POST *fb* Mid POST	29 oz/a + 16 oz/a + 2 qt/a 29 oz/a	0 e	79 def	83 de	68 de	55 e	20 fg
Liberty + Flexstar + Pursuit +Warrant	10 + 14 + 2 + 15	Early POST	29 oz/a+16 oz/a+4 oz/a+2 qt/a	0 e	81 cde	58 g	25 g	19 g	15 hi
Liberty + Flexstar + Pursuit + Warrant *fb* Liberty	10 + 14 + 2 + 15 *fb* 10	Early POST *fb* Mid POST	29 oz/a+16 oz/a+4 oz/a+2 qt/a 29 oz/a	0 e	82 cde	85 de	63 e	58 e	19 fg
Valor *fb* Liberty	14 *fb* 10	PRE *fb* Mid POST	3 oz/a 29 oz/a	88 c	83 cd	88 cd	73 d	59 e	22 ef
Valor + FirstRate *fb* Liberty	14 + 2 *fb* 10	PRE *fb* Mid POST	3 oz/a + 0.6 oz/a 29 oz/a	99 a	96 ab	97 ab	91 bc	87 cd	27 bc
Envive *fb* Liberty	2 + 2 + 14 *fb* 10	PRE *fb* Mid POST	5.3 oz/a 29 oz/a	99 a	98 a	99 a	98 a	96 ab	32 a
Intrro *fb* Liberty	15 *fb* 10	PRE *fb* Mid POST	3 qt/a 29 oz/a	96 b	93 b	96 b	90 bc	86 cd	26 bcd
Dual II Magnum *fb* Liberty	15 *fb* 10	PRE *fb* Mid POST	1.33 pt/a 29 oz/a	76 d	71 h	80 ef	61 ef	54 e	23 def
Dual II Magnum + Pursuit *fb* Liberty	15 + 2 *fb* 10	PRE *fb* Mid POST	1.33 pt/a + 4 oz/a 29 oz/a	78 d	74 gh	81 ef	68 de	61 e	23 def
Prefix *fb* Liberty	15 + 14 *fb* 10	PRE *fb* Mid POST	2 pt/a 29 oz/a	99 a	99 a	99 a	98 a	98 a	31 a
Boundary *fb* Liberty	15 + 5 *fb* 10	PRE *fb* Mid POST	2.25 pt/a 29 oz/a	99 a	98 a	99 a	97 a	95 ab	30 ab
Authority MTZ *fb* Liberty	14 + 5 *fb* 10	PRE *fb* Mid POST	18 oz/a 29 oz/a	98 ab	96 ab	96 b	95 ab	91 bc	27 bc
Sharpen *fb* Liberty	14 *fb* 10	PRE *fb* Mid POST	1 oz/a 29 oz/a	90 c	87 c	92 c	89 c	83 d	24 cde
Sharpen + Outlook *fb* Liberty	14 + 15 *fb* 10	PRE *fb* Mid POST	1 oz/a + 18 oz/a 29 oz/a	99 a	99 a	99 a	98 a	97 a	33 a

[a]DAP, days after planting; PRE, preemergence; POST, postemergence; *fb*, followed by.

[b]Means presented within each column with no common letter(s) are significantly different according to Fisher's Protected LSD test where $P \leq 0.05$

Integrated Management of Weeds in Rangeland and Pasture

By Dr. Stevan Knezevic, IWM Specialist, sknezevic2@unl.edu, 402-584-3808

Integrated weed management (IWM) has been commonly described as “a combination of mutually supportive technologies in order to control weeds”. Some have also called it “a multi-disciplinary approach to weed control utilizing the application of numerous alternative control measures”. In practical terms, it means developing a weed management program using a combination of preventive, cultural, mechanical, and chemical practices. It does not mean abandoning chemical weed control. Instead, chemical control is considered to be one of many mutually-supportive weed management options, although a reduction in herbicide use can result from implementing an IWM approach. An IWM approach advocates the use of all available weed control options such as: selection of a well adopted grass mixture with good early season vigor and appropriate disease and pest resistance; optimal plant density; mowing ; use of fire and planned grazing; as well as biological and chemical control methods. A single weed control measure is not feasible due to the number of different weed species, their highly variable life cycles, and survival mechanisms. In addition, controlling weeds with only one or two methods gives weeds a chance to adapt to those practices. Therefore, instead of relying on only one or two management tools, the IWM toolbox includes a large number of options.

