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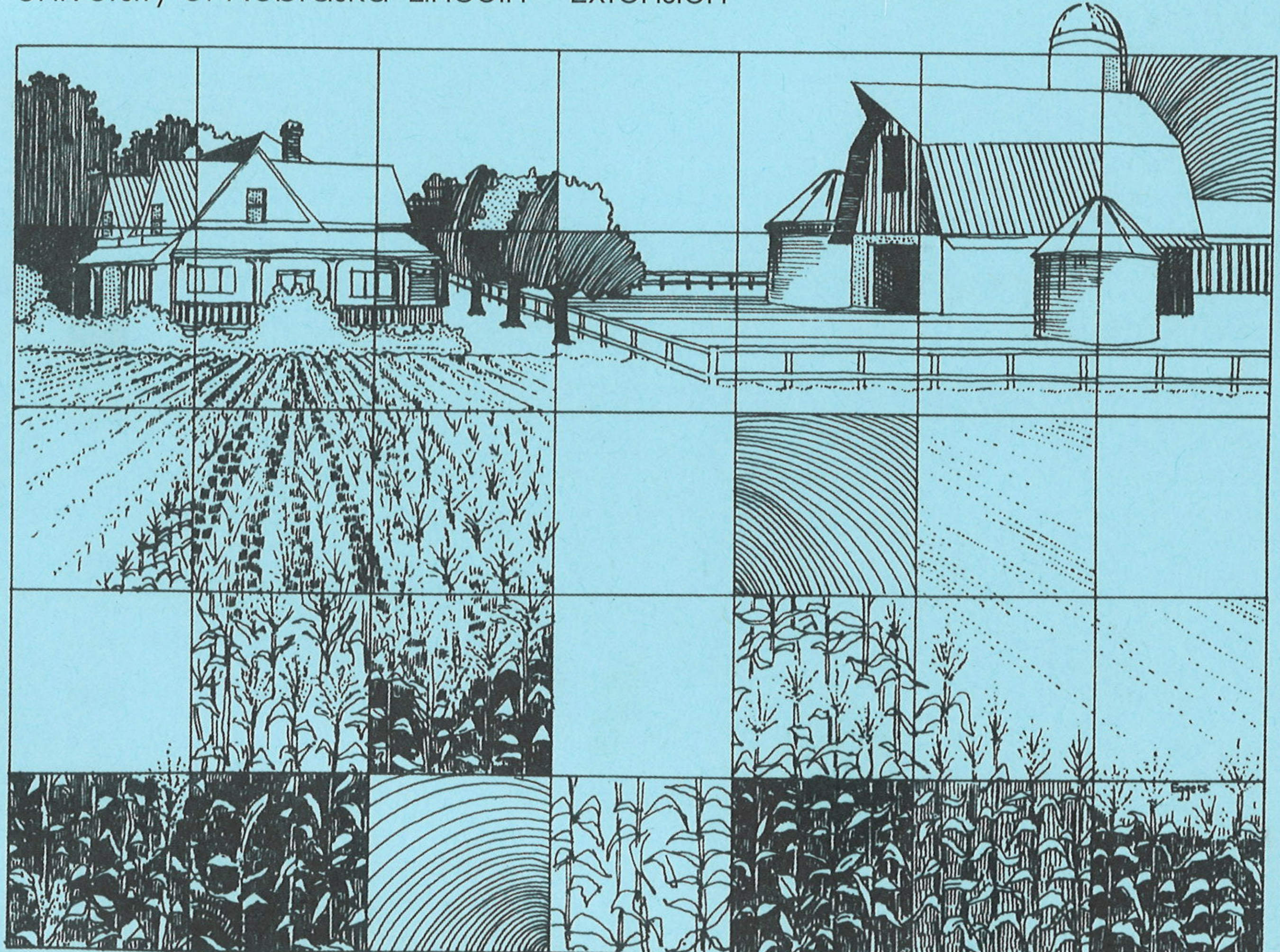

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Trends in Nebraska Cropland Markets and Rental Considerations for 2016

Jim Jansen, Extension Educator
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Leading into 2016 Nebraska crop producers are facing challenging financial circumstances given lower grain prices and uncertainty in the future exchanges. Given these constraints, making informed decisions regarding purchasing or renting of crop ground remains more important than ever. This article summarizes trends in cropland values and rental rates along with discussing key considerations when negotiating and setting 2016 lease arrangements.

Trends in Nebraska Cropland Values and Rental Rates

Cropland markets in Nebraska on average peaked across the state in 2014 and slightly declined leading into 2015. 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 new 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 complete 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 2015

Trends in Dryland Cropland Values

Dryland cropland in Nebraska had a weighted average value of $3,390 per acre in 2015. Compared to 2014, this value declined approximately 9 percent. Across the 8 agricultural districts of Nebraska the average dryland cropland value declined from about 4 to 14 percent. These changes correlate with lower grain and oilseed.

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 rental rates across the state in several years. Recent observation from survey participants have also noted a decline in number of dryland cropland transactions offered for sale during 2015.

Table 1. Average Reported Value per Acre of Dryland Cropland in Nebraska, February 1, 2015[a]

Agricultural District	Dryland Cropland[b] Values		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	935	730	580
North	2,150	1,580	1,440
Northeast	7,085	5,645	4,475
Central	3,635	3,115	2,285
East	7,595	5,980	4,650
Southwest	2,180	1,855	1,260
South	4,050	3,340	2,465
Southeast	6,655	5,060	3,560

Source: [a] Nebraska Farm Real Estate Survey, 2015
[b] Dryland cropland without irrigation potential.

Differences in the quality of dryland cropland are display 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 $580 per acre and highest per acre dollar value of $7,595 per acre in the East district.

The lowest rates of decline were noted in the South district with the greatest rate of decline noted in the Northwest district. The strong growth in dryland cropland values were hard to maintain into 2015 as returns for grain or oilseeds declined while input costs remained fairly constant.

Trends in Center Pivot Irrigated Cropland Values

Center pivot irrigated cropland in Nebraska had a weighted average value of $7,315 per acre in 2015. Center pivot irrigated cropland has historically been the highest valued land class reflecting the higher productivity of the ground. Rates of decline were slightly lower for this land class compared to dryland cropland. On average across the state, center pivot irrigated cropland declined about 3 to 5 percent.

The lower rate of decline for center pivot irrigated cropland reflects a higher and more consistent yield potential compared to dryland cropland. The highest rate of decline in center pivot irrigated cropland was noted in the Central district at 12 percent while a slight increase of 1 percent was noted in the Southwest district.

Table 2. Average Reported Value per Acre of Center Pivot Irrigated Cropland in Nebraska, February 1, 2015[a]

Agricultural District	Center Pivot Irrigated Cropland[b] Values		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	4,925	3,625	3,415
North	5,985	4,835	4,435
Northeast	9,245	8,150	6,650
Central	8,475	7,825	5,830
East	10,885	9,575	7,915
Southwest	7,055	5,790	4,880
South	9,155	8,270	6,675
Southeast	10,645	9,425	7,320

Source: [a] Nebraska Farm Real Estate Survey, 2015
[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 show in Table 2. High grade center pivot irrigated cropland in the East and Southeast district noted land values of well over $10,000 per acre. A low of $3,415 per acre low grade center pivot cropland was noted in the Northwest districts.

Considerations for Cropland Values in 2016

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. Simply put, return on an investment takes into account the income earning potential of an asset over future years. With the current expectation of lower crop prices into the future and input costs remaining relatively unchanged, the resulting return on the asset will most likely be lower for 2016.

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. These dynamics will be discussed in further detail later in this article.

Cropland Rental Rates for 2015

Trends in Dryland Cropland Rental Rates

Dryland cropland rental rates peaked in 2014 and declined on average between 5 to 10 percent leading into 2015. Survey participants noted current commodity prices and farm input costs as the most negative factors leading to the lower rental rates paid by cropland tenants. Entering into 2016 cropland tenants face very similar dynamics in terms of returns on cropland acres.

Table 3. Reported Cash Rental Rates for Dryland Cropland in Nebraska: 2015 Averages[a]

Agricultural District	Dryland Cropland Rental Rates		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	50	35	25
North	85	65	40
Northeast	305	235	175
Central	140	105	85
East	255	205	155
Southwest	60	45	30
South	115	85	65
Southeast	215	170	170

Source: [a] Nebraska Farm Real Estate Survey, 2015

Rental rates for dryland cropland across Nebraska ranged from High of $305 per acre in the Northeast district to a low of $25 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, irrigated cropland declined about 5 to 10 percent across the state.

Table 4. Reported Cash Rental Rates for Center Pivot Irrigated Cropland in Nebraska: 2015 Averages[a]

Agricultural District	Center Pivot Irrigated Cropland[b] Rental Rates		
	High	Average	Low
	---------- Dollars per Acre ----------		
Northwest	295	175	150
North	275	235	190
Northeast	430	365	285
Central	295	245	215
East	385	330	270
Southwest	310	250	225
South	330	255	240
Southeast	360	300	265

Source: [a] Nebraska Farm Real Estate Survey, 2015
[b] Cash rents on center pivot irrigated cropland assumes landowners own the total irrigation system.

A high of $430 per acre was reported in the Northeast district with a low of $150 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 2015 crop producers reported on average good yields across the state, but still have foreseeably lower commodity prices to market these commodities.

Landlord and Tenant Negotiations

Fumbled Negotiations and Amending the Situation

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. The landlord should have appropriate production information if the owner has interest in obtaining this kind of information. Landlords may feel that the tenant has all the power because this individual was in the field all year long and knows how the ground yielded for that production year.

The tenant should receive information on the landlord's preferences for management of the land asset. In the vast majority of cases, with proper communications, the lack of trust would become less of an issue.

Successful Elements of Communication

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

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. At the time of this publication, the demand for farms to lease far exceeds supply. Losing a land lease contract is a common fear among many tenants.

The lease should not be about a feeling that one party has the 'power' over the other. 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.

Lease considerations for 2016

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.

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 minimums.

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. An appropriate clause can be included in the lease, if the landlord wants a different outcome.

Other Resources:

For more information about the 2014-2015 Farm Real Estate Report, or for cash lease provisions go to the articles: "Farmland Leasing Checklist" or "Frequently Asked Questions – Farmland leases",http://agecon.unl.edu/realestate

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Economics: Making Your Farm or Ranch a Lean Green Money Making Machine

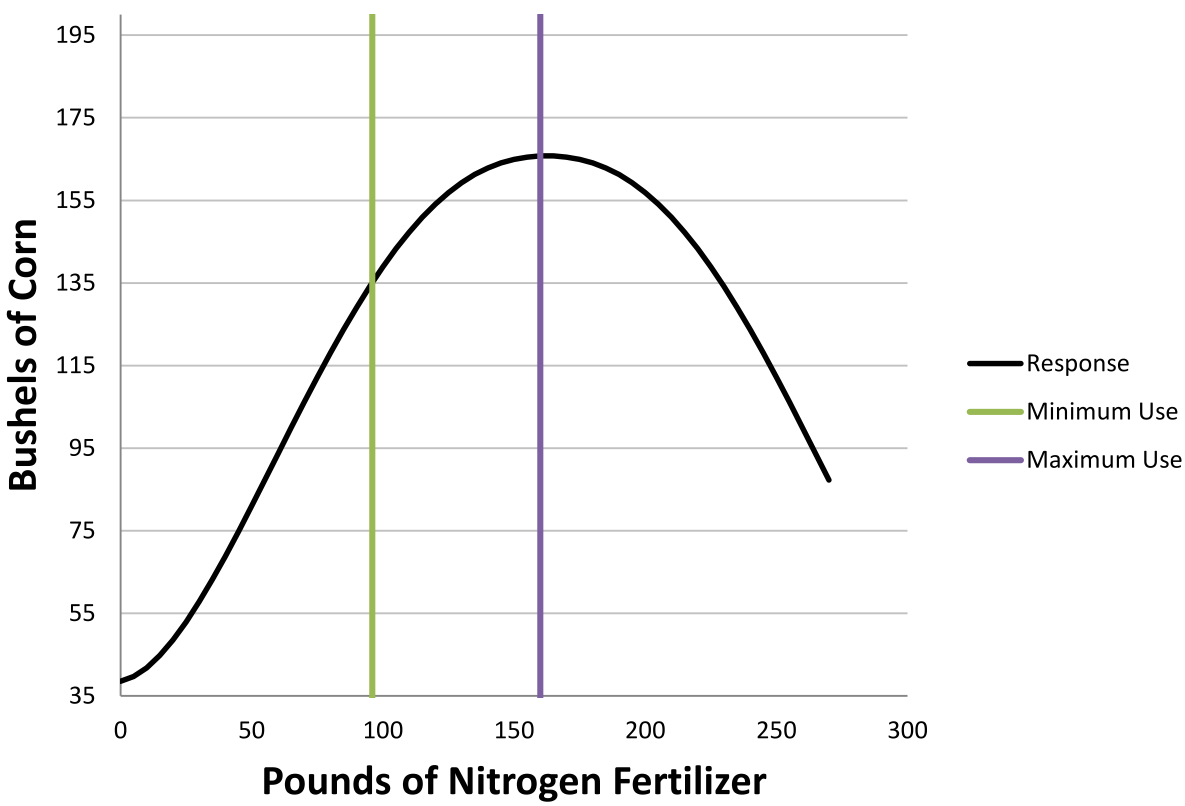
Matt Stockton and Robert Tigner

When considering current markets and production costs ag producers face, it is evident that producers need to manage wisely. While no one can provide a “silver bullet” that makes any particular operator successful, basic economic concepts exist that can help decision makers make the best choices possible under any circumstance. There is not enough room to describe all of the strategies one could use to do this. However, the material explained in the next few pages is a way of thinking which, when followed consistently, will lead to making decisions more likely to lead to economic success. After all, there is no guarantee, even when making proper choices, that the outcome will be exactly what is expected.

Let’s first start out by talking about the nature of the agricultural production business (farm or ranch). This business is based on using biological (physical) relationships to produce an output such as food or fiber. This means that varying levels of inputs, such as fertilizer, feed ingredients, water, and chemicals, has an effect on productivity. This is one reason why inputs are measured. Producers generally use inputs under the assumption that the nature of the relationship between productivity and input use is known. In the text that follows we will delve a bit deeper, as a clearer understanding of this basic concept leads to a specific way of thinking and increased profitability.

For example, if you were to take a corn farm and apply varying levels of nitrogen (N) fertilizer (say 0 to 250 lbs. of N/acre), then over time you could use that yield information to create a nitrogen response map. Your outcome may look something like that illustrated in Figure 1.

Figure 1. Example Corn Yield Response to Nitrogen Fertilizer



Note from the figure that the corn yield (response) to each additional pound of fertilizer varies depending on how much fertilizer has already been applied. In the case where the application level of 96 pounds of nutrient N/acre is applied, (the "Minimum Use" line marked in Figure 1) results in a expected yield of 135 bushels (bu.)/acre. The average bushels gained for each pound of N fertilizer applied at this rate can be calculated and is; (135 bu./acre minus 38 bu./acre (yield without any use of N) which equals 97 bu./acre then divided by 96 pounds of applied N which averages to be just over one bushel of corn grain/lb. of N. For each additional pound of the N/acre applied above this minimum point the figure shows a decrease in the average bushels obtained for each pound of N. In effect each additional pound of N fertilizer applied in addition to the first 96 lbs. is consistently losing potency to increase production. Economists call this effect a diminishing marginal effect and consider it to be a big deal. Each additional or marginal unit of N fertilizer added per acre provides less additional corn grain then the previous unit of that input. This marginal effect in biological systems, such as agriculture, usually continues to shrink and eventually becomes negative. This idea is analogous to the statement that you can't feed the world out of a flower pot.

Expectedly, as the effect of the N continues to erode at some level the additional pound of N will result in a negative effect. At this point the additional use of 1 more lb. of N will actually result in a decrease in yield. This point is illustrated by the intersection of the yield response "curve" and the "Maximum Use" line in Figure 1. This happens at approximately 160 pounds of N/acre, as shown in Figure 1, yields are maximized close to 166 bushels/acre. While sections of land or herds of animals may differ in (productivity) where this maximum occurs, each has a unique maximum. The critical piece to understand is that each pound of N/acre (input) does not result is equal amounts of corn grain (production or output). In fact as you look at the response of corn grain produced for the additional pounds of N/acre applied you will note that as yields approach the maximum point, yield response declines. For instance, the last 5 lbs. of N/acre added after 155 lbs. of N/acre results in slightly more than .05 bushels of grain, on average. For each additional pound of N/acre a little over 5% of a bushel (2.84 lbs. of grain per acre) is gained.

SO, SO WHAT?

In this example, if the 2.84 lbs. of grain were valued at $3.50/bushel, making their worth less than $.18, whereas the 1 lb. of N which was assumed to cost $.50/lb. makes the value obtained from the added pounds of corn worth less than the costs of fertilizer by $.32. This simple comparison is known as marginal analysis and is representative of a profit maximizing mind set verses the traditional idea of simply maximizing yields. This relationship changes everything, since it prohibits maximum yield from ever being maximum profit, except in the unlikely event that the input is entirely costless (including opportunity costs). Think about it; producing at maximum yield focuses on only production and disregards costs and revenues. Notably, maximizing production is simpler to think about and apply.

But is it worth it?

Let us use this same information to make comparisons among three different methods of optimizing. Method 1: Is an arbitrarily chosen level of production, chosen by the producer for reasons only known to him, whereby inputs are selected to minimize production costs. This approach is identified as (Cost Min). Method 2: Is the traditional idea of shooting for the maximum amount of production using the most efficient amount of inputs to achieve that goal. This approach is identified as (Prod. Max). Method 3: In this method, we adopt the idea that the level of production is based on that point where profits will be maximized. This last method considers both input costs and revenues, and is labeled the (Profit Max) approach.

In our case using the Cost Min approach we adopt a yield goal of approximately 160 bu./acre, this level of productivity requires 130 lbs. N/acre. Also from the example we know that maximum yield occurs near 166 bushels/acre requiring 162 lbs. of N/acre. Using Table 1, the highest return (Profit Max.) is identified as ($276.32), which has an expected yield close to 165 bu./acre and requires 150 lbs. of N/acre.

Table 1. Profit maximizing lbs. of N, for $3.50/bu. corn and $0.50/lb. N, identified by the highest return

Lbs. N/acre	Corn Yield (bu./acre)	Returns
149	164.8012	$276.30
150	**164.9493**	**$276.32**
151	165.0843	$276.29

This outcome is based on a corn price of $3.50 bu., N fertilizer cost of $0.50/lb., and all other production costs set at $226/acre (no land costs).

Table 2. Results of the three methods of Optimizing, with $3.50/bu. corn and $0.50/lb. Nitrogen Fertilizer

Cost Component	**Prod. Max** **~165.78 bu./acre**	**Cost Min** **~159.26 bu./acre**	**Profit Max** **~164.95 bu./acre**
Revenue	$580.24	$557.41	$577.32
Fixed Costs	226	226	226
Nitrogen Costs	$81	$65	$75
Total Costs	$307	$291	$301
Returns	$273.24	$261.41	$276.32
@3000 acres that is $9,247.98			**$3.08/acre difference**

The estimated budgets for these three optimizing methods are shown in Table 2 (above), and indicate that shooting for the most production (Prod Max) results in a loss in returns of $3.08/acre verses the Profit Max method. The Cost Min method provides lower costs than the other two methods but results in $11.83 and $14.91 less return than either Prod. Max. and Profit Max. respectively.

How do these budgets change when the value of the output (corn grain) increases? To make this comparison we follow the same procedures but, increase corn bushel price by a $1, to $4.50/bu. and keep all other costs and yields unchanged. The Prod. Max. and the Cost Min. yields and fertilizer use are unaffected by the increased value of corn since they are not determined by revenue and cost interactions but by other means. As expected, the added value of the corn increases the use of N/acre by 2 lbs., (from 150 to 152 lbs. of N/acre) for the Profit Max solution, shown in Table 3.

Table 3. Profit maximizing lbs. of N, for $4.50/bu. corn with all other cost unchanged, identified by the highest return

Lbs. N/acre	**Corn Bu/acre**	**Return**
151	165.0843	$ 441.38
152	**165.2066**	**$ 441.43**
153	165.3163	$ 441.42

This is a logical result, since one would expect that as the value of the production increases, more can be spent profitably to obtain that production. Table 4 shows Returns to have a smaller difference between Profit Max. and Prod. Max. then the first result ($3.50/bu corn, $0.50 lb. N). However, in the case of Cost Min. method, which still provides lower costs than the other two methods, shows returns that are greater in difference, $13.35 and $15.76 less returned than Prod. Max. and Profit Max. respectively. This increase in difference is consistent with corn value increases, indicating that a higher level of production would produce increased returns.

Table 4. Results of the three methods of optimizing, with $4.50/bu. corn and $0.50 per lb. Nitrogen Fertilizer

Cost Component	**Prod. Max** **~165.78 bu./acre**	**Cost Min** **~159.26 bu./acre**	**Profit Max** **~164.95 bu./acre**
Revenue	$746.02	$716.67	$743.43
Fixed Costs	226	226	226
Nitrogen Costs	$81	$65	$76
Total Costs	$307	$291	$301
Returns	$439.02	$425.67	$441.43
@3000 acres that is $7,220.73			**$2.41/Acre difference**

Finally, looking at the case where corn prices remain at the $3.50/bu. value and fertilizer (input) prices increase we are able to see the effect increasing costs have on the three methods. The expectation is that as production cost increase, Profit Max yields should decrease. Since the cost to produce each bushel becomes more expensive, and the value remains unchanged, less would be produced. Table 5 is verification of that expectation and logic. Profit Max. N use drops from form 150 lbs. N/acre to 140 lbs. N/acre. Interestingly, this input cost increase results in a change in the Cost Min. method's economic ranking, making it more profitable than the Prod. Max., by $9.17/acre, and only $2.56/acre less profitable then the Profit Max., Table 6. Profit Max. also increases in its returns over the Prod. Max. method, to a positive difference of $11.73/acre. This last result illustrates the direction of profitability, that when costs are increasing producing near or at the Profit Max. level provide added returns over Prod. Max..

Table 5. Profit maximizing lbs. of N, for $3.50/bu. corn with increase N costs to $1/lb., identified by the highest return

Lbs. N/acre	Corn Bu/acre	Return
139	162.5581	$ 203.95
140	**162.8476**	**$ 203.97**
141	163.1221	$ 203.93

Table 6. Results of the three methods of optimizing using $3.50/bu. corn and $1 per lb. Nitrogen Fertilizer

Cost Component	**Prod. Max ~165.78 bu./acre**	**Cost Min ~159.26 bu./acre**	**Profit Max ~164.95 bu./acre**	
Revenue	$580.24	$557.41	$569.97	
Fixed Costs	226	226	226	
Nitrogen Costs	$162	$130	$140	
Total Costs	$382	$356	$366	
Net Revenue	$192.24	$201.41	$203.97	
@3000 acres that is $35,179.80.			**$11.73/Acre difference**	

While it may not be possible to know the exact Profit Max level at which to produce, it is “economically” worth applying the “marginal analysis” thinking to production. Whenever a choice about using any input is being made, it is wise to consider: 1) Whether that choice provides the necessary value to implement it, and/or 2) At what level is an input best applied.

For example, a certain producer has the choice between two types of seed to purchase. In this illustration, seed 1 costs $50/acre while seed 2 costs $75/acre. He expects that if seed 1 is used its yields will likely be 3 bu./acre less compared to seed 2. If the value difference is based on a $3.50/bu. corn price, making the added production by seed 2, $10.50/acre with the added cost of $25/acre and a difference of $14.50 in favor of seed 1—making seed 1 the optimal choice. However, if in addition to the added yield herbicide and insecticide savings were expected in this case seed 2 amount provides an additional $23/acre savings, seed 2 would be more profitable by $8.50, This example is shown below in Table 7.

Table 7. Seed costs comparison using "marginal analysis"

Income increase From Using Expensive Seed		**Costs Increase From Using Expensive Seed**	
3 bu/acre @ $3.50	$10.50	Seed	$25
Reduced costs From Expensive Seed (Savings)		**Reduced Income**	
Applied Herbicides	$15	None	
Applied Insecticides	$8		
Increased Income + Total Savings	$33.50 Benefit	Increased Costs + Reduced Income	$25 (Costs)
Net Benefit	**$33.50 - $25 = $8.50 Use the more expensive seed since the *benefit* out ways the *costs***		

The use of marginal analysis may seem overly obvious, or to easy, yet it can be a powerful way of thinking and making decisions. So next time when faced with an input choice take some time to consider the pros and cons, use marginal analysis and try to quantify the overall gain by using that next unit of input verses the overall value returned for using that unit". More generally "Do the benefits outweigh or at least cover all the costs?". In the case of Prod. Max., while certainly gratifying to be known as the top producer, perhaps even more satisfying is being the most PROFITABLE.

What does it take to produce 80+ bu/ac soybean routinely?

Patricio Grassini, Assistant Professor
Jennifer Rees, Associate Extension Educator

Yield potential is defined as the yield of a crop cultivar when grown with optimal management, with non-limiting water and nutrient supplies, and good control of weeds, insects, and diseases. Weather during the growing season (i.e., sunshine, temperature, rain) will determine the yield potential in a given year. You have an opportunity via your management techniques to increase the odds of capitalizing on the yield potential. A previous funded project, supported by the Nebraska Soybean Board, used data from 500+ producer soybean fields in NE planted in 2010, 2011, and 2012 to identify key factors driving NE producer soybean yields **(SEE FIGURE #1)**.

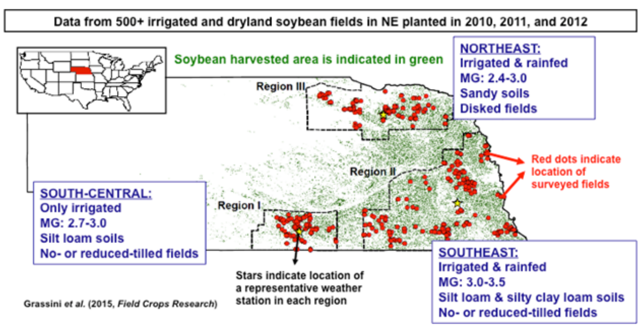


FIGURE #1. Location of the irrigated and dryland soybean fields that were surveyed during 2010, 2011, and 2012 (red circles). Surveyed fields portrayed well the range of management practices across major soybean production regions of Nebraska.

Water supply sets an upper limit to soybean yield **(SEE FIGURE #2)**. Below is a graph of the producer-reported on-farm actual soybean yield (vertical axis) for various rainfed and irrigated fields versus the total amount of seasonal water supply (horizontal axis). Water supply includes available soil water at planting and in-season rainfall plus irrigation. Each data point represents an individual field-year observation. Obviously, irrigated fields (blue) are not typically water-stressed during reproductive development because of well-timed irrigated dates and amounts, and thus have the highest yields in this graph. Around 25 inches of water supply are needed for maximum yields; hence, it is very difficult to achieve 80 (or more) bu/ac without irrigation. The leftmost red line is a best-fit boundary function for the steepness of soybean yield response to water (rain and/or irrigation), which is estimated to be 3.7 bu/ac per inch of seasonal water supply **(SEE FIGURE #2)**.

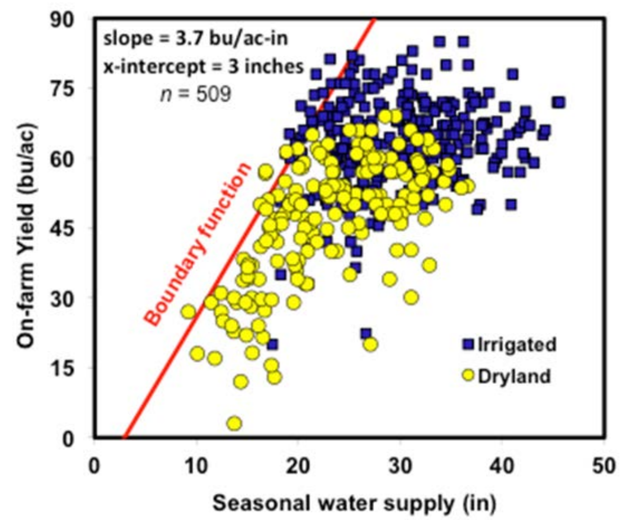


FIGURE #2. Relationship between producer soybean yield and seasonal water supply (available soil water at planting plus in-season rainfall plus irrigation). Each symbols corresponds to an individual producer field in a given year. Rainfed and irrigated fields are indicated with yellow and blue symbols, respectively. The red line indicates the boundary function for yield along the range of water supply.

In few words, with good management, soybean can deliver 3.7 bu/acre per inch of water supply. Rainfed and irrigated field data points near that red line reflect two things all soybean producers want – the highest yields possible for each inch of water (3.7 bu/ac in), which is now referred to as soybean Water Productivity. However, along the range of water supply, most producer fields are well below their potential yield, indicating that other non-water related factors are limiting yield. Likewise, many fields exhibited water supplies larger than 25 inches, which means a water supply in excess of the crop water requirement for highest yields. These data will be very useful in determining what individual producers can do in their specific farm fields by alteration of soybean production management to shift their field yields leftward (to get the same yield for less water), and/or shift their field yields upward (to get higher yield for the same amount of water). Ultimately, soybean producer supplied soybean data for one or more fields on his/her farm each year can provide information to State Soybean Board, university agronomists and extension personnel as to how to help soybean producers manage their soybean fields to get "crop per drop". Doing that, in net profitability terms provides producer s with "more revenue, less expense"!

Early planting is also key to set a high yield ceiling. Early planting helps building a canopy that harvests most of the available sunlight, especially during crop stages that are crucial for yield formation. Building and maintaining a green, healthy canopy also requires proper crop nutrition and pest control.

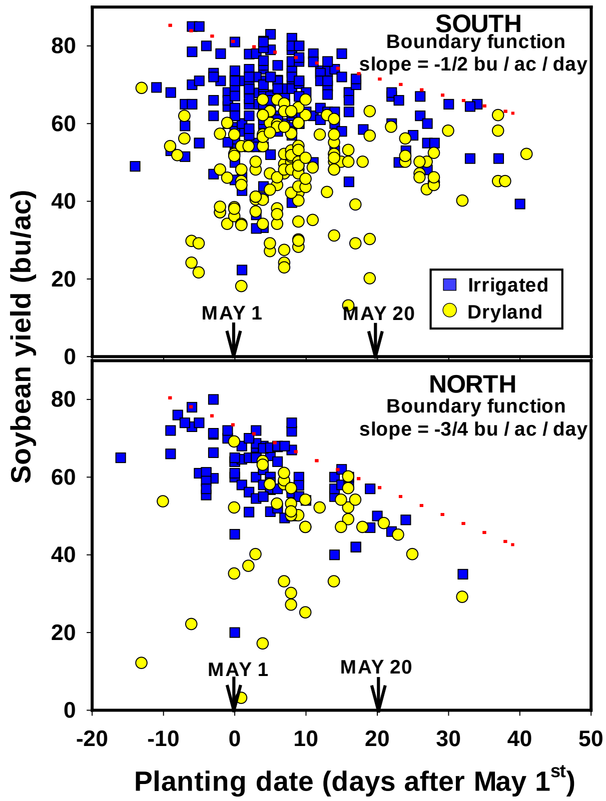


FIGURE #3. Relationship between producer soybean yield and planting date in south and north Nebraska (upper and lower panels, respectively). Planting date is shown as days after May 1st. Vertical arrows indicate May 1st and May 20th. Rainfed and irrigated fields are indicated with yellow and blue symbols, respectively. The red line indicates the boundary function for yield along the range of planting date.

Above is a graph **(SEE FIGURE #3)** that shows the producer self-reported yields (vertical axis) plotted against self-reported planting dates (horizontal axis) for specific producer reported irrigated (blue) and rainfed (yellow) soybean fields in South East NE (left graph) and North East NE (right graph). The dashed line ('boundary function') was derived from the observed highest yields across the range of planting date. This boundary delimits the potential yield for irrigated soybean for a given planting date. Reaching (or not) that potential yield will depend on other factors such as field water supply, in-season field weather, field-specific soil characteristics, and other producer- & field-specific management practices besides planting date. Also note that most dryland fields are below the potential-yield boundary because in rainfed production scenarios, the amount of water supply imposes the FIRST key upper limit to soybean yields.

The above graph indicates that there was a YIELD PENALTY of ½ bu/ac (South East NE) and an EVEN BIGGER PENALTY of ¾ bu/ac (North East NE) in potential yield (bu/ac) per day of delay in planting date **(SEE FIGURE #3)**. These values represent the "opportunity cost" of planting soybean late in the season. For a given farm, the overall opportunity cost can be estimated by multiplying the daily yield penalty by the number of acres, the current soybean price, and the extent of delay in planting. For example, given current soybean price of $10/bushel, the estimated lost benefit for planting a 160-acre in south NE with soybean on May 8th (7 days after May 1st) would be 7 x ½ x 160 x 10 = $5,600! That would be a nice net bottom line return to a producer who simply elects to plant that 160 acre field one week earlier!!!!!

Ultimately, the objective of this NSB project is to understand what is needed to achieve 80+ bu/ac soybean routinely and, based on this information, help optimize current management practices in order to bring current NE soybean yields closer to their potential. In this project, our objective is to WORK FOR YOU. Our goal is to use the data YOU supply to help YOU get soybean yields on YOUR farm fields that, in the future, will be closer to the potential soybean yields that are possible on those fields, once you know what production system factors are holding back YOUR current soybean yields.

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Cover Crop Truths: Ignoring the Fiction and 'Rural' Legends

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The term "cover crop" is a general term used to describe crops grown to 'cover' the soil in some sequence with major cash crops like corn or soybeans either for purely environmental reasons or to produce forage for livestock feed. Cover crop species vary widely in seed cost and intended use. Thus, it is important to first identify where cover crops fit into cropping systems. There are several questions to ask that help evaluate how to incorporate cover crop cover crop/forage double crop production into current cropping systems.

1. Will it be managed only as a cover crop to reduce soil erosion, reduce soil compaction, increase organic matter, or reduce nutrient leaching?

2. Will it be managed primarily as a cover crop with forage production as a secondary outcome if enough production is available?

3. Can it be managed as a forage crop first with potential for simultaneous cover crop benefits?

There is not much information on seasonal production and forage potential for many of the annual grasses and broadleaf species used as cover crops. Regardless of planting date, growth will slow by October 1 and cease with the first killing frost. Spring cover crop species and varieties have minimal or no cold tolerance and will not resume spring growth. Winter species and cultivars require a combination of cold temperatures and high humidity coupled with short days to trigger stem elongation and the flowering process. These will usually resume growth in the spring – likely sometime in March.

Ease of establishment and probability of success

The timing of cover crop establishment or planting date is often determined by harvest date of the primary crop. The relative ease of establishment and probability of success for planting, establishing, and producing biomass from cover crops and forage double crops is different based on the cropping system (**Table 1**). The greater the availability of light, water, and nutrients, the greater the probability of success. Secondarily, there must be adequate growing season remaining to provide enough growing degree days for the cover crops.