Below are weed control options for 5 species, including: eastern red cedar, hoary vervain, western ragweed, buckbrush and common mullein. Weed control information presented in this article is based on the data and research studies conducted by my team in Eastern, and North-Central Nebraska. Feel free to call my office with any questions.

Integrated Management of Eastern Redcedar:

Eastern redcedar (*Juniperus virginiana* L.) is one of 13 juniper species native to the United States. It is the most widespread tree-sized conifer and is native to every state east of the 100th meridian. Throughout this vast range, eastern redcedar grows on many soils and under varying climatic conditions. This adaptability has enhanced eastern redcedar's recent spread into areas where it was formerly rare or absent. Eastern redcedar is a dioecious species, which means individual trees are either male or female. Staring in the 6th or 7th year of growth, female trees produce small, berrylike fruits that are eaten by many birds and some small mammals, which indirectly helps spread the seed via droppings. Digestion actually improves germination.

Eastern redcedar is a problem on grasslands primarily because it reduces forage production and livestock handling. Developing trees alter the microclimate, which encourages a shift from desirable warm-season native grasses to introduced cool-season grasses such as Kentucky bluegrass. Heavy infestations make livestock handling more difficult. All these adverse effects can be reflected in lower rental rates or sale prices for infested grassland. Established infestations usually get worse over time due to overproduction of seeds and established trees et bigger, thus shading grass benight even more. On many sites complete coverage by eastern redcedar can be expected, resulting in total loss of grass production unless controlled. Control measures should be initiated as soon as possible, both to improve effectiveness and reduce total control costs.

As previously described, Nebraska's eastern redcedar infestations have developed over several decades. Likewise, management of these infestations is best viewed as a long-term or on-going effort, both to reduce the initial infestations and prevent them from redeveloping to economically damaging levels. It is best to begin treatment as soon as possible, once treatment has begun considerable time is gained to continue long-term management. The emphasis should be on management of the infestation, rather than eradication. Eradication is not economical, and probably not physically possible in most cases. Instead, it should be recognized that some remaining larger trees, which are the most difficult and expensive to kill, do little damage. In fact, at low levels, eastern redcedars can be viewed as a potential resource, providing livestock shelter, wildlife habitat, timber products, and aesthetic values. Most important, long-term selective management is considerably less expensive than a more intensive, short-term approach.

If the goal is to just reduce overall number of trees, and stop further spreading (eg. management of wildlife habitat), it is recommended to cut female trees only. Female trees are the ones that produce berry-like fruits. This would allow “male trees” to grow and provide much needed cover for wildlife, or land beautification, while reducing further spreading.

Manual and Mechanical control:

Manual and mechanical control involves methods such as digging trees, cutting and mowing. It is very effective for small areas, and it is most efficient on trees up to 2 feet tall. Cutting is an effective method of control because eastern redcedar is a non-sprouter. Trees cut below the lowest branches will not regrow. A variety of handheld or motor-powered cutting tools can be used. Hand-held tools (shears, saws, spade, shovel, heavier hoe) are effective on small trees (<5ft tall), while larger trees require a chain saw or vehicle-mounted shears. The equipment varies from tractor pulled PTO driven shredders to hydraulic drive devices that mount on skid steer loaders. Most of the shredders can easily handle up to 3-4 inch stem diameter trees, while some can cut tress up to 15 inches. In general, cutting is a method that can be time consuming and labor intensive. Cutting alone also fails to remove all of the problem because fallen trees continue to occupy space. Thus, all cut trees should be gathered and burned, or permanently removed from the grassland. Mowing of short trees (<3ft tall) can be conducted using shielded mower shortly after regular cutting and haying.

Biological control of eastern redcedar:

Biological control is the use of natural enemies to reduce weed populations to economically acceptable levels. In the case of red cedar control, goats can be utilized as an effective bio-control agent for trees that are up to 3-4 ft tall. Experience from Nebraska suggests that most cedar trees < 24 inches tall were killed by goats utilizing paddock grazing system. The control level was reduced by 50 percent on trees 4-8 feet tall tress, however the goats managed to defoliate bottom branches and stripe bark from branches and trunks up to three inches in diameter.