Ease of establishment ranges from very easy to difficult and the probability of success ranges from very high to moderate. There are many instances where cover crop production is not practical and several more instances where recommendations cannot be made to ensure ease and success.

Table 1. Relative ease and probability of success for cover crops/forage double crops following different cropping systems in Nebraska.

Cropping system	Relative Ease	Probability of establishment and production success		
		Fall only	Fall and Spring	Spring only
Wheat	Very easy	Very high	Very high	Not practical
Hybrid seed corn	Very easy	Very high	Very high	Cannot recommend
Corn (silage)	Easy	High	High	Cannot recommend
Sorghum (silage)	Easy	High	High	Cannot recommend
Soybean	Difficult	Not practical	Not practical	Very high
Corn (grain)	Difficult	Not practical	Not practical	Moderate
Sorghum (grain)	Difficult	Not practical	Not practical	Moderate

Table 2. Cover crop/Forage cover crop choices for fall only, spring only, and fall and spring production.

Cropping system	Species choice		
	Fall only	Fall and Spring	Spring only
Wheat[1]	Spring small grains, brassicas; legumes Summer annual grasses, summer annual legumes, Summer annual broadleaf species	Spring small grains, brassicas Summer annual grasses, legumes, and broadleaf species Winter small grains	Not practical
Hybrid seed corn[2]	Spring small grains, brassicas	Spring small grains	Cannot recommend
Corn (silage)[3]	Spring small grains, brassicas	Spring small grains, brassicas Winter small grains	Cannot recommend
Sorghum (silage)[4]	Spring small grains, brassicas	Spring small grains, brassicas Winter small grains	Cannot recommend
Soybean[5]	Not practical	Not practical	Winter small grains
Corn (grain)[6]	Not practical	Not practical	Winter small grains
Sorghum (grain)[7]	Not practical	Not practical	Winter small grains

[1] Establishment of fall only species and winter and spring cover crop/forage cover crop species recommended immediately following grain harvest.
[2] Establishment of fall only and fall and spring cover crop/forage cover crop species recommended at male row destruction.
[3] Establishment of fall only cover crop/forage cover crop species recommended immediately following silage harvest. Establishment of fall and spring species also recommended following silage harvest.
[4] Establishment of fall only cover crop/forage cover crop recommended immediately following silage harvest. Establishment of fall and spring cover crop/forage cover crop also recommended following silage harvest.
[5] Establishment of winter small grains immediately following harvest for spring only cover crop/forage cover crop with minimal fall growth expected.
[6] Establishment of spring only cover crop/forage double crop can occur following harvest.
[7] Establishment of spring only cover crop/forage double crop can occur following harvest.

Key target dates for cover crop/forage cover crop establishment in Nebraska cropping systems

Before August 1

Following wheat, the possibility exists to plant numerous cover crop species and produce substantial biomass yields both in the fall and spring (**Table 2**). Oftentimes, many of the summer annuals will reach the reproductive stage. While they may produce mature seed, the maximum biomass potential and forage value can be reached earlier based on growing conditions and resource availability.

After August 1

If fall biomass production is a major goal and planting occurs prior to September 1st, then spring species are more desirable. Planting oats or spring cultivars of other cereal grasses and brassicas between August 1st and September 1st in Nebraska can produce 1 to 2 tons of biomass per acre.

After September 1

Later planting of spring cover crops (after September 10th) typically does not provide enough time to accumulate sufficient biomass to support grazing animals prior to the onset of winter. Therefore, it is best to plant winter species that can be grazed or harvested in the spring prior to planting of a summer crop (such as corn or soybeans). Planting winter cover crops in late summer or early fall can provide forage in the spring but the forage production in the fall is often less than for spring species.

After October 1

Regardless of planting date, growth will slow by October 1 and cease with the first killing frost. The spring species and varieties have minimal or no cold tolerance and will not resume spring growth. Planting winter cover crops in late summer or early fall can provide forage in the spring but the forage production in the fall is often less than for spring species.

Table 3. Current and previous cover crop research in Nebraska cropping systems.

Cropping systems	Current	Previous
Wheat	Drewnoski et al.; Redfearn et al.; Jasa et al.; Blanco-Canqui et al.; Proctor; Elmore et al.	Nielson et al. 2015
Hybrid seed corn	Irmak	
Corn (silage)	Drewnoski et al.	
Sorghum (silage)[1]		
Soybean	Elmore et al.; Proctor; Jasa et al.	Kessavalou and Walters, 1997
Corn (grain)	Elmore et al.; Jasa et al., Blanco-Canqui et al.; Proctor; Kranz	
Sorghum (grain)[2]		
Cover crop species	Most of above	Power and Koerner, 1994

[1] Information from research in corn (silage) should transfer to sorghum (silage).
[2] Information from research in corn (corn) should transfer to sorghum (grain).

Cover Crop/Forage Cover Crop Basics

All common crop production systems in Nebraska are prime targets for cover crops to reduce soil erosion and capture excess nitrogen, whether they include cattle grazing or not (**Table 2**). To be considered effective, integrated systems must maintain crop productivity and have no negative environmental impact.

Wheat offers the greatest flexibility for cover crops, which increases the ease of cover crop establishment and potential success rate. This is because the length of the growing season following wheat harvest is longer following harvest of many of the other crops. In addition, there is often adequate residual soil moisture immediately following harvest. In Nebraska, nearly all wheat has been harvested by mid- to late-July and certainly before August 1. The potential exists for either a late-summer planted summer annual or an early-planted winter annual. Termination the following spring prior to corn planting can be either through winter kill for spring species or herbicide application the following spring for winter species. From a cover crop standpoint, wheat is the only crop where warm-season cover crops can be planted with any reasonable chance of success for producing cover before winter.

Hybrid seed corn production is input intensive, oftentimes with both surplus irrigation and fertility. Seed corn production practices lend themselves to cover crops that provide cover and serve as nitrogen scavengers. Seed corn producers have successfully used a double-cropped system in seed corn production with a grazed late-summer planted forage cover crop. It is a common, but underutilized practice. Typical planting dates occur from early- to late-August during male row destruction. Common species used are oats, turnips, and radishes. Reliable information on beef gain while grazing cover crops is unavailable.

Similarly, there is no data on how grazing effects on the subsequent crop. Information is needed on the effects of grazing cover crops and crop residues on crop yields, soil health, and livestock performance.

Corn and sorghum (silage) is unique in that this system removes nearly all of the crop biomass during harvest. Thus, it is extremely important that a cover crop be established to reduce erosion potential. Planting dates from late August to late September will increase the probability of success for fall only cover crops, but it may be desirable to plant a combination of spring fall and winter cover crop/forage cover crop species.

Soybean harvest is usually completed by mid- through late- October in most areas. This does not allow enough time for any species to accumulate appreciable growth prior to the first killing frost. Cover crop and forage cover crop choice following soybean will be limited most likely to winter small grain forage species, such as cereal rye, triticale, wheat, or barley. The planting date will likely range from after October 1 until December 1. If possible, planting should occur in advance of the first killing frost.

Corn and sorghum (grain) is often completed after soybean harvest. However, it is not as critical to establish a cover crop following corn and sorghum grain harvest as either corn or sorghum silage or soybean due to the amount of residue that remains. In Nebraska corn grain systems, in-season establishment of cover crops in actively growing corn has been used with variable rates of success. There seems to be a greater success rate as this practice moves northward into northern Nebraska, the Dakotas and Minnesota and into eastern parts of the Corn Belt. There are several research projects in progress to evaluate the feasibility of this establishment method (**Table 3).**

Summary

Cover crop and forage cover crops have been used in Nebraska cropping systems, sometimes for many years. There are few published studies on the cover crops and forage cover crops and the potential services they provide that provide definitive guidelines or expectations for success. There is much information remaining to be learned.

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Discovering Answers! – Nebraska 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 take an active role in the research. On-farm research can provide a great avenue to accelerate learning about topics that impact your farm productivity and profitability. Research done on your farm will be directly applicable to your operation. The Nebraska On-Farm Research Network has been working with farmers, consultants, and industry since 1989.

How it works:

1. Farmers and/or educators identify research topics.
2. Research protocols are developed – generally for field length strips.
3. Trials are implemented, usually by the farmer, using his or her equipment.
4. Trials are often repeated at multiple locations and for several years.
5. Extension educators help collect data that is pertinent to the study topic.
6. Statistical analysis and a summary report are generated by educators.
7. At the Annual Results Updates meetings each winter the findings are shared and discussed by farmers, consultants, Extension Educators, and Extension Specialists.

2015 Research Studies

In 2015, we have a record of 65+ farmers working with over 25 Extension Educators and Specialists to conduct 100+ studies.

Topics include:

- Cover Crops
- Variable Rate Seeding
- Planting Populations
- Maize-N Nitrogen Rate Decision Tool for Sidedress Nitrogen
- Starter Fertilizer
- Fungicide Applications
- Row Spacing
- Foliar Micronutrients
- Seed Treatments including new treatment for Sudden Death Syndrome
- Project SENSE (crop canopy sensor directed in-season nitrogen application)
- and MORE

Annual Results Updates

Results of 2015 studies will be shared at 4 locations. 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.

February 8 - West Central Research and Extension Center, North Platte – 12 noon to 4:30 P.M.

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

February 11 - Lifelong Learning Center, Northeast Community College, Norfolk – 9 A.M. to 4:30 P.M.

February 12 - Agricultural Research and Development Center, near Mead – 9 A.M. to 4:30 P.M.

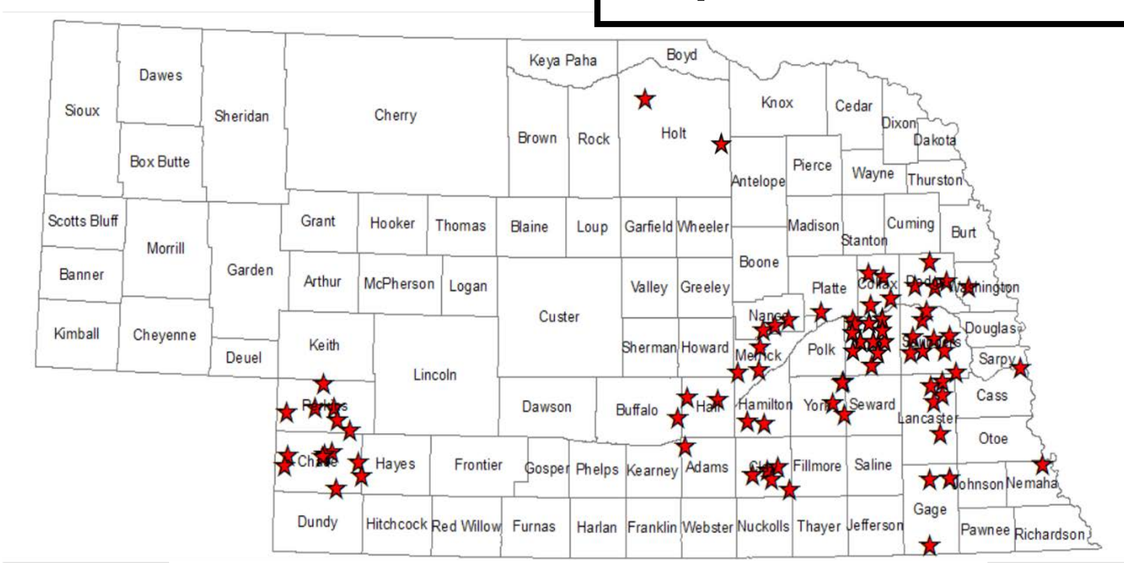


Figure 1: 2015 Nebraska On-Farm Research Network study locations.

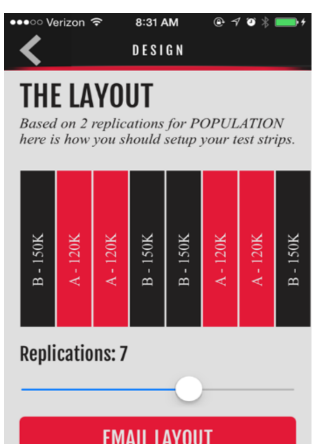
The Nebraska On-Farm Research Network has produced a number of excellent resources that will aid farmers in designing and carrying out research studies.

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

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.



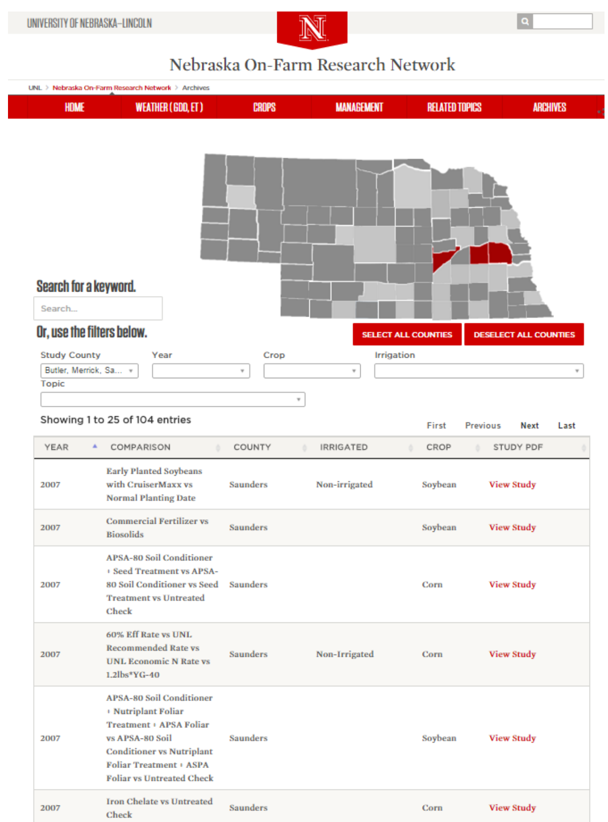
The app is available on iPhone and Android platforms.

Android	iOS/Apple
http://go.unl.edu/onfarmappandroid	http://go.unl.edu/onfarmappiphone

Archive Database

When designing a study, you should ask yourself the question "will this be of importance to my farm productivity, profitability, and long term sustainability?" Think about potential scenarios that may provide benefit to your operation, perhaps through lowering input costs, increasing yields, or both. A great starting place is to take a look at research that has previously been conducted with the Nebraska On-Farm Research Network. Are there practices that other growers have tested that you want to evaluate on your own farm? Are there questions left unanswered by previous research that you want to address?

An archive database of 800+ studies conducted over 26 years will soon be available on the Nebraska On-Farm Research website. This tool allows users to filter study results by county, year, crop, irrigation status, and topic. Check www.cropwatch.unl.edu/farmresearch for up-to-date information on the release of this tool.



CornSoyWater: real-time, online irrigation recommendation for corn and soybean fields

Haishun Yang, Crop Simulation Modeler (hyang2@unl.edu)
James Han, PhD student
Jim Specht, Soybean Physiologist

Irrigation decision must be made in real-time. To determine whether a field needs irrigation, one must (1) drive to the field, (2) estimate how much crop-available water is in the soil root zone, and (3) know if this amount is below the pre-determined depletion threshold for irrigation, or if the crop is or going to experience water stress. The decision-making process takes time (to get to the field) and requires good experience on judging the soil moisture status relative to irrigation threshold and crop stages.

To help irrigators make irrigation decisions, we have developed the **CornSoyWater** (Fig. 1, cornsoywater.unl.edu), an online program that predicts, in real-time with prediction of next three days, if a particular corn or soybean field needs irrigation now based on predictions of (1) crop stage, (2) stage-based irrigation threshold, (3) amount of crop-available water in the soil root zone, and (4) possibility of crop water stress. Users get those results, in digital numbers, from their home computers or their smartphones without the need of driving to the fields and scratching their heads to guess. In addition, the program can help users schedule their work more efficiently by visiting those fields that likely need attention.

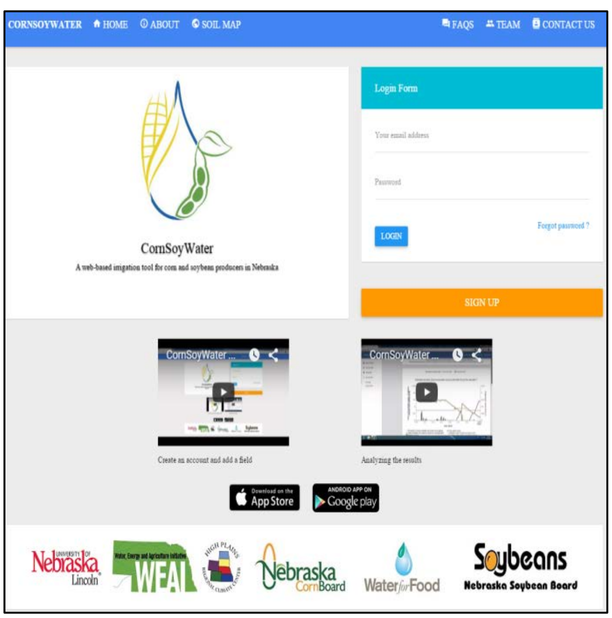


Fig. 1 Login page of the CornSoyWater program at cornsoywater.unl.edu

What does it takes to use CornSoyWater?

1. A user must open an account at cornsoywater.unl.edu by clicking on the yellow SIGN UP button. It is free.
2. Registering a field is simple:
   a. Choose 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.

How do predictions for a field look like?