Generally, goats are browsers with diets consisting of about 70% of non-grassy species, which indicates that they should not compete with cattle for grass. Goats prefer non-grassy species, but they would eat grass if no other species are available. This also suggests that goats in general can help in controlling many plant species that cattle do not eat, including various noxious weeds (eg. leafy spurge, thistles). Goat production can be also a profitable livestock enterprise that provides income through meat and milk production, and leasing fees for goat leased to control various invasive forbs and shrubs. Important factors in managing goats include the use of appropriate stocking rates and quality fencing. In essence, the number of goats needs to be adjusted to the amount of plant material needed to control.

The grazing strategy with the goats should vary depending on the management goals set for the pasture. Adding one or two goats per cow and letting the goats and cattle run together is an excellent maintenance strategy for pasture with moderate to low cedar infestation. However, if the goal is to get a quicker response and try to suppress denser stands then the area needs to be fenced off using temporary fencing. Thus per acre stocking rate should be at least 10 goats/acre of land infested. This stocking rate with moderate cedar infestation should result in significant damage to the trees within 30 days. Higher stocking rates would be better, but will require moving the fence more often. Trees and other perennial plants have high energy reserves in their root systems and repeated defoliation over a few years is required to control them. Cedar trees however, will not resprout and thus, if the goats remove most of the needles and/or bark, the tree will eventually die. Other issues that need to be addressed before getting goats may include predator control (eg. coyotes) and perhaps learning how to raise goats for meat production. A good place to start is at the ATTRA - National Sustainable Agriculture Information Service web site.
The page "Goats: Sustainable Production Overview, Livestock Production Guide" http://www.attra.org/attra-pub/goatoverview.html has information on numerous topics relating to meat goat production.

Many ranchers in other parts of the US have run cattle and goats together for decades. They view goats both as a profitable part of their business and as a very important part of their grazing land management program.

Use of prescribed fire for redcedar control:

This method is inexpensive and very effective against smaller trees. Its effectiveness declines as tree size increases, however there were cases of successful burning of tall trees. Adequate fine fuel (usually, last year's dead grass) is necessary for satisfactory results. Safety also is a concern since many managers lack experience with fire and the equipment required to conduct fires.

The controlled use of fire is a large subject in itself. It is beyond the scope of this publication to provide detailed instruction on conducting prescribed fires. Two other Nebraska Extension publications provide information on the use of fire in general and on how to safely conduct fires. They are NebGuide G88-894, Grassland Management with Prescribed Burning, and Extension Circular 90-121, Conducting a Prescribed Burn. A fire plan should be prepared and a prescribed-burning permit obtained from the local fire jurisdiction, as required by state law. Specialized fire equipment can be purchased. Two sources are the Ben Meadows Company, 3589 Broad St., Chamblee, GA 30341; and Forestry Suppliers, Inc, Box 8397, Jackson, MS 39284-8397.

Chemical control of eastern redcedar:

Herbicides can also be considered for control of this tree species, however, they should be viewed as just another tool in the integrated management program. Depending on the application method and chemical type, the use of herbicides can be time consuming and expensive, especially when used on denser tree infestations or large tracts of land. Effectiveness also is variable depending on the tree size and label directions and/or restrictions. Therefore, always read and follow herbicide label directions. Herbicide information on control of troublesome plant species, including eastern cedar, is update annually in the Guide for Weed Management in Nebraska (EC-130). In general, herbicides for eastern redcedar control can be used for broadcast application or individual-tree spraying.

Broadcast treatments:

Broadcast application is the most common method of applying herbicides in agricultural settings. The key message for the efficacy of broadcast treatments in eastern redcedar control is: “the shorter the tree the better control”.