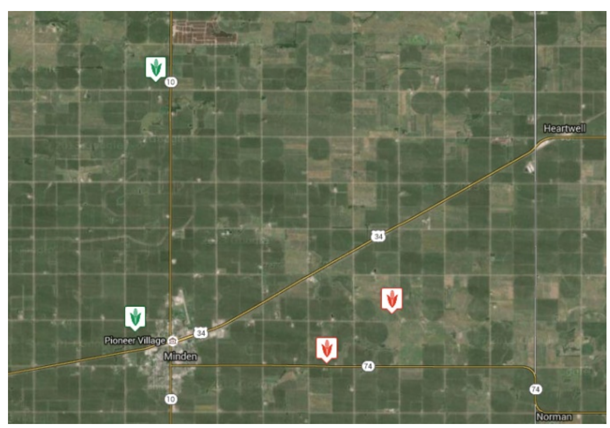


Fig. 2. Upon login of CornSoyWater, the map shows all registered field icons in green to indicate fields without need for irrigation or in red to indicate fields that may need irrigation.

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

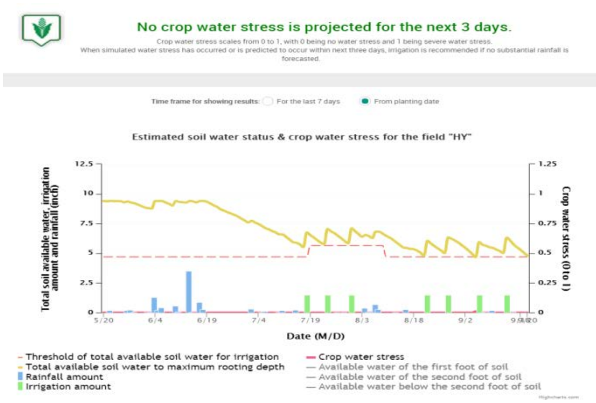


Fig. 3. Predicted total available water in root zone (yellow line), threshold for irrigation (dotted red line), rainfall (blue bars), and user input irrigation events green bars). X-axis is calendar date, left Y-axis is for water amount, and right Y-axis is for water stress (the red line that has been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

How does CornSoyWater work in the background?

CornSoyWater uses crop simulation models (Hybrid-Maize model corn and SoySim for soybean) to predict, on daily basis, 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 typed into the program so that a new prediction will show when the irrigation records are saved.

Summary

The **CornSoyWater** provides a recommendation on irrigation, in real time mode, based on quantitative predictions 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 a summary of 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 program can be implanted into irrigation control modules for automated irrigation control, variable rate irrigation, and other irrigation decision supports packages.

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Climate Information and Decision-Making

Tyler Williams, Extension Educator, University of Nebraska – Lincoln
Martha Shulski, Associate Professor and Director of HPRCC, University of Nebraska – Lincoln
Guillermo A. Baigorria, Dept. of Agronomy and Horticulture and School of Natural Resources, University of Nebraska – Lincoln
Consuelo C. Romero, Next Season Systems, LLC. Lincoln, NE

Introduction

Climate and weather have a substantial impact on agriculture in Nebraska. The spatial and temporal variability of the Nebraska climate can create many difficulties for agricultural management. Because Nebraska's location on the North American continent is far removed from large bodies of water, Nebraskans experience strong continental type climate. As such, residents do not benefit from the moderating influence of the ocean, and temperatures can have wide swings from day to day and season to season. Typical characteristics for a continental climate at this latitude are large temperature variability with warm summers dominated by convective thunderstorms, and cold winters influenced by snow and wind from mid-latitude cyclones[1].

There are many climate and weather tools and resources available to assist in short-term and long-term agricultural decisions. Historical data and trends can be used as a reference to the past and also make connections to the current trends being realized in a specific area. Tools created by regional climate centers, Universities, among other organizations can help analyze historical data, current conditions and forecasts to aid in short-term decisions, such as irrigation, or long-term decisions, such as crop rotations.

Trends in Nebraska

Many weather stations in Nebraska have been collecting data since the late 1800's. This long-term monitoring allows us to study the data to find trends that may aid in making decisions. Globally, there is an increasing trend in average surface temperatures, with 2015 expected to be the warmest on record[2]. Global temperature trends, however, do not always represent regional, state or local trends. For example (*see Figure 1*), the Climate at a Glance Time Series[3] from the National Climatic Data Center (NCDC) illustrates the 1895-2014 trend in annual average maximum temperature for Nebraska. The average maximum temperature is increasing at 0.1° F per decade; however, there is a temporal and spatial component that is important to consider. When looking specifically at the Panhandle Climate Division (Division 1), this trend increases to 0.2° F per decade, but the trend is 0.0° F per decade for the Scottsbluff location.

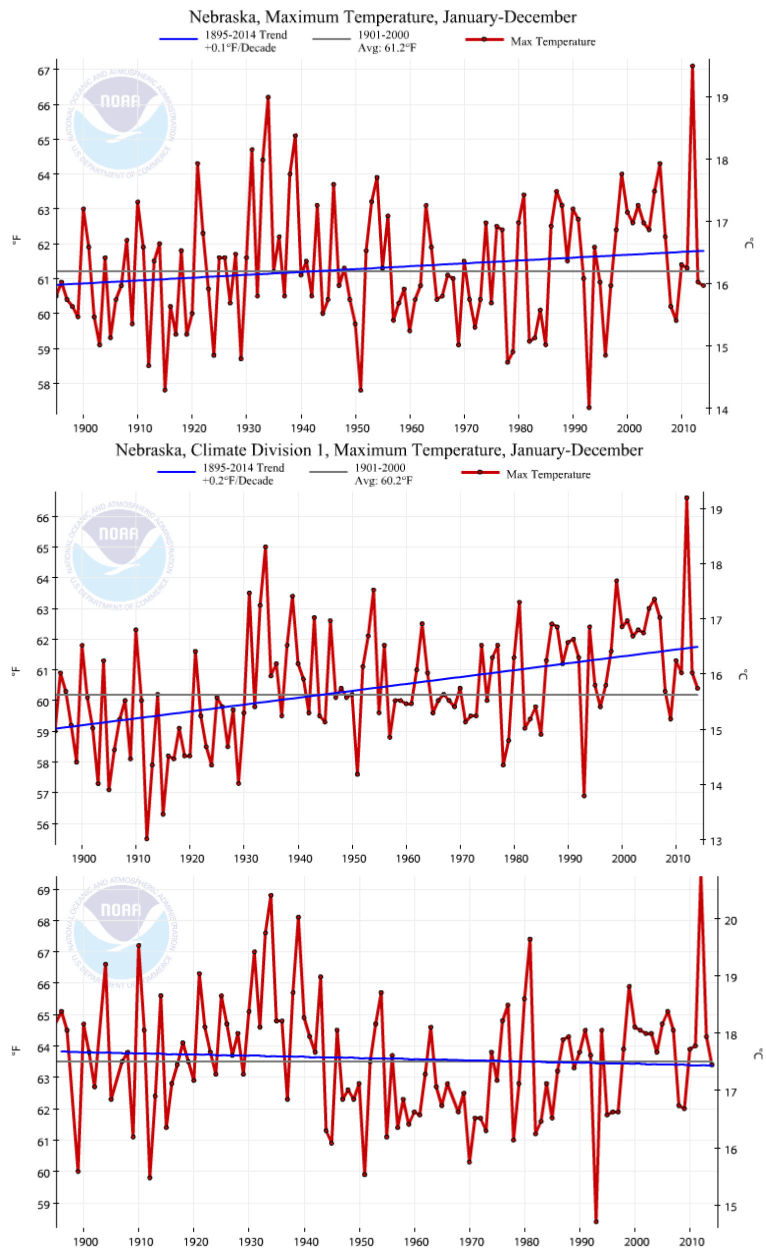


Figure 1. Average annual maximum temperature trends for Nebraska (top), Panhandle Climate Division 1 (middle), and Scottsbluff (bottom) from 1895-2014. Graphs from the NOAA NCDC Climate at a Glance Time Series[3].

Many trends may also be seasonal or on a shorter time scale that may not be evident when analyzing long-term data. *Figure 2* shows the average winter (December – February) temperature for Nebraska with the 1970-2015 trend line. This graph shows the obvious warming trend for Nebraska during the winter months and may be important to consider when planning some agricultural management practices. There are many micro and macro-scale components that play a role in climate trends, but it is important to consider local, regional, and global climate trends when making agricultural marketing, management, and estate-planning decisions.

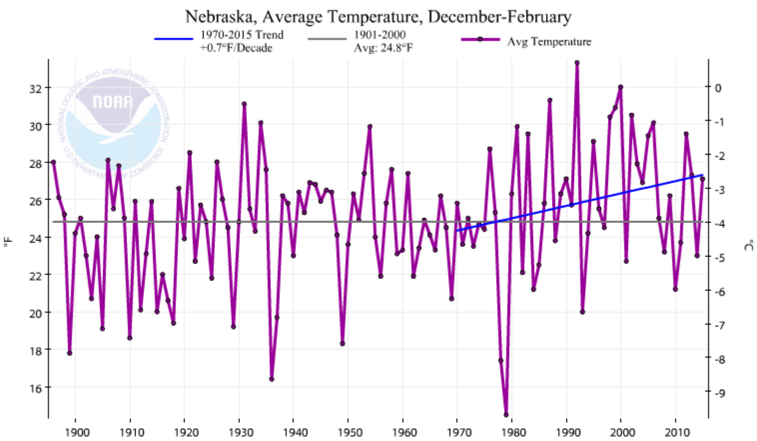


Figure 2. Average temperature (purple) for Nebraska from December through February from 1895-2015. The trend line (blue) is showing a 0.7° F per decade increase from 1970-2015. Graphs from the NOAA NCDC Climate at a Glance Time Series[3].

Climate Data

The amount of climate and weather data available is extensive and growing by the day. Using and managing large datasets can be challenging; however, many resources are available to provide maps, charts, and tools to transform data into a usable form. The University of Nebraska – Lincoln has numerous resources available through the High Plains Regional Climate Center (*hprcc.unl.edu*), National Drought Mitigation Center (*drought.unl.edu*), AgriTools mobile phone application, Useful 2 Usable (*AgClimate4U.org*), Nebraska State Climate Office, among other resources.

Local data provided by the National Weather Service Cooperative Observer Stations[4], the Automated Weather Data Network (AWDN)[5] from the High Plains Regional Climate Center (HPRCC), or other potential sources allow the user to look at local data and analyze their location in comparison to areas or time periods. Climate Normals are calculated every 10 years and are often used to describe the current state of the climate. Climate Normals are three-decade averages of climatological variables including temperature and precipitation. The 1981-2010 Climate Normals is the current dataset that contains temperature, precipitation, snowfall, heating and cooling degree days, frost/freeze dates and growing degree days.

CropClimate.org

CropClimate[6] is a platform intended to produce climate-related useful information for agricultural decision makers at scales finer than county level. CropClimate uses state-of-the-art knowledge in climate-, soil-, and crop-modeling to link the effects of environmental conditions and management on crop growth. Based on categorical climate forecasts, soil and agronomic information, and dynamic models and tools; producers, lenders, and agrochemical companies, and others can tailor their management and services according to the forthcoming season (Figure 2). CropClimate.org is part of several tools and methods developed by the International Consortium of Categorical Climate Forecast Applications (IC3FA) lead by the University of Nebraska-Lincoln. CropClimate is currently being developed in Brazil, Peru and Indionesia.

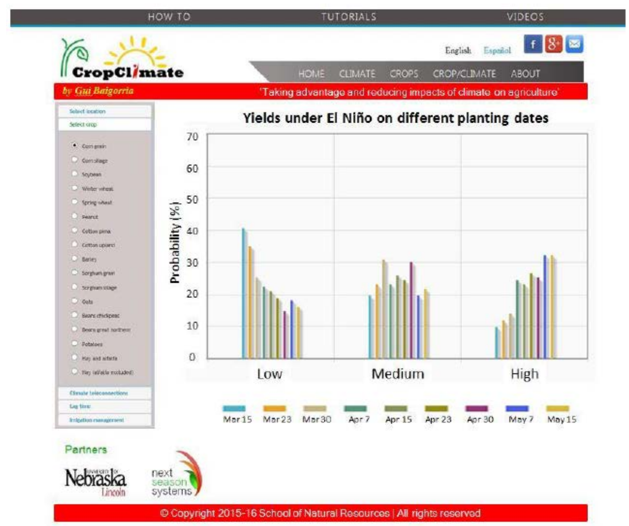


Figure 2. Sample output produced by CropClimate.org showing the probability of receiving Low, Medium, or High corn yields based on multiple planting dates during an El Niño. Developed by Guillermo A. Baigorra and Consuelo C. Romero.

References

[1] Shulski et al., 2013. *Climate Change: What Does it Mean for Nebraska.* NebGuide G2208

[2] Global Analysis – September 2015. NOAA National Climatic Data Center. *https://www.ncdc.noaa.gov/sotc/global/201509*

[3] *Climate at a Glance Time Series* – NOAA National Climatic Data Center. *http://www.ncdc.noaa.gov/cag/*

[4] *Cooperative Observer Program.* National Weather Service - *http://www.nws.noaa.gov/om/coop/wfo-rfcmap.htm*

[5] *Automated Weather Data Network*. High Plains Regional Climate Center - *http://www.hprcc.unl.edu/awdn.php*

[6] *CropClimate*. Department of Agronomy and Horticulture and School of Natural Resources - University of Nebraska – Lincoln, Next Season Systems, LLC. - *http://cropclimate.org/*

UNL Entomology Update

Online M.S. Degree in Entomology

The Department of Entomology at the University of Nebraska-Lincoln (UNL) offers a full curriculum online M.S. degree in Entomology. This 36 credit hour program, taught through the internet, emphasizes course work in entomology (i.e. insect ecology, identification, physiology) and flexibility in non-entomological training specific to individual student needs and interests.

The online program offers students an Option III (non-thesis) Masters degree. To fulfill the requirements of the Option III Masters degree, students complete 36 credit hours of course work. Students must also successfully complete a 4 credit hour Masters Degree Project. (The 4 credit hour project is included in the 36 credit hour program).

The online M.S. option was developed for students who cannot participate in an on-campus degree program. Intended audiences for this degree are individuals actively involved in entomologically related professions where advanced training in entomology is desirable, as well as those seeking such positions. Examples include agricultural professionals, crop consultants, pest control operators, middle and high school science and biology teachers, and military personnel. Students enrolled in the online program will have the opportunity to apply the training they receive in this program to their individual professions. Details about the program can be found at http://entomology.unl.edu/online-education, or by contacting Tom Weissling (tweissling2@unl.edu) or Erin Bauer (ebauer2@unl.edu)

New Pollinator Health Faculty position in Entomology

Dr. Judy Wu-Smart started as an Assistant Professor of Entomology in Lincoln in October 2015. Her research/extension emphasis will be pollinator health. Judy received her M.S degree in entomology from Washington State University and her Ph.D. degree in entomology from the University of Minnesota. Judy will focus on developing a pollinator health program to help understand the underlying stressors in bee health and their interactions with environmental toxicants contributing to global pollinator decline.

What was New in Entomology in 2015?

Jeff Bradshaw, Entomology Specialist

Pest Issues of 2015

This past growing season didn't really see a major outbreak of any particular pest insect, but there were a few notable pests that were abundant. Our chief issues with pest insects this year in the Nebraska panhandle were western bean cutworms, wheat stem sawflies, sunflower head moth and very localized high populations of grasshoppers.

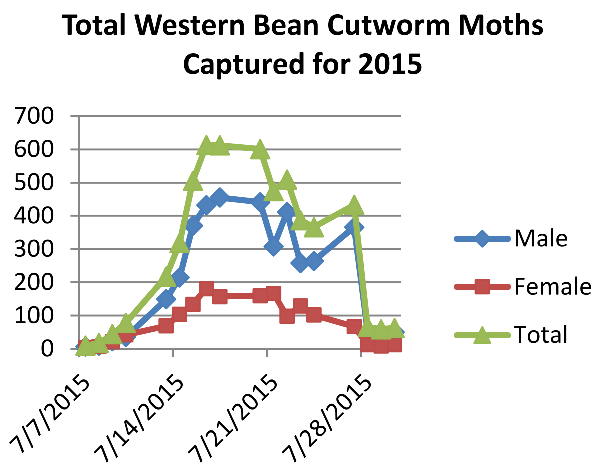


Figure 1. Total numbers of western bean cutworm moths captured in blacklight traps from July 7th to July 29th from 4 locations in the Nebraska panhandle.

Western bean cutworms were abundant throughout much of the state this year, with some of the highest populations that we have recorded in our blacklight traps in the panhandle in the past 5 years (Fig. 1). For corn and dry bean growers in the panhandle, this likely meant high infestations of western bean cutworm larvae in their bean in corn. For corn producers, transgenic traits in corn appear to be effective in our area to protect corn from injury. However, for dry bean producers, transgenic tools are not an option. While chemical controls are effective for western bean cutworms in dry beans; however, scouting for these insects in dry beans is very challenging for several reasons. Therefore, timely need for an insecticide application can be difficult to determine.

Sunflower acres were up this year; therefore, sunflower moth concerns were prevalent. For growers who planted their flower early (such as middle of May) they may have seen high numbers of sunflower head moths (Fig. 2). With current sunflower hybrids, planting early can mean heavy infestations of one or two generations of sunflower head moth in July and August.

Wheat stem sawflies continue to be a very important pest in wheat throughout the Nebraska panhandle. Additional survey efforts with the help of Julie Peterson (Extension Entomologist, West Central Research and Extension Center) have added several new field sample locations to our annual survey.

Figure 2. Sunflower damage from sunflower head moth.

We are currently going through samples; however, as usual lodging remains to be a function of severe weather timing. In 2014 and 2015, most of the panhandle counties had measurable infestations of wheat stem sawflies in their fields. Lodging was very noticeable especially in some areas north of the valley. While it's obvious that lodged wheat can have a tremendous impact on yield, yield loss (as much as 15%) can still occur as a result of sawfly larval feeding within tillers. Importantly, although we continue to assess survey samples, some of our survey locations are starting to see significant numbers of parasitoids. In one sample location so far, we have found greater than 60% of sawfly larvae killed by *Bracon* sp. (Fig. 3).

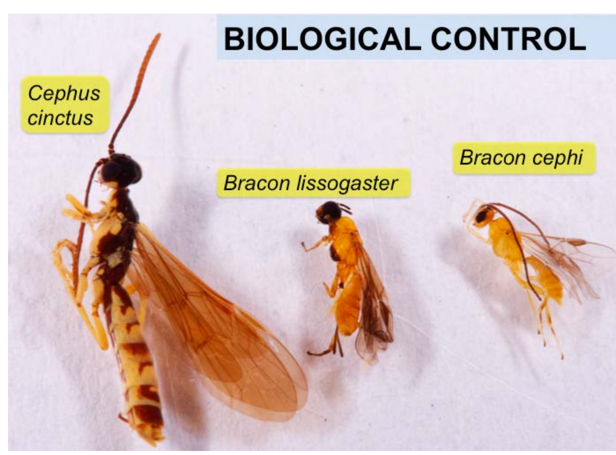


Figure 3. The wheat stem sawfly next to two of its biological control agents, *Bracon lissogaster* and *Bracon cephi*.

What's New in Entomology: West Central Nebraska

Julie A. Peterson, Extension Entomology Specialist

Wireworms in Corn

Wireworms are elongate, yellow to red-brown larvae of click beetles that live in the soil (Fig. 1). The adult beetles prefer to lay their eggs in grass; for this reason, they are more numerous in fields that have been in grass, pasture, or have had an abundance of grassy weeds. After hatching, larvae will remain in the soil for 2-6 years, depending on the species. Larvae prefer cooler soil temperatures (below 70°F), placing early-planted and high residue fields at greater risk. Wireworms feed on the belowground parts of a plant, including the seed, stem, and roots. Feeding on seeds prior to germination will cause reduced plant emergence; later feeding can kill or stunt small seedlings. Wireworm damage is often first noticed if plant stand is poor and seedlings appear wilted and discolored.

There is currently no effective rescue treatment for this pest- any actions taken must be preventative. **Insecticidal seed treatments provide good protection against typical levels of wireworm pressure.** Under very high pressure, additional at-plant insecticides may be warranted.

Figure 1. Wireworm larvae. Photo: Jim Kalisch.

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. 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).

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.

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

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 2015 than 2013-14, but higher than 2010-12 (Figure 2). Single night trap catches peaked at 287 moths on July 15, 2015 compared to 469 moths on July 16, 2014. These high moth flights have resulted in high oviposition rates in some corn fields in west central and southwest Nebraska counties. For example, fields scouted in Perkins Co. had up to 29% infestation on July 24, 2015 (courtesy L. Appel); fields in Buffalo Co. had up to 25% infestation on July 20, 2015.

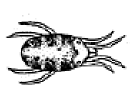
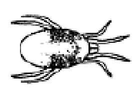
Scattered reports from southwest and north central Nebraska of greater than expected damage from western bean cutworm to corn hybrids expressing the Cry1F protein and/or following pyrethroid insecticide applications have prompted investigation into the possibility of Bt resistance issues. UNL Entomologists 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 2015 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 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.

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

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

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

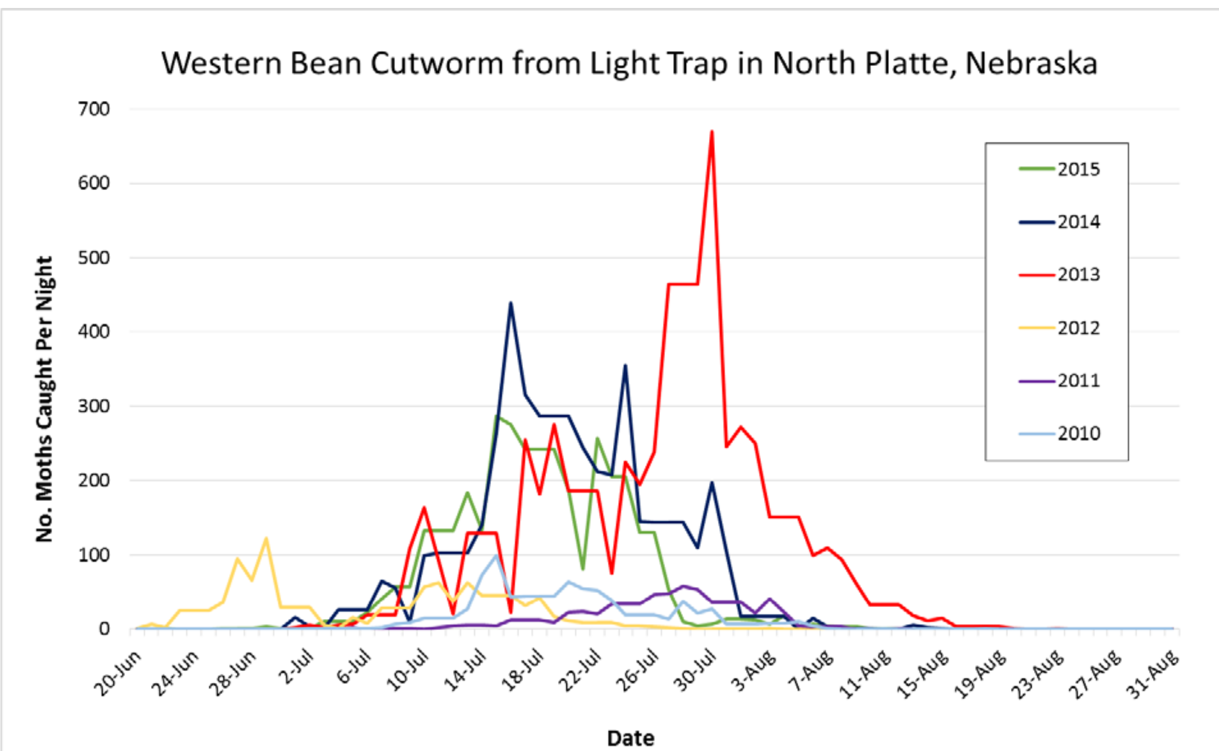


Figure 2. North Platte light trap data for western bean cutworm populations over the past 6 years.

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.

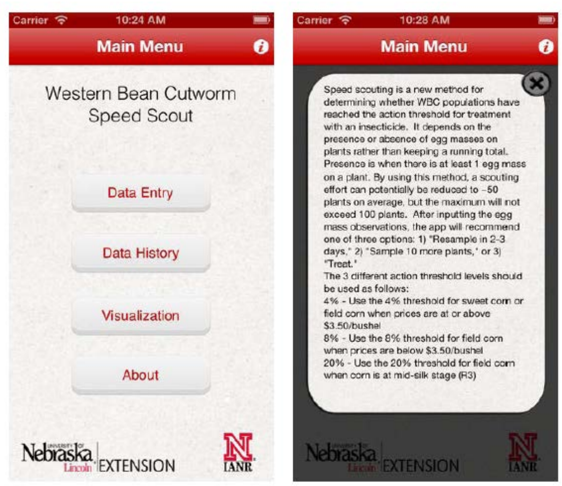

Figure 1. Screenshots from the WBC Speed Scout mobile app

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 this year was that a single western bean cutworm egg can produce at least 5 parasitoids. Research is proposed for 2016 to evaluate these effects at the larger field scale.

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, 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.

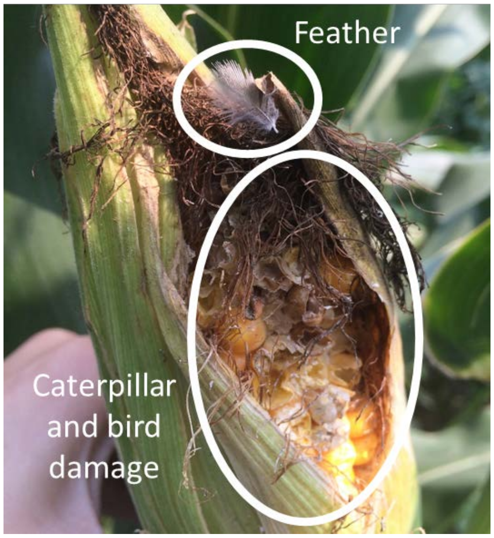

Figure 3. Corn ear with WBC damage followed by bird predation.

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 must be above tassels to ensure that early instar larvae feeding in the tassels are treated.** 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

Field corn hybrids that contain genes that cause the plants to produce Cry 1F or VIP3A *Bacillus thuringiensis* toxins have been shown to provide about 80% control of western bean cutworm larvae. Use of these hybrids may be an adequate strategy for managing this pest, but effectiveness should be monitored. The protein Cry1Ab, which is effective against other caterpillars such as European corn borer, does not protect the plant against western bean cutworm. Understanding whether the hybrid in your field will provide protection against WBC is essential in making management decisions for this pest. The Handy Bt Trait Table can provide this information.

Western Bean Cutworm Populations in 2015

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 (North Central). In 2015, North Platte had high moth flights (cumulative 3,572 moths compared with 4,760 in 2014) compared to more moderate numbers in Clay Center (470 cumulative in 2015 and 176 in 2014) and Concord (34 cumulative in 2015 and 412 in 2014). At North Platte, single night trap catches peaked at 287 moths on July 15, 2015 (lower than the 469 moths on July 16, 2014). At Clay Center, moth flight peaked at 88 on July 14, 2015 (higher than the 18 moths on July 10, 2014). At Concord, moth flight peaked at 4 on July 22, 2014 (much lower and earlier than the 81 moths on August 29, 2014) (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 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 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.

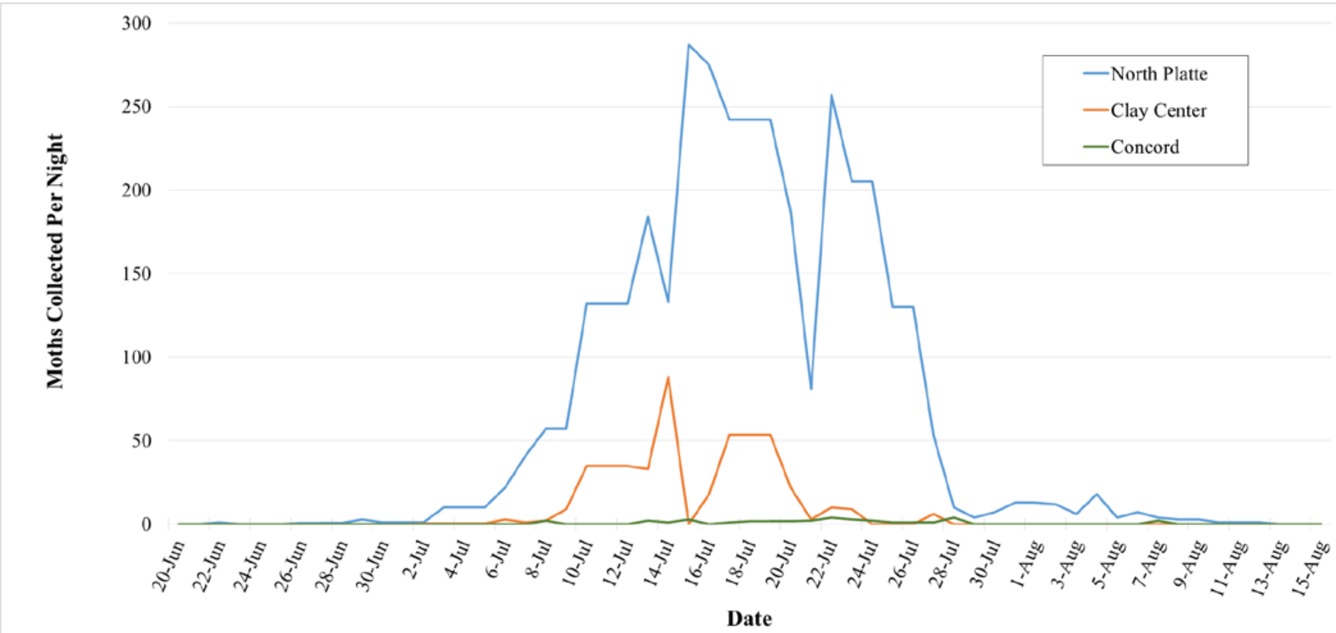

Figure 4. Number of moths caught per night at North Platte (left axis), Clay Center (right axis), and Concord (right axis).

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Western Bean Cutworm in Corn and Dry Beans

Ronald C. Seymour, Extension Educator; Gary L. Hein, Professor of Entomology; and Robert J. Wright, Extension Entomologist

This NebGuide addresses the life cycle, scouting and treatment of the western bean cutworm in corn and dry beans.

Western bean cutworm (WBC) can be a severe pest in 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. Traditionally, the western bean cutworm has largely been limited to areas in the western Great Plains, but in the last 10 years, western bean cutworm has steadily spread eastward through the Corn Belt to as far east as Pennsylvania.

Life History

Western bean cutworm has one generation per year with moth emergence usually beginning in early 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 *(Figure 1)*. 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.

Figure 1. Adult western bean cutworm.

Figure 2. Newly laid western bean cutworm eggs.

After mating, eggs are usually laid on either 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 5 to 200 with an average of about 50 eggs per mass *(Figure 2)*. 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 *(Figure 3)*.

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 move to protected feeding sites, the location depending on the growth stage of the host. Larvae feed for about 31 days and develop through five stages (instars) on

Figure 3. Eggs immediately prior to hatch.

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 *(Figure 4)*. As the larvae develop, they become light tan to pink and the cross-hatch markings on their backs become more distinct *(Figure 5)*. 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 *(Figure 6)*. 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 *(Figure 7)*. 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.

Figure 4. Newly hatched larvae.

Figure 5. Larger larva on corn ear.

Figure 6. Larva with stripes on prothorax.

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, but only a small percentage of the larvae actually survive to maturity. In pre-tassel corn, newly hatched larvae move to the whorl where they feed on the flag leaf, the flowers of the tassel, and other yellow tissue *(Figure 8)*. Once tasseling begins, newly hatched larvae feed within the tassel, leaf axils, or the green silks of the developing ear. Once pollen shed is complete and the tassels dry up, the larvae move to the silks. Through this dispersal behavior, larvae from one egg mass may infest several plants down the row and in immediately adjacent rows in an area 6 to 10 feet in diameter. Second and third instar larvae continue to feed on the silks and move into the ear to feed on the kernels of the developing ears. Fourth instar larvae feed primarily on kernels near the ear tip *(Figure 5)*. 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 *(Figure 9)*.

Figure 7. Pupa.

Figure 8. Larvae in corn tassel.

Figure 9. Cutworm damaged corn ears.

Research has shown that a field average of one larva per plant at dent stage can reduce yield by 3.7 bu/ac. Western bean cutworm larvae are not cannibalistic, thus often infestations of multiple larvae per ear may occur. In years with severe infestations, two or more larvae per ear may be common and, although unusual, corn ears infested with 10 or more larvae have been recorded. In these crowded situations, as much as 50 to 60 percent of an ear's kernels may sustain feeding damage.

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 ponds develop, they begin to feed in the

Figure 10. Cutworm damage to bean pod.

Figure 11. Cutworm-damaged dry beans.

pods and on the developing seeds *(Figure 10).* 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 *(Figure 11).* Economic injury levels for yield loss are difficult to determine because of the uncertain impacts on product quality and market price, 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.

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 cutworms, check 10 consecutive plants in several randomly selected locations of each field. These locations should be representative of all areas of a field. Egg laying also will vary with plant growth stage; therefore, portions of a field planted to hybrids with different maturities should be sampled separately. Checking as few as five locations in the field may be adequate to establish the infestation level, particularly if either a low (0 in 10) or a high (more than 2 in 10) number of plants in each location have egg masses or larvae. If the number of infested plants falls between these extremes, observations in 10 to 15 locations may be required to accurately establish the western bean cutworm damage potential for the field.

If 5 to 8 percent of field corn plants have egg masses and/or small larvae, consider an insecticide application. This 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 a higher economic 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.

Sampling Dry Beans

Figure 12. Milk jug trap.

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 *(Figure 12)* and pheromone may be purchased from a commercial supplier *(Table I).* 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

Table I. Suppliers of western bean cutworm sampling equipment and supplies.

Light traps

Gempler's, Inc., *www.gemplers.com*, phone (800) 382-8473

Scentry® pheromone

Gempler's, Inc., *www.gemplers.com*, phone (800) 382-8473

Great Lakes IPM, *www.greatlakesipm.com*, phone (800) 235-0285

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

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

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. Nabids, ladybird beetle adults, spiders and perhaps other predators feed on both eggs and larvae up to the third instar. 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. 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.

Insecticide controls target the larvae stage of western bean cutworms. Liquid insecticides applied by airplane or through a center pivot irrigation system typically provide acceptable control. 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.

Many transgenic corn varieties that express toxin(s) produced by *B. thuringiensis* (*Bt* corn) are not effective against western bean cutworm. Only the *Bt* corn hybrids containing the Cry1F toxin (e.g., Herculex I, Herculex XTRA, SmartStax) are labeled for control of western bean cutworm larvae. Control with this transgenic product has been shown to be about 80 percent effective in reducing cutworm numbers.

This publication has been peer reviewed.

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

Index: Insects and Pests
Field Crops
Issued April 2010

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.