Since tree height was the most important factor influencing the level of chemical control (tree injury) with broadcast treatments, the herbicide efficacy data from Nebraska study was categorized by tree height (Table 1). Recommended herbicides for trees that are up to two feet tall include: Surmount, Grazon P&D and Tordon (Table 1). However, the same herbicides will not provide satisfactory control of trees taller than 2 ft, indicating the importance of tree heigh. Surmount at the rate of 5pts/acre can also cause short-term grass injury in the form of leaf yellowing and top growth burning (Table 1). Cost of Grazon P+D and Tordon 22 K for broadcast applications can range from $21-$26 per acre. Since Surmount is not marketed product yet, its costs is not known.

Individual-tree treatments:

Individual-tree treatments can be applied directly to the tree foliage or to the soil around tree base. Soil treatments can minimize the amount of herbicide used and the exposure to non-target species. However, soil treatments may not be effective unless applied before rainfall, preferably in Spring or Fall. Rain water is needed to move the herbicide into the root zone allowing an easier uptake by a tree. Recommended herbicides for soil application around tree base include Tordon 22K at the rate of 1 cc (ml) per every foot of tree height, Velpar-L at 4 (cc) ml and Spike 20P at 1cc (ml) per every inch of tree diameter. Cost of Tordon is about $85 per gallon, Velpar is about $65 per gallon and Spike 20P is about $9 per pound of product.

Individual-tree foliage can be also treated with various herbicides (Figure 8). Based on a study conducted in northeastern Nebraska, recommended herbicides for control of 2-10 feet tall trees include Surmount at 1.5 % volume per volume (v/v), Grazon P+D at 2.0% (v/v) and Tordon 22K at 1.0% v/v (Table 2).

To help you determine volume per volume basis, for example, the 1% v/v equals 1 gall of product per 100 gallon of water. For smaller back pack sprayers use an equivalent of 1.3 oz of product per every gallon of water. Apply about 1.5 oz of the herbicide spray solution per every foot of tree height. Walk around the tree and just spray enough solution just to get a glisten (shine) on the canopy surface. Solution dripping off the canopy indicates a rate that is too high, and a likely waste of time and money. As an example, it was calculated that 1 gallon of spray solution could cover 15 individual trees that are 6 feet tall at a pressure of 20 PSI and a single nozzle type XR8002..

Grass injury in the form of temporary yellowing and burning of top growth was evident among all treatments especially for Tordon 22K. Roundup is not recommended for use in pasture settings due to poor activity on cedar trees and high injury level to the grass (Table 2). Cost of Grazon P+D and Tordon 22 K can ranged from $11-$16 per acre.

***Practical hint for chemical control**:*

Use of selective herbicide treatments should be based on a tree height. Broadcast treatments are effective only on short trees (up to 2-ft tall), while the medium height trees (2 to 10 ft) can be controlled with individual-tree treatments. For broadcast treatments use 6-8 pints of Grazon P&D or 4-5pts of Surmount in a 20 gallon of water per acre. To prepare 1 gall of spray solution for individual-tree canopy treatments use 1.3 oz of Tordon, or 2.6 oz of Grazon P&D, or 2oz of Surmount. For larger spray tanks adjust herbicide rates accordingly.

Take home message:

Since there are many different scenarios under which eastern redcedar trees can grow, they obviously can not be managed by a single IWM control method; however, if the methods are implemented in a systematic manner, significant advances in eastern redcedar control can be achieved. Obviously you can not use all of the above described techniques at once. We recommend to use the best combination of techniques for your needs. There are many ways to start developing an IWM program. The easiest start will be to try a one or two techniques and then add more practices as the time goes on or the field conditions change. Cost of control methods can also vary thus choose the operation that can fit your budget the best.

We recommend to use tree-height as a determining factor for control options. There are many control options for trees that are up to 2 feet tall, which may include: cutting, pulling, digging, mowing, burning, use of goats and broadcasts herbicide application. Trees that are 2-10 feet tall can be controlled effectively by cutting and individual-tree herbicide treatments of soil or foliage. Trees that are over 10 ft in height are the most effectively and economically controlled by cutting. Therefore, in order to save time and labor expenses the main take-home message is to “control redcedar trees while they are small”.

Table 1: Percent eastern redcedar control a and grass injury levels at about 100 days after treatment as influenced by the tree height (feet) where herbicide treatments were broadcast applied.

ID	Product	Dose	Tree Height (ft)		Grass Injury		
		pt/acre	0 to 1	1 to 2	2 to 4	4 to 6	
1	Surmount	4	84	70	52	12	35
2	Surmount	5	95	81	46	20	55
3	Grazon P & D	6	90	59	51	16	15
4	Grazon P & D	8	95	79	60	18	20
5	Tordon 22K	2	85	65	33	25	20

-Treatments 1, and 2, were mixtures of picloram + fluroxypyr each at 0.66 lbs ae/gal,
-Treatments 3 and 4 were picloram at 0.54 lbs ae/gal + 2,4-D at 2.0 lbs ae/gal,
-Treatment 5 was picloram at 2.0 lbs ae/gal.

Table 2: Percent of eastern redcedar and grass injury at 100 days after treatment that were applied to individual-trees.

ID	Product	Dose v/v	Tree Injury	Grass Injury
		(%)	(%)	(%)
1	Surmount	1.0	75	39
2	Surmount	1.5	89	48
3	Grazon P & D	2.0	90	50
4	Tordon 22	1.0	94	60
5	Roundup Ultra	1.0	5	55
6	Roundup Ultra	2.0	31	91

-Treatments 1, and 2, were mixtures of picloram + fluroxypyr each at 0.66 lbs ae/gal,
- Treatment 3 was picloram at 0.54 lbs ae/gal + 2,4-D at 2.0 lbs ae/gal,
- Treatment 4 was picloram at 2.0 lbs ae/gal.
- Treatment 5 and 6 were glyphosate at 3.7 ae/gal
- Dose was a herbicide/water solution on a volume/volume basis

Biology and Control of Western Ragweed:

Western ragweed *(Ambrosia psilostachya)* is a commonly found native weed in northeastern Nebraska's rangeland, prairies and disturbed sites in all soil types. It is a perennial forb from the sunflower family (Asteraceae) that reproduces both by seeds and rhizome. Rhizome is a horinzontal creeping root system growing within top 5-10 inches from soil surface. The plants usually grow in sparse groups (patches or clusters). Stem is very erect, up to 3 ft tall, with many branches and long hairs giving the stem a coarse feeling. Leaves are alternate on the upper part of the stem, opposite on the bottom, with many divisions and teeth. Like many other plant species, the overall growth and development depends on the amount and timing of rainfall. Western ragweed, in Nebraska, can flower from July to October, with greenish-yellow flowers positioned on the top of the main stem and branches, and produces an inch long bur-like fruits with a single seed within each bur.

Western ragweed provides forage for deer and the fruits are an important food source for upland game-birds, wild turkeys and songbirds. Native Americans also made a tea from the whole plants to treat colds and cramps. Western ragweed has almost no value to livestock because of its low palatability. With other forage limited, it may be eaten. Pollen produced in late summer causing late summer hay fever in many people, due to presence of volatile oils, which can also cause skin irritation.

Due to its low value for livestock forage, it is a concern to livestock producers and ranchers. This weed can be controlled by various means. Mowing the plants when they are 4-6 inch tall can reduce ragweed population considerably for the season. Mowing can be done one or two times per season depending on the amount of rainfall during the season. One mowing done in mid June is effective if the season is dry, due to lack of moisture needed for weed regrowth. If the season is wet, an additional mowing is needed in July-August. Herbicides can be also very effective in providing season long control. Herbicide application should be conducted when ragweed plants are 3-5 inches tall. The list of effective herbicides and their rates per acre includes: Salvo (12 oz/acre), 2,4-D-Ester (1qrt/acre), Grazon P+D (32 oz/acre), Weedmaster (32oz/acre), Ally or Cimarron (0.25oz/acre), and Vista (22 oz/acre).

Biology and Control of Common Mullein:

Common mullein (*Verbascim thapsus*) is a weed species on the increase in northeastern Nebraska's rangeland, woodland, and pastures. It is a biennial plant that reproduces only by seeds, but it is a prolific seed producer. Taproot of this species can access soil moisture from a deeper profile at much better rate than fibrous roots of pasture grasses, giving common mullein the competitive advantage over grass, especially during dry years.