Sunflower Moth Resistance in Sunflower

Jeff Bradshaw, Entomology Specialist
Dawn Sikora, Graduate Research Assistant

Host plant resistance is one of the most economically and environmentally sustainable tools in crop management. It can allow for reduced input control costs while conserving biological control agents. As discussed in the 2015 *Crop Production Clinic*, plants can resist injury by insect by; impacting the biology of the pest (antixenosis), altering the pest's behavior (antixenosis), or by the host plant tolerating or recovering from pest injury (tolerance). For the sunflower moth, *Homoeosoma electellum*, we are just beginning to learn about strategies for developing resistance in sunflower.

Sunflower Moth Biology

Figure 1. An adult *sunflower head moth.*

The sunflower moth is native throughout much of North America where it infests and feeds on the developing flower heads of a variety of sunflower species and relatives (Asteraceae). As an adult (Fig. 1**)**, this insect is a small, white moth (1.5-2.0 cm long) and the larvae are most notable by their cream and purple stripe pattern (Fig. 2). The larvae, which are active at night, leave mats of webbing on the sunflower 'face', which is a clear indication of an infested head.

Figure 2. A larva of a sunflower head moth.

Sunflower moths breed year-round in the southern U.S. and migrate northward as they pass through successive generations. Sunflower pollen is a stimulus for female moths to lay eggs and once sunflowers (wild or cultivated) begin to flower egg-laying will commence. A female moth can lay up to 400 eggs, each at the base of a floret. For the first two instars, larvae will feed exclusively on pollen and later burrow into the receptacle and chew through the pith and achenes of the developing sunflower seeds. Depending on temperature, larvae will feed for 2-3 weeks and descend on silken threads to pupate in the soil. One generation can be completed in 30 days. As a result, two generations of sunflower moth are possible in Nebraska.

Sunflower Moth Management

When scouting sunflower fields at the R4 stage, flowers can be sampled at night with a flashlight and counting the number of moths on the faces of at least 20 flowers at each of five locations in a field. A threshold of as few as 1-2 moths per 5 flowers can be used as a treatment threshold depending on crop condition and anticipated market value of the crop. Generally, insecticides are used to control sunflower moth and are most effective if targeting moths prior to egg laying (however, first and second instar larvae are also susceptible to insecticides). Because eggs are deposited up until R6 developmental stage, more than one insecticide application may be needed. Furthermore, in years where large moth populations may develop in the south, a second generation may develop and require additional insecticide applications.

Sunflower Resistance to Sunflower Moth

Because of the potentially high control costs for sunflower moth, we have been exploring the potential of resistance in sunflower against the sunflower moth. Working in collaboration with Jarrad Prasifka, USDA-ARS-NCSL, and Gary Brewer, UNL Department of Entomology, we have been exploring the potential of developing sunflowers with seed pericarps (the sunflower seed "shell") that resist feeding by sunflower head moth larvae. Using USDA and commercial lines or cultivars we have been conducting experiments in field plots as well as laboratory bioassays to evaluate the potential for sunflower moth larvae to injure lines of varying pericarp feeding resistance.

Previous research has shown that a device called a penetrometer can be used to measurer the "hardness" of the pericarp of a sunflower seed and that this hardness (measured in Newtons of force) is related to a possible tolerance to sunflower moth larval injury. That is, the harder a pericarp of a sunflower seed, the more resistant it is to sunflower head moth larvae.

In 2014, we evaluated a large number of entries by collecting pericarp hardness characteristics and injury. We used that data set to then select for some top candidates that best illustrate the desired characteristics. In 2015, we planted four lines in the field (based on our 2014 selections); HA441, HA467, RH1130EX, and RH841. We evaluated these lines in the field for both their absolute hardness and the rate at which the pericarps harden as well as yield and sunflower moth injury.

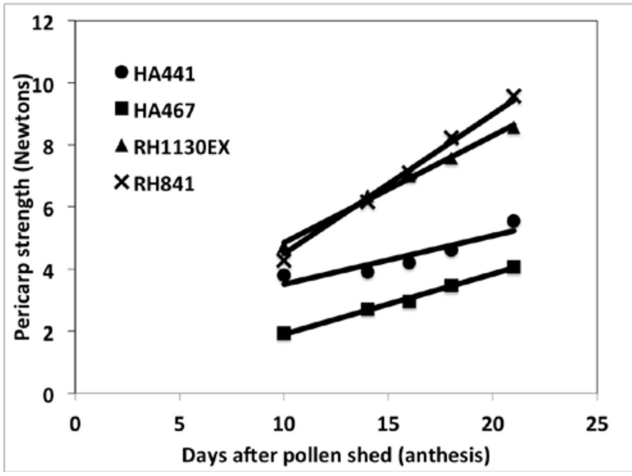

Figure 3. Pericarp strength of sunflower seeds collected from field-grown sunflower plants at 10, 14, 16, 18, and 21 days following beginning antheses (pollen shed).

We also evaluated seeds from these same field plants using bioassays in the lab. In the lab bioassays, we compared larval injury to seeds from mature and less mature sunflower seeds between our four entries that were planted in the field.

The current data as of the time of this writing has revealed a vast difference between both the rate and absolute amount of pericarp hardness between the four tested entries (Fig. 3). Generally, entries that maintain pericarp hardness above 4 Netwons appear to provide tolerance to sunflower moth injury. However, the initial data from the laboratory bioassays appear to indicate that line HA441 may have as effective tolerance as RH841 and RH1130EX which may indicate an additional tolerance mechanism besides just pericarp hardness. However, further analysis is needed before concrete conclusions can be made. Ultimately, even this tolerance trait alone may not be sufficient to protect sunflower from heavy infestations of this pest. However, even modest reductions in pesticide input costs as a result of these efforts could represent a notable savings to sunflower growers.

Soybean Insect Defoliators

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Basic management recommendations for soybean defoliation in Nebraska are presented in the Nebraska Extension publications “Managing Soybean Defoliators G2259” and “Soybean Defoliation Scouting Spreadsheet EC1589”. Soybean defoliation by insects is typically managed by assessing percent injury, not by using economic thresholds for specific insect species. However, the species and stage of insects present is important to fully understanding the potential injury your soybeans may suffer. Defoliation is difficult to estimate. Often, it is over estimated. Careful scouting is encouraged. Use of the tools above will enhance scouting efforts.

Soybean defoliators are numerous. The main types we see in Nebraska are adult beetles, caterpillars, and grasshoppers. Each group, and even species within the groups, has characteristics that determine the magnitude, location, and duration of their injury to soybean. Knowledge of these characteristics can help farmers make more precise evaluations of potential damage to their fields. There is a brief description of common soybean defoliators in the management publications, but here we would like to explore the insect defoliators a bit more so farmers can better understand what to expect when they see them in and around their soybean fields.

Beetles

Bean leaf beetle (*Cerotoma trifurcata*) is the primary beetle observed in Nebraska soybean. They defoliate as adults. You may see them in your soybean three times during the season, early spring, mid-summer, and late-summer. The primary injury to soybean in the spring through mid-summer is defoliation, but the primary economic damage caused by the late summer beetles is to the pods.

Typical bean leaf beetle defoliation injury is small round to oval holes between the major veins of the leaflets. Most of the injury will be in the top third of the soybean canopy, so injury to the top of the canopy can often be compensated for by the undamaged leaves below the injured leaves.

Because they are adults, they do not have increasing injury per insect as do insects like caterpillars or grasshopper nymphs, which are growing while they feed on soybeans. They also may remain in the soybean field after their main feeding period is over. By themselves, bean leaf beetles rarely cause economic damage through defoliation, except occasionally to early-planted soybeans during the seedling stages.

An interesting beetle, with sometimes dramatic presence and injury, is the imported longhorned weevil (*Calomycterus setarius*). The larvae feed on roots of a variety of plants outside of the field, so since this beetle is flightless, the injury is almost always confined to the edges of fields. Although only on the edge of the fields, it can be alarming. The weevils invade the field in early vegetative stages, with numerous weevils per plant. Injury results in a ragged leaf with a scalloped edge, to complete defoliation. On rare occasions a field that was just taken out of pasture or CRP may have a field level problem, but usually injury is confined to the first few rows of the soybean field.

A relatively new beetle to Nebraska soybean, the Japanese beetle (*Popilliae japonica*) is starting to appear in the eastern part of the state. The larvae feed on grass roots. As such, the adults are the only stage capable of defoliating soybean. Adults feed on leaf tissue between the veins. Early stages of feeding may resemble that of bean leaf beetle. However, holes in the leaves are typically not as symmetrical. More advanced feeding will leave a net-like pattern of leaf veins. Concentration of the beetles will be higher in the field margins. Right now populations of Japanese beetle are not high enough to for them alone to cause economic defoliation. They d0 add to the complex of defoliators.

Other beetles that cause defoliation injury to soybean are southern corn rootworm beetles (*Diabrotica undecimpunctata howardi*), blister beetles (*Epicauta spp.*), grape colaspis (*Colaspis brunnea*), and a few others. Most of these enter soybean during the reproductive stages. They rarely by themselves reach economically damaging levels, but do add to the complex of defoliators.

Caterpillars

Caterpillars, the immature forms of various moths and butterflies, can cause considerable defoliation injury to soybean. They can typically be observed in soybeans from mid-summer through fall, but some, like the painted lady caterpillar (*Vanessa cardui*, also called the thistle caterpillar) can be observed in soybean during the early vegetative stages. Depending on species, there can be several generations a year.

Caterpillar injury can vary according to species and size of caterpillar, but it typically consists of asymmetric holes and jagged leaflet margins. While most injure the upper portion of the canopy, there are some, like the soybean looper (*Pseudoplusia includens*) that cause injury lower in the canopy.

As noted earlier, caterpillars increase injury as they grow. Most defoliation is done in the last few instars. When most larvae are in the last instar, it is often too late to recoup economic loss by treatment, as most of the damage has been done. This is why it is important to scout your fields early and regularly so you can make management decisions early in the feeding period.

There are numerous caterpillar species that can be found in Nebraska soybeans. Often they make up a complex of defoliators that may require management, but on occasion a single species may predominate and reach economically damaging levels. We have seen this in Nebraska with wooly bear caterpillars.

Some of the most common caterpillars we see in Nebraska are painted lady caterpillar, soybean looper, green clover worm (*Plathypena scabra*), yellow woolybear (*Spilosoma virginica*), and silverspotted skipper (*Epargyreus clarus*).

Grasshoppers

Grasshoppers defoliate soybean as both immatures (nymphs) and adults. They lay their eggs in undisturbed soil outside of crop fields, so they typically move into soybean fields (or other crops) after the plants they have been feeding on become unpalatable or have been consumed in or near their emergence site. However, sometimes they lay eggs in no-till or reduced tillage fields, so farmers should be vigilant and scout their fields regularly.

Grasshopper defoliation appears as ragged holes and leaflet margins. Like caterpillars, injury level depends on species and size. Because grasshoppers are difficult to manage as adults, it is advisable to scout areas surrounding fields and manage the grasshoppers along field borders or when they are entering fields as nymphs.

Weather is the primary factor influencing grasshopper populations. In eastern Nebraska, warm spring rains during early nymph stages favor high grasshopper mortality by the fungus *Entomophagus grylli*. This usually keeps grasshopper populations from reaching damaging populations in soybeans.

There are numerous species of grasshoppers in Nebraska, but not all of them injury soybean. The most common grasshoppers in Nebraska soybeans are the redlegged grasshopper (*Melanoplus femurrubrum*) and the differential grasshopper (*Melanoplus differentialis*). For a wealth of information on these and other Nebraska grasshoppers, visit Grasshoppers of Nebraska at http://entomology.unl.edu/grasshoppers .

Conclusion

There are numerous species of soybean defoliators in and around Nebraska soybean fields. Although we use common defoliation level thresholds to management them, each species has their specific life history traits and injury characteristics. Learning to identify the various defoliators and understanding their behaviors and injury characteristics can help farmers “fine-tune” their management.

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

G2259

Managing Soybean Defoliators

Wayne J. Ohnesorg, Extension Educator
Thomas E. Hunt, Extension Entomology Specialist

Defoliation, leaf feeding of soybean leaves by insects, is the most commonly observed type of soybean insect injury, but soybean plants have the ability to compensate for insect defoliation. When making pest-management decisions, a crucial consideration is the size of the remaining leaf canopy and the soybeans' stage of growth.

Soybean defoliation is one of the most readily observed types of insect injury to soybean and can occur from emergence to harvest. In 2010, there were numerous reports of green cloverworm, southern corn rootworm, grasshoppers, bean leaf beetle, and yellow woollybear in Nebraska soybean fields. Nebraska soybean producers expressed a great deal of concern.

A complex of insects defoliate soybean in Nebraska. These include bean leaf beetle, imported longhorned weevil, grasshoppers, woollybear caterpillar, thistle caterpillar, green cloverworm, and a few others. Rarely does any single species reach population levels that defoliate soybean enough to cause economic damage, but the combined injury of two or more defoliating insects can result in economic damage.

This was observed in 1997 when the combined defoliation from grasshoppers and bean leaf beetles reached 50 percent in the soybean reproductive stage near Mead, Neb. When this occurs, multiple-species recommendations must be used. These can be multiple-species economic threshold tables, or more general "catch-all" defoliation level recommendations.

University of Nebraska–Lincoln Department of Entomology multiple-species economic threshold tables do not cover all of the different species of insect defoliators, so the following are more general soybean defoliation thresholds.

Insect Defoliation and Yield Loss

Soybean plants have a great capacity to compensate for defoliation by insects. Research over the last 20 years has established that the key factor driving yield losses from defoliating insects is the degree that defoliation reduces light interception of the soybean canopy. Soybean can lose tremendous leaf area without yield loss if the remaining leaves are still intercepting at least 90 percent of the incident light. So, in making pest management decisions about defoliating insects, a crucial consideration is the size of the remaining soybean canopy. Small canopies cannot tolerate as much leaf loss as large canopies.

Another consideration is when defoliation occurs. Unless severe, defoliation in vegetative stages usually doesn't cause yield loss. Reproductive stages are more sensitive. A final factor is growing conditions. When environmental conditions are very favorable for soybean development (e.g., adequate water), plants have a greater capacity for regrowth and compensation.

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.

Defoliation is notoriously difficult to estimate and is almost always overestimated. This is because the injury is so dramatic and often not all parts of the canopy are considered when making defoliation estimates. Some insect species primarily feed in the upper part of the canopy (e.g., bean leaf beetle), and some feed lower in the canopy. Different portions of the canopy will suffer different levels of injury. Therefore, when estimating defoliation, the entire canopy, not just the injured portion, must be considered.

Scouting Defoliation

To predict if defoliation will exceed 30 percent for the vegetative stage or 20 percent for the pod-forming or pod-filling stages, the current injury must be estimated. The following steps are suggested:

1. Remove a trifoliolate leaf from the top, middle, and lower third of 10 randomly selected plants.
2. Discard the most and least damaged leaflet from each trifoliolate leaf. This will leave 30 leaflets.
3. Compare the 30 leaflets with the leaflets in *Figure 1* and determine the average level of defoliation.
4. Repeat steps 1-3 at four or more randomly selected locations in the field.

The Nebraska Extension publication EC1589 can be used for scouting. If treatment is warranted, identify the defoliating insect(s) and use the insecticide guides found at the UNL Department of Entomology website: *http://entomology.unl.edu/instabls/soydefol.shtml.*

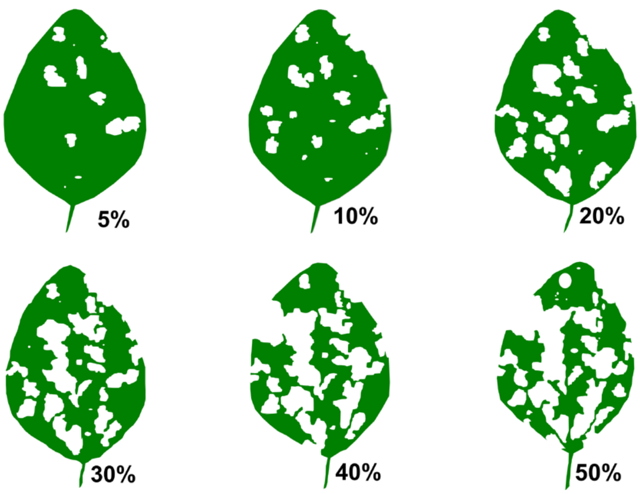

Figure 1. Insect defoliation levels of soybean leaflets

Most of the commonly used foliar insecticides are effective against most soybean defoliators.

Bean leaf beetle, *Cerotoma trifurcata* —

Adults are about ¼ inch long and can be green, yellow, tan, or red. There is always a black triangle located behind the head on the wing covers (called elytra). There are two generations of bean leaf beetles per year in Nebraska. Bean leaf beetles can be found in soybean from emergence until senescence.

Bean leaf beetle photo by James A. Kalisch

Blister Beetles, *Epicauta spp.* —

Ashgray blister beetle and striped blister adults can be found feeding on soybean late in the season. They are ½ to 1 inch long with the head broader than the prothorax. Blister beetles are beneficial in that they parasitize grasshopper eggs and their populations can be higher the year following high grasshopper populations.

Ashgray blister beetle photo by James A. Kalisch

Striped blister beetle photo by James A. Kalisch

Imported longhorned weevil, *Calomycterus setarius* –

They are flightless, gray-brown weevils about ¼ inch long. As they are flightless they usually will be found in higher numbers in edges of fields. Rarely do populations reach economically damaging levels, but they do add to complexes of defoliators in soybean fields.