Common mullein usually starts growing sparsely as individual plants and then spreads further if not controlled. A cluster of leaves, commonly known as a rosette, with a thick hair cover is a distinct identifying feature of this species. Stem is also woolly, erect, 2-6 ft tall, with no branches. Leaves are opposite, elliptic to ovate. Like many other plant species, the overall growth and development depends on the amount and timing of rainfall. Common mullein, in Nebraska, can flower in June and July, with yellowish flowers, and it has no value to livestock because of its low palatability.

Ranchers need to control this species because heavy stands can reduce grass production as much as 50%, especially in dry years, and the common mullein plants have no value for livestock forage. This weed can be controlled by various means. The best strategy is to control while the density is low. Density of this species can easily expand from few to hundreds plants per acre just over couple of years due to prolific seed production. Sparse populations can be controlled by mechanical removal using a spade or shovel in late April and early May. Individual plants can be dug out or cut just at the soil surfaces as long as whole rosette is removed. Single mowing of new 1-2 feet tall plants can reduce population and seed production for the season, especially in dry years. Herbicides can be also effective tools in providing season long control. However, one thing to note is that a thick wooly coat of hairs on the leaves can reduce herbicide uptake and level of control. Herbicide application should be conducted when the rosette has 6-12 leaves, before the stem starts to grow, which is usually in May. The list of effective herbicides and their rates per acre includes: Grazon P+D (3-4 pints/acre), Cimarron (0.75-1 oz/acre), and a 3-way-mix of Cimarron (0.5oz) with Glean (0.5oz) and RangeStar (32 oz). Make sure to use enough additives such are Crop Oil at 1-2 q/acre to help herbicide penetrate the thick wooly coat.

Biology and Control of Hoary Vervain:

Hoary vervain *(Verbena stricta),* also known as wooly verbena or tall vervain, is a commonly found native weed in northeastern Nebraska's on over-grazed rangeland, prairies and disturbed sites in all soil types. There are several other types of vervain in

Nebraska (prostrate, white, and blue), of which most have similar growth forms and habits as hoary vervain. Hoary vervain is a perennial forb from the vervain family (Verbenaceae) that reproduces by seeds. The taproot (perennial structure) produces individual erect plants. Stem is nearly round, simple or branched above and can be up to 5 ft tall, covered with soft white hairs. Leaves are opposite, leaf blades are ovate with many teeth. Lower surface is pubescent with highly visible veins. Like many other plan species, the overall growth and development depends on the amount and timing of rainfall. Hoary vervain, in Nebraska, can flower from May to September, with blue or purple flowers positioned on the top of the main stem and branches and producing a two seeded fruit.

Hoary vervain provides forage for deer while seeds are important food source for small mammals and upland birds. Native Americans also made a tea from the leaves to treat stomachache. Hoary vervain has no value to livestock because of its low palatability.

This weed can be controlled by various means. Mowing the plants when they are 3-5 inches tall can reduce vervain population considerably for the season. Mowing can be done one or two times per season depending on the amount of rainfall during the season. One mowing done in mid June can be effective (>75% control) if the season is dry, due to lack of moisture needed for weed regrowth. If the season is wet, an additional mowing is needed in July-August. Herbicides can be also very effective in providing a season long control. Herbicide application should be conducted when vervain plants are 3-5 inches tall, which is usually in early part of June. The list of effective herbicides, their rates and cost per acre includes: Salvo (12 oz/acre, $4), Grazon P+D (32 oz/acre, $8), Weedmaster (32oz/acre, $6), Ally or Cimarron (0.25oz/acre, $6), and Vista (22 oz/acre, $8).

Biology and Control of Buckbrush:

Buckbrush (*Symphoricarpos orbiculatus*) is a commonly found native weed in northeastern Nebraska's rangeland, woodland, ravines and along streams. It is a perennial forb that reproduces both by seeds and rhizome. Rhizome is a horinzontal creeping root system growing within 2-12 inches of top soil. Rhizome can access soil moisture from a deeper profile at much better rate than fibrous roots of pasture grasses, giving buckbrush the competitive advantage over grass, especially during dry years.

Buckbrush plants usually start growing in sparse groups (patches or clusters) and then spread further if not controlled. Stem is erect, 2-6 ft tall, brownish, somewhat smooth, with many branches. Leaves are opposite, elliptic to ovate with pointed tips. Like many other plant species, the overall growth and development depends on the amount and timing of rainfall.