Imported longhorned weevil photo by Tim Miller

Grasshoppers –

A number of grasshopper species can cause defoliation in soybean. Each species has a single generation per year. Both nymphs and adults should be considered when scouting. Treatment of field margins should be considered when there are ≥20 grasshoppers per square yard. More information can be found in the NebGuide G1627, *A Guide to Grasshopper Control in Cropland.*

Redlegged grasshopper nymph photo by Leon G. Higley

Redlegged grasshopper photo by James A. Kalisch

Southern corn rootworm, ***Diabrotica undecimpunctata howardi*** –

Adult southern corn rootworm beetles are about 3/8 inch long, yellow to light green, and have 12 black spots on the wing covers (called elytra). This insect is rarely in numbers high enough to warrant treatment directly, but they do contribute to overall defoliation.

Southern corn rootworm beetle photo by James A. Kalisch

Yellow woollybear, ***Spilosoma virginica*** –

These are hairy caterpillars that can range in color from white to dark brown or reddish. There are two generations per year, and they are typically more abundant in drier years. Populations tend to crash due to disease.

Yellow woollybear caterpillar photo by Leroy Peters

Yellow woollybear caterpillar photo by James A. Kalisch

Yellow woollybear caterpillar photo by James A. Kalisch

Loopers –

Multiple species of loopers can be found in soybean fields. They are pale green and can be distinguished from green clover worm by the presence of two pairs of prolegs. Loopers typically add to a complex of defoliators in soybean fields.

Soybean looper photo by Marlin E. Rice

Cabbage looper photo by James A. Kalisch

Green clover worm, Plathypena scabra –

These are light green caterpillars with two thin, white stripes along each side of the body. They can be distinguished from loopers by the presence of three pairs of prolegs. Parasites and diseases commonly will keep green clover worms under control. Therefore, it is very important to watch for parasitized and diseased worms.

Green cloverworm photo by David L. Keith

Various caterpillars –

Besides the caterpillars already mentioned, a number of other caterpillars can defoliate soybean. The other species include yellowstriped armyworm (*Spodoptera ornithogalli*), fall armyworm (*Spodoptera frugiperda*), corn earworm (*Helicoverpa zea*), European corn borer (*Ostrinia nubilalis*), and thistle caterpillar (*Vanessa cardui*). These caterpillars add to a complex of defoliators in soybean fields.

Thistle caterpillar photo by Wayne J. Ohnesorg

This publication has been peer reviewed.

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

Index: Insects & Pests
Field Crop Insects
May 2015

Corn Rootworm Management Update

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During the last decade corn hybrids that express Bt toxins have been widely adopted by growers as a primary tactic used to control corn rootworms. During 2011-2013, greater than expected root injury by western corn rootworm larvae to hybrids expressing the Cry3Bb1 protein has been reported in some fields in Nebraska. In Cry3Bb1 problem fields, severe root pruning was present in parts of each field and was often accompanied by plant lodging. Before 2013, most reports were primarily concentrated in some northeast and southwestern counties. In 2013, unexpected injury was also observed in some central Nebraska counties. A consistent pattern has been observed at all Cry3Bb1 problem sites. All sites have been in continuous corn production and hybrids expressing the Cry3Bb1 toxin have been planted repeatedly for multiple years (often 3-6 consecutive years).

To determine if shifts in rootworm susceptibility to Cry3Bb1 have occurred at some Nebraska locations, both lab and field research has been conducted at UNL during 2012-2014.

Lab Bioassays

Western corn rootworm beetle collections were made at Cry3Bb1 problem sites in northeastern and southwestern Nebraska during 2012 (6 populations) and larval offspring from each collection were screened during 2013 for susceptibility to Cry3Bb1, mCry3A, and Cry34/35 proteins using whole plant bioassays. See the attached handy trait table for a listing of companies and trait names that express different Cry proteins. First instar offspring from field locations that had not experienced unexpected injury to any Bt protein (3 populations) or lab colonies that had not been previously exposed to Bt toxins (6 populations) were used as control populations. For each Bt protein, survival of problem field and control populations were compared on a hybrid that expressed the Bt protein (i.e. Cry3Bb1) and a near isoline hybrid without the Bt protein (i.e., no Cry3Bb1).

Lab Bioassays: Results

Trends from lab bioassays were fairly consistent across the six Cry3Bb1 problem sites. Survival (corrected for survival on the near isoline hybrid) on Cry3Bb1 expressing plants ranged from 61-90% for problem field populations and only 0-14% for control populations. A similar trend was observed when larvae were reared on mCry3A and near-isoline plants. Survival on mCry3A expressing plants ranged from 59-100% for problem field populations but only 4-42% for control populations. In contrast, a different pattern was observed with Cry34/35 expressing plants as survival ranged from 14-37% for problem field populations and 0-34% for control populations.

Field Trials

Field trials were conducted on three Cry3Bb1 problem sites (Clay, Perkins, Keith Counties) and a control site (Saunders County, no control problems with any Bt event) during 2013 to evaluate the efficacy of single or pyramided Bt traits with and without an at-plant soil insecticide application (see Table 1 for treatment list). The 0-3 node injury scale was used to evaluate root injury in each treatment. Even though rootworm pressure was variable across sites, a similar trend was apparent at each Cry3Bb1 problem site when efficacy of treatments was placed on a relative control basis (i.e., treatment root rating/appropriate near-isoline root rating was compared between Cry3Bb1 problem sites and the control site). Trends observed in field trials were similar to those observed in lab bioassays.

2013 Field Trials: Key Results

<u>Cry3Bb1</u>

--Relative level of root protection (Cry3Bb1 root rating/near-isoline root rating) was significantly lower at Cry3Bb1 problem sites (average of 45.9% control) than at the control site (92.8% control).

<u>mCry3A</u>

--The relative level of control (mCry3A root rating/near isoline root rating) followed a similar pattern as described for Cry3Bb1. The relative level of root protection provided by mCry3A was significantly lower (average of 44.9% control) at Cry3Bb1 problem sites than at the control site (86.3 % control).

<u>Cry34/35</u>

The relative root protection obtained with Cry34/35Ab1was not significantly different across all four sites (3 problem sites and the control site; relative rootworm control averaged 90.6 % across sites). The greatest root protection was obtained with single trait Cry34/35 or a pyramid of Cry34/35 with either Cry3bb1 or Cry34/35.

The at-plant soil insecticide provided a significant root protection benefit only when applied to non-Bt near-isoline treatments or single traits exhibiting greater than expected relative injury (i.e., <u>Relative root protection:</u> Cry3Bb1 +

insecticide: average of 3 problem fields = 81.3% control; Cry3Bb1 + insecticide: control site= 95.3% control; mCry3A + insecticide: average of 3 problem fields = 80% control; mCry3A + insecticide: control site =92.4% control. Little root protection benefit was obtained by adding soil insecticide to single trait Cry34/35 (average across 4 sites = 95.6 % control) or pyramids containing Cry34/35 (Cry34/35 + Cry3B1 average control across four sites = 95.2 %, Cry34/35 + Cry3Bb1 + insecticide: average control across four sites = 95.7 %; Cry34/35 + mCry3A: average control across four sites = 94.3%; Cry34/35 + mCry3A + soil insecticide: average control across four sites =96.5%.

Overall Conclusions

Bioassay results demonstrate that there are heritable differences in susceptibility of some Nebraska western corn rootworm populations to rootworm Bt proteins.

Bioassay and field trial data jointly support the conclusion that a level(s) of resistance to Cry3Bb1 has evolved in some populations after repeated use of single trait hybrids over time which has reduced the effectiveness of Cry3Bb1 in the field.

Data suggest that a possible cross-resistance relationship exists between Cry3Bb1 and mCry3A which reduced the effectiveness of mCry3A hybrids in Cry3Bb1 history/problem fields. However, there was no apparent cross resistance relationship between Cry3Bb1 or mCry3A and Cry34/35 expressing corn.

General corn rootworm management recommendations

The following options are suggested if you have had higher than expected injury from corn rootworms in your Bt corn field this year:

1. Rotate to a crop other than corn—this is still the best way to reduce corn rootworm populations in Nebraska. Regularly rotating some corn acres can help reduce rootworm densities on a farm. In Nebraska we do not have the "rotation resistant variant" western corn rootworm that has been found in the eastern Corn Belt. It has increased the number of crops in which it will lay eggs to include soybean and other crops, thus reducing the benefit of crop rotation.

2. If you must plant corn after corn:

- Change to a hybrid containing a different Bt corn toxin active against rootworms, or one containing more than one Bt corn toxin active against corn rootworms. See the following for a list of available Bt corns and the toxins they express (C. DiFonzo and E. Cullen. 2014. Handy Bt Trait Table).
- Follow all refuge requirements for any Bt corn hybrid.

3. It is important to use a diversity of control measures to manage rootworm populations, rather than relying on only one Bt corn. Crop rotation and use of different Bt corn hybrids that express different or multiple Bt proteins are important strategies for rootworm management. In addition, conventional insecticides may be used to provide some level of protection as part of a rootworm management program, including the following:

- Liquid or granular insecticide applied at planting
- Postemergence applications targeted for larval or adult control

IRAC Statement

See below for statement by Insecticide Resistance Action Committee on Considerations for the resistance management value of using insecticidal chemistry on transgenic crops expressing insecticidal proteins.

Version 1.6, 04.09.2014

IRAC International Statement: Considerations for the resistance management value of using insecticidal chemistry on transgenic crops expressing insecticidal proteins.

Chemical insecticides can be applied to conventional and transgenic crops expressing insecticidal proteins. Insecticidal chemistry may be applied to transgenic crops for a number of reasons, particularly to broaden the range of pests controlled or increase the level of target pest control. In certain circumstances, the application of chemical insecticides to transgenic crops also may be considered for insecticide resistance management (IRM) purposes.

All currently commercialized synthetic insecticidal chemistries offer an alternative mode of action to the insecticidal proteins expressed in transgenic plants and there is little evidence for cross---resistance between these chemistries and the insecticidal proteins*. Therefore the combined use of synthetic insecticidal chemicals and proteins which target the same insect pest offers the potential for an IRM tactic that could be beneficial for preserving the susceptibility of the target insects to both components. However, negative IRM impacts may arise if chemical insecticides are applied to a non---transgenic refuge as this reduces the population of insects that are susceptible to the plant expressed protein. Therefore when selecting refuge size and structure, it is important to take into account chemical insecticide application programs.

When considering a pest management program, it is important to take into account IRM considerations for both the transgenic trait (i.e. refuge adoption) and the chemistries being employed (both foliar applied and seed treatments). The following should be considered when assessing the IRM value of applying chemical insecticides to transgenic crops expressing insecticidal proteins:

1) An IRM benefit of the combined use of insecticide chemistry and transgenic crops expressing insecticidal proteins will only occur while the target insect population is exposed simultaneously to lethal doses of both the insecticide chemistry and the insecticidal protein(s).

2) For there to be an IRM benefit, the insecticide should be applied to the transgenic crop but not the refuge. In cases where both the transgenic crop and the refuge are treated with the insecticide, the IRM benefits will be neutralized. In circumstances where only the refuge is sprayed, this will have a negative effect on IRM for the transgenic crop. Despite the neutral or negative effects on IRM, insecticide sprays applied to the refuge may offer other benefits such as improved pest control.

3) In most cases, a refuge---in---a---bag (RIB) strategy does not allow for the selective application of chemical insecticides only to the transgenic plants, and therefore the impact of chemical applications to both the transgenic plants and the embedded refuge is unlikely to provide an IRM benefit.

4) The application of insecticides to a field that contains, or is suspected to contain, a significant proportion of target pests that are resistant to the transgenic crop can provide local suppression of the pest population and slow the geographic spread of the resistant insects. This use of insecticides can therefore provide area---wide IRM benefits.

5) The combined effects of the chemical insecticide and the expressed insecticidal proteins will be less effective and potentially detrimental if resistance has or is already developing to either the chemical or the protein(s).

*Not including foliar applied sprays which are based on *Bacillus thuringiensis* proteins.

Table 1. Entries included in 2013 field trials.

Entry	Hybrid Trait Package	Supplemental Treatment
1)	RR2, near isoline to entries 3-6 (control, no Bt)	None
2)	RR2, near isoline to entries 3-6	Aztec 2.1G
3)	VT3 or VT3 PRO (Cry3Bb1)	None
4)	VT3 or VT3 PRO (Cry3Bb1)	Aztec 2.1G
5)	GEN SS (Cry3Bb1, Cry34/35Ab1) SmartStax	None
6)	GEN SS (Cry3Bb1, Cry34/35Ab1) SmartStax	Aztec 2.1G
7)	Agrisure RW (mCry3A)	None
8)	Agrisure RW (mCry3A)	Aztec 2.1G
9)	Agrisure 3122 (mCry3A, Cry34/35Ab1)	None
10)	Agrisure 3122 (mCry3A, Cry34/35Ab1)	Aztec 2.1G
11)	Near isoline to entries 7-10 (control, no Bt)	None
12)	Near isoline to entries 7-10	Aztec 2.1G
13)	Herculex Xtra (Cry34/35Ab1)	None
14)	Herculex Xtra (Cry34/35Ab1)	Aztec 2.1G
15)	Near isoline to entries 13-14(control, no Bt)	None
16)	Near isoline to entries 13-14	Aztec 2.1G

Randomized complete block design, four replications
All seed were treated with a standard fungicide package and either Poncho 250 or Cruiser 250
Aztec 2.1G applied infurrow at planting; rate: 0.141 oz. ai / acre

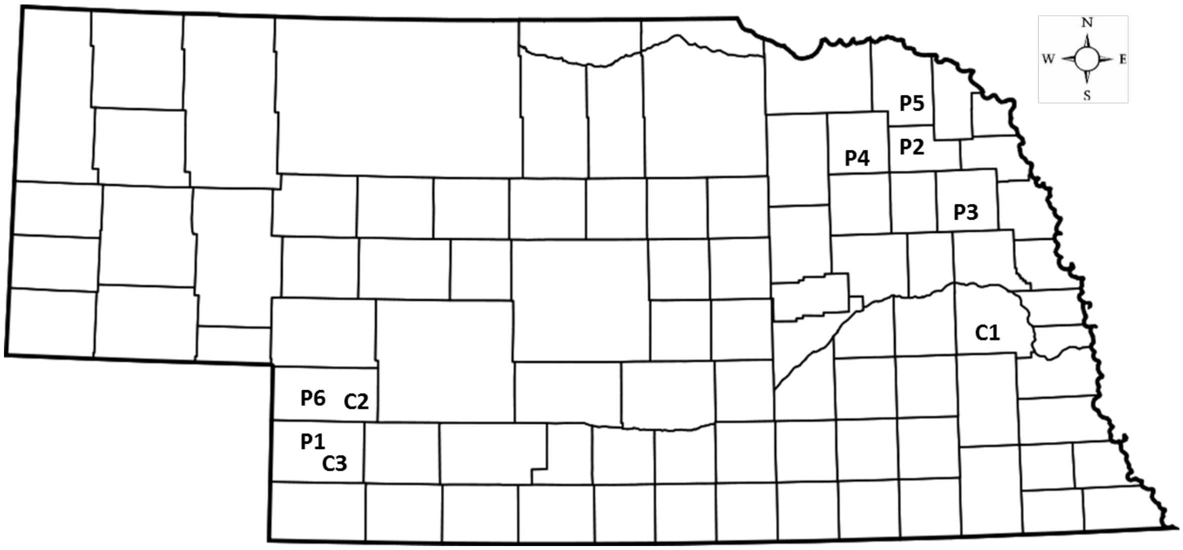

Figure 1: **A map of the state of Nebraska showing distribution of sites sampled in 2012. Sites beginning with P were Cry3Bb1 history/problem fields, sites beginning with C were control fields.**

Be on the lookout for the sugarcane aphid on sorghum

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The sugarcane aphid, *Melanaphis sacchari*, was first reported damaging grain sorghum in Louisiana and Texas in 2013. Previously, it had only been known as a pest of sugarcane. This aphid pest has been spreading across the southern U.S. since then, and now is found in sorghum as far east as Virginia and as far north as central Kansas this summer. It can also feed on other Sorghum species such as forage sorghum, shattercane and Johnson grass. It has not been reported from Nebraska.

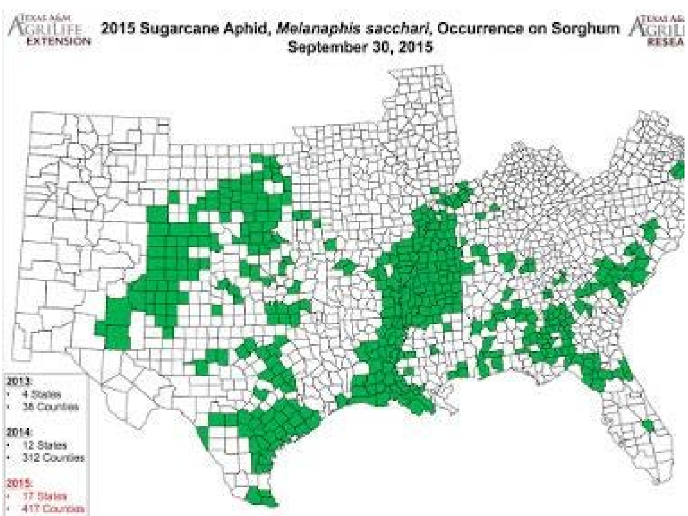

Fig. 1. Distribution of sugarcane aphid, Sept. 30, 2015. Texas A&M Univ.

Grain sorghum producers should watch their fields for the potential presence of this insect in Nebraska. Aphid colonies are initially most common on the undersides of lower leaves but can be found higher in the canopy as populations increase. The presence of dark sooty mold growing on the sugary secretions of aphids called 'honeydew' can also be an indicator of their presence. The sugarcane aphid is light yellow to gray in color, with dark cornicles ('tail-pipes') at the end of the body and dark tarsi (feet). Adult aphids can be winged or wingless.