Buckbrush, in Nebraska, can flower from July to August, with greenish-white to purple flowers. Buckbrush can provide forage for deer early in the season, while the fruits are an important food source for upland game-birds, wild turkeys and songbirds. Buckbrush has no value to livestock because of its low palatability.

Ranchers need to control this species because heavy stands of buckbrush can reduce grass production as much as 80%, especially in dry years, and the buckbrush plants have no value for livestock forage. This weed can be controlled by various means. Goats and sheep can reduce the stands of buckbrush considerably if kept confined in the area. Single mowing of new 1-2 feet tall plants can also reduce buckbrush population, especially in dry years. Additional mowing will be needed in wet years. Mowing can also help remove previous years growth to prepare the site for broadcast applications of herbicides. Herbicides are the most effective tools in providing season long control. Herbicide application should be conducted when the new growth is 6-12 inches tall. The list of effective herbicides and their rates per acre includes: 2,4-D-Ester (2-3 qrt/acre), Grazon P+D (1-2 qrt/acre), Telar (1.0 oz/acre); mix of Cimarron (0.25oz) with WeedMaster (16 oz); mix of Cimarron (0.25oz/acre) with RangeStar (16 oz/acre), and Cimarron (Ally, Escort) used alone at 0.5oz/acre.

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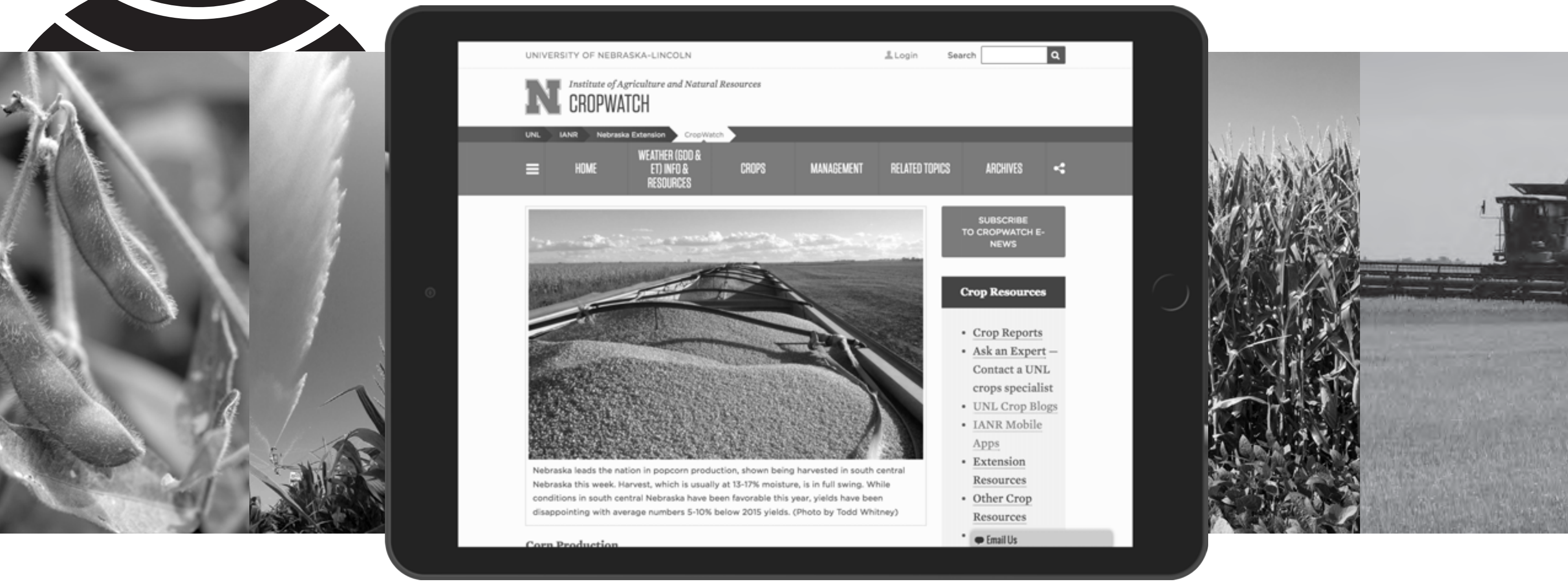

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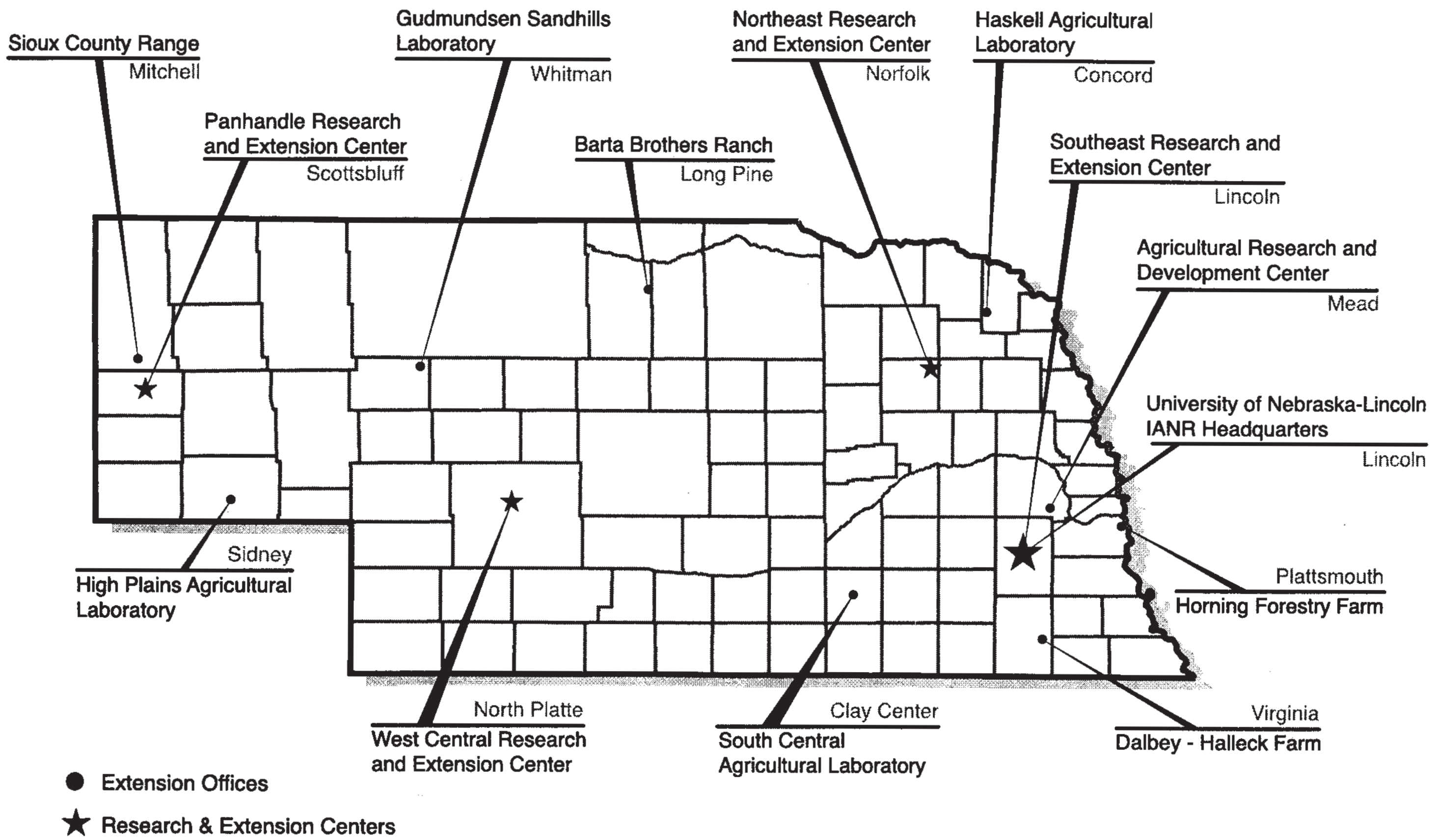

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