Fig. 2. Sugarcane aphid. Photo credit: Patrick Porter, Texas Cooperative Extension, Bugwood.org

The other two common sorghum aphids in Nebraska, the greenbug and corn leaf aphid have significantly different coloration and markings. Greenbugs are light green or greenish-yellow aphids with a narrow, darker green stripe down the center of their backs. The legs of greenbugs are green, and their feet are black. The cornicles (small "pipes" near the rear end) are green with black tips. Corn leaf aphids are darker blue-green and do not have a darker stripe down their backs. The heads, feet, legs and cornicles of corn leaf aphids are black. Another common aphid on weedy and wild grasses that looks similar is the yellow sugarcane aphid. This aphid is not a common pest of sorghum in Nebraska, but can reach economic numbers in southern states. It can occasionally be found in large colonies on foxtail grasses (e.g., common foxtail).

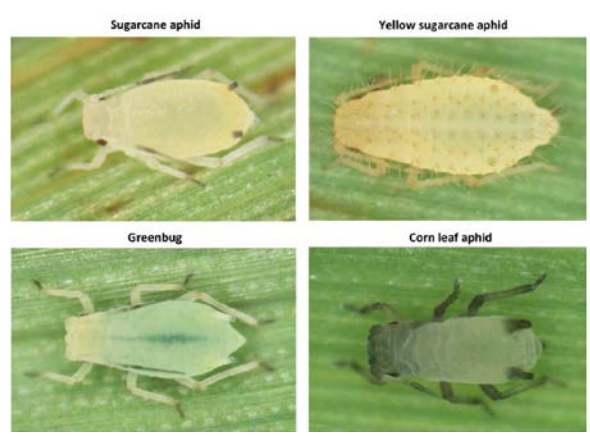

Fig. 3. Common sorghum aphids. Photo credit: Richard Grantham and Tom Royer, Oklahoma State University

High populations of sugarcane aphids on sorghum can be a concern because of direct yield loss, as well as the effects of their sugary secretion, honeydew, which has been reported to interfere with harvest in heavily infested fields. Additionally, these aphids can also transmit millet red leaf, sugarcane yellow leaf, and sugarcane mosaic viruses; none of which pose a threat to sorghum in Nebraska.

Threshold recommendations vary somewhat by state. Texas Agricultural Extension Service recommends treatment if the field average infestation is 50-125 sugarcane aphids per leaf. Oklahoma State University Cooperative Extension Service recommends treatment if 30-40% of plants are infested (have at least one colony of sugarcane aphids).

Reports from southern states indicate that the sugarcane aphid is relatively difficult to control with standard aphid insecticides. Products containing chlorpyrifos (Lorsban Advanced, NuFos, etc.) are reported to provide moderate to good control when applied at 2 pints per acre, with 1 pint per acre providing suppression. A concern is that the 2 pint per acre rate has a preharvest interval of 60 days for grain, so this may not be a good choice for later season applications. The 1 pint per acre rate has a 30 day preharvest interval for grain.

Other states have recommended not to use pyrethroid insecticides against the sugarcane aphid. They are not highly effective and may lead to aphid resurgence due to their negative effect on aphid natural enemies (lady beetles, minute pirate bugs, wasp parasitoids, etc.).

A new product from Bayer CropScience, Sivanto 200 SL (active ingredient flupyradifurone), now has a federal label for aphid control on grain sorghum, and is effective against sugarcane aphids. Sivanto 200 SL is labeled at 7-10.5 fl oz per acre for sugarcane aphid control. It is more selective and is less likely to reduce natural enemy populations than organophosphate or pyrethroid insecticides. The preharvest interval for Sivanto 200 SL is 21 days for grain, and 7 days for forage.

Regardless of the product used, good spray coverage is important. Control may be improved by using 5 or more gallons/acre by air, or 10 or more gallons per acre by ground, since the aphids feed on the undersides of the leaves.

If you find aphids on sorghum that you suspect may be sugarcane aphids, please submit a sample to the UNL Plant and Pest Diagnostic Clinic (http://plantpathology.unl.edu/plantpestdiagnosticclinic) so we can document the presence of this aphid in Nebraska.

Additional sources of information

Be on Guard for Sugarcane Aphids in Sorghum

http://unlcms.unl.edu/ianr/extension/cropwatch/sorghum-sugarcane-aphid-8-5-15

Sugarcane Aphids Are Infesting Sorghum in Oklahoma

http://entoplp.okstate.edu/pddl/pddl/2015/PA14-32.pdf

http://sorghumcheckoff.com/pest-management/

http://agrilifeextension.tamu.edu/solutions/sugarcane-aphid/

Insect Resistance Management: Basic Concepts and Importance to Modern Agriculture*

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Insect resistance to insecticides or other control tactics is not new. It has been a problem faced by farmers for years. There are now over 540 instances where insect and mite species have developed resistance to pesticides (Arthropod Pesticide Resistance Database 2014), with some developing resistance to several pesticides. The consequences of resistance include higher frequency and rates of insecticide application (and so higher costs to the farmer), increased applicator exposure, increased environmental contamination, and the loss of effective pest management tools. Consequently, the United Nations Environmental Program has listed pesticide resistance as the third most serious threat to global agriculture behind soil erosion and water pollution. (Pimentel 2005). In the U.S. alone, crop losses due to pesticide resistance are estimated at $1.4 billion annually (Oerke 2005). Because of the apparent inevitability of resistance, the concept of resistance management has taken a central role in the use of new pest control technologies.

Current agronomic and economic trends are contributing to the resistance problem. A "clean-up the field" or "insurance treatment" philosophy has led to an increase of various methods of insecticide application regardless of the presence of economic populations of insect pests or significant risk of insects causing damage (e.g. tank-mixing, at plant insecticide application, factory applied seed treatments). These insecticide application methods in themselves are not a problem, but their use when not necessary is.

But what exactly is resistance? Resistance is a decreased response of a pest population to a control agent or tactic as a result of previous exposure to the control agent or tactic (McKenzie 1996). It is important to differentiate resistance from "tolerance". Tolerance is the innate ability to survive a given insecticide dose or control agent without prior exposure and evolutionary change. You can think of resistance as "accelerated evolution", where a population responds to an intense selection pressure and resistance evolves over a relatively short period of time. For insects, the intense selection pressure is most often the frequent and/or widespread use of a specific insecticide or class of insecticides.

Resistance is pre-adaptive, that is, it is the result of random genetic mutations that are present in the insect population. A small number of individuals have pre-existing traits that allow them to survive a normal control tactic, such as a given dose of insecticide. The insecticide does not produce the genetic mutation, but rather allows the individuals with the advantageous mutation, expressed as a trait, to survive. If enough of these survivors meet and reproduce, the percentage of resistant individuals in the population increases and we eventually see this in the field as resistance through reduced control.

The Solution: Insect Resistance Management

There are a variety of strategies collectively referred to as insect resistance management (IRM) that are designed to prevent or at least delay the resistance in insect populations. The primary goals of IRM are to 1) avoid the development of resistance in pest populations, 2) extend the number of generations that a given pest population can be economically and effectively controlled with a given technology (slow the rate of resistance), or 3) cause resistant populations to revert to more susceptible populations.

Most IRM programs are curative, that is, resistance has already appeared and the programs are implemented after the fact. Ideally, IRM programs should be proactive (designed to prevent resistance from developing) and be implemented along with the adoption of a technology. An example of the proactive approach is the high-dose, refuge resistance management plan used to prevent resistance to the Bt toxins in Bt transgenic corn from developing in European corn borer populations. In this case, IRM has proven to be successful. No field resistance in European corn borer populations to Bt toxins has been documented since the wide-spread deployment of Bt transgenic corn in 1997. Another strategy is "refuge-in-the-bag" (RIB). This is an approach where the refuge is incorporated into each bag of seed by using a seed mixture of both Bt and non-Bt seed at the appropriate ratio. Whether curative or proactive, to be successful an IRM program must be acceptable to all stakeholders, such as farmers, Industry, extension personnel, regulators, or consumers.

Factors Affecting Resistance Development

There are many factors that influence the selection for resistance in an insect population. These factors must be considered and taken advantage of when designing a resistance management program. They include genetic factors, biological and ecological factors, and operational factors.

Genetic factors include such things as the frequency of resistance genes prior to selection pressure, dominance of resistance genes, the number of genes that are involved in resistance, and the fitness of resistant individuals in the absence of the selection pressure. These factors are not known prior to the development of resistance, although scientists can sometimes estimate their levels and effects.

The biological and ecological factors include the pest reproduction rate, number of offspring, movement, and number of host plant species, among other things. These factors are known to varying degrees from various research studies prior to resistance development, but often there is much to learn when asking specific IRM questions.

Operational factors are those that relate directly to the method of control and can be controlled to some extent by the farmer. They include insecticide chemical characteristics (e.g. rate, mode of action, formulation, and residual activity) and application technique (e.g. frequency of application, mode of application).

Insect Resistance Management Tactics

There are numerous techniques that can be used alone or in combination to prevent, slow, or "revert" resistance. They are designed to either reduce the fitness of any resistant individuals or reduce the total amount of selection pressure. In general, the use of sound integrated pest management (IPM) is one of the best ways to prevent or delay resistance.

An important component of several current IRM strategies is the use of "refuges". A refuge is a habitat that supports a portion of the insect pest population that does not experience a specific selection pressure (e.g. untreated habitats). It can be made up of native host plants or untreated crop plants (native or structured). The purpose of the refuge is to supply a source of insects that are susceptible to the specific control tactic employed. These susceptible pests are expected to mate with any resistant insects potentially emerging from the areas receiving the control tactic.

Many farmers are familiar with the structured refuge concept that was initiated with the use of Bt transgenic corn targeting European corn borer. Farmers were required to plant a certain percentage of their farm to non-Bt corn, either in blocks or strips, to act as refuge for Bt susceptible corn borers. Currently, we are seeing the use of "seed-mixture" refuges for IRM designed for corn rootworm. For example, non-Bt corn seed is mixed with Bt transgenic corn seed to provide in-field refuge for Bt susceptible rootworms. Another tactic with which farmers are becoming familiar is the pyramiding of more than one transgene toxins that target a single insect pest. These two tactics, refuge and transgene pyramids, are used together for European corn borer and corn rootworm IRM. See a "Handy Bt Trait Table" developed by Michigan State University at www.msuent.com for more details on current IRM for transgenic corn.

A few examples of resistance management tactics that farmers can easily use include the following (Note that these are also IPM tactics).

- Use of action or economic thresholds. Almost all significant crop insect pests have action or economic thresholds. If thresholds are used, you only expose the insect pests to a selection pressure when it is necessary to prevent economic loss. An insecticide's mode of action is presented on the label, or go to www.irac-online.org/documents/moa-classification/?ext=pdf for more information.
- Rotation of insecticides. This relies on rotating insecticides with different modes of action. Using different modes of action reduces the selection pressure for any given mode of action, and possibly kills any insects that have survived the previously used mode of action. This is particularly important if you are treating a field more than once a growing season, or have yearly pest problems.
- Rotation of control tactics. Use of other effective control tactics (e.g. biological, cultural, host plant resistance) can further reduce selection pressure of single tactics.

While farmers can use the tactics described above to reduce the chance of resistance occurring, the tactics are not in themselves an IRM program. An IRM program is designed to deal with a specific insect management situation. Also note that rotation is a common theme, be it rotate insecticides, rotate crops, rotate tactics, etc. Rotation can vary from rotating insecticides during a single year to manage soybean aphids, to having a multiple year rotation scheme to manage corn rootworm resistance. For example, Figure 1. presents a 7-year rotation scheme for managing corn rootworm in a specific field. This might be part of an IRM plan for a producer who feeds cattle and requires significant amounts of corn each year.

Figure 1. Long term IRM tactic for corn rootworm

➢Rotation example:
2 year pyramid A → 2 yrs Non-Bt w/insecticide →
2 year pyramid B → 1 yr Soybean → ....

In this scheme the farmer never uses the same tactic for more than 2 years in a row, and inserts a year of soybean to break the corn rootworm cycle in that field.

Additional Components of IRM

Additional components of IRM include detection and monitoring for resistance, monitoring for IRM compliance (if required), and remedial action plans should resistance occur.

Resistance detection and monitoring is an important part of an IRM program. While one would like to prevent resistance from developing, sometimes the best that can be done is to slow resistance. Regular scouting is still needed to confirm that tactics are still working and alert the farmer that additional action may be required to manage pests. For current insect resistant transgenic crops, EPA mandated monitoring procedures are required of companies to hopefully detect resistance should it develop.

Compliance is also very important to the success of the IRM program. It can be a relatively "soft" requirement, such as simply keeping to one's plan to rotate tactics. Or, it can be more "rigid", as is IRM compliance as mandated for current Bt transgenic corn production.

The remedial action plan is designed to mitigate resistance should it occur and is most important with respect to current insect resistant transgenic crops. For these crops it is the responsibility of the registrant company, but it is always to have a plan of action ready should a particular tactic fail due to resistance. Hopefully, adequate IRM will prevent the need of remedial action plans.

*Adapted from "Hunt, T., Wright, R. 2014. Insect Resistance Management. (pp. 20-22). Lincoln, NE: Proceedings of the 2014 Crop Production Clinics. University of Nebraska Extension."

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6 April 2015
Updates to this bulletin posted at www.msuent.com

Handy Bt Trait Table

With questions or for corrections, contact:
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Michigan State University, East Lansing, MI

Most corn hybrids planted in the U.S. now contain one or more transgenic traits for weed or insect management. These traits are meant to increase flexibility and profitability for producers, but sometimes also lead to questions or cause confusion about their spectrum of control or refuge requirements to delay resistance. This bulletin provides a handy one-stop-guide to understand sales materials, bag tags, and the hybrids you purchase.

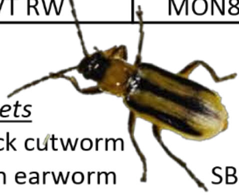
Table 1 lists the names of the important 'events' (transformations of one or more genes) in corn, their more familiar Trade Names, the protein(s) expressed, and their pest targets. Table 2 lists specific trait packages (combinations of events) sold by various seed companies, with their spectrum of control plus refuge % and location. In recent years, the pyramiding of Bt traits allowed for the reduction of some refuges from 20% to 10% or 5%, depending on the trait package. Some hybrids still require a structured refuge planted as a block or series of rows (within, adjacent to, or ~½ mile from the Bt field) , but many hybrids are now sold as a convenient refuge-in-the-bag (RIB). But it is still important to take the following steps:

*Understand the ***biology*** of each trait, the expected level of control, and refuge requirements;
****Confirm that the seed you ordered the previous year*** is the seed delivered in the spring;
*Keep good ***planting records*** and save a representative sample of ***bags or bag tags;***
*For herbicide applications, ***Ask Twice-Spray Once***, especially if you hire a custom applicator;
*Most important, if you see **unexpected damage or poor performance** of a trait (especially damage from corn rootworm), contact your seed dealer and extension educator immediately so that the field can be visited while the problem is still fresh and samples can be taken. This is critical to **identify and manage cases of rootworm Bt resistance**.

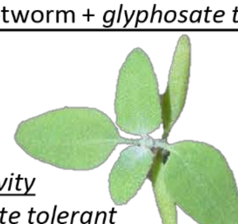
This bulletin strives for completeness, but keeping track of Bt traits isn't easy. For a searchable, easy-to-use database of GM crop approvals, see the ISAAA web site at http://www.isaaa.org/gmapprovaldatabase

Table 1. Event names for proteins expressed in Bt corn plants

Trade name	Event name	Protein(s) expressed	Insect Target or *Herbicide Activity*
Agrisure CB/LL	Bt11	Cry1Ab+PAT	corn borer + *glufosinate tolerance*
Agrisure Duracade	5307	eCry3.1Ab	rootworm
Agrisure RW	MIR604	mCry3A	rootworm
Agrisure Viptera	MIR162	Vip3Aa	broad lep control
Herculex 1 or CB	TC1507	Cry1F + PAT	corn borer + *glufosinate tolerance*
Herculex RW	DAS-59122-7	Cry34Ab1/Cry35Ab1+PAT	rootworm + *glufosinate tolerance*
Roundup Ready 2	NK603	CP4 EPSPS	*glyphosate tolerance*
YieldGard CB	MON810	Cry1Ab	corn borer
YieldGard VT Pro	MON89034	Cry1A.105+Cry2Ab2	broad lep control
YieldGard VT RW	MON88017	Cry3Bb1+CP4 EPSPS	rootworm + *glyphosate tolerance*



Abbreviations used in Table 2 on page 2



Insect targets
BCW black cutworm
CEW corn earworm
ECB European corn borer
FAW fall armyworm
RW corn rootworm
SB stalk borer
SWCB southern corn borer
TAW true armyworm
WBC western bean cutworm

Herbicide activity
GT *glyphosate tolerant*
LL Liberty Link, *glufosinate-tolerant*
RR2 Roundup Ready 2, *glyphosate-tolerant*

Table 2. Bt corn trait packages, with spectrum of control and refuge requirements.

(Updated 6 April 2015)

Trait Family Product	Bt protein(s)	Insects controlled or *suppressed* Above-ground	In soil	Herbicide tolerant?	Refuge %, placement (for the MIDWEST)
AGRISURE					
Agrisure GT/CB/LL, 3010A	Cry1Ab	ECB SWCB *CEW FAW SB*	---	GT LL	20% structured-½ mile
Agrisure 3000GT, 3011A	Cry1Ab mCry3A	ECB SWCB *CEW FAW SB*	RW	GT LL	20% structured-w/in, adj
Agrisure Viptera 3110	Cry1Ab Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	---	GT LL	20% structured-½ mile
Agrisure Viptera 3111	Cry1Ab mCry3A Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	RW	GT LL	20% structured-w/in, adj
Agrisure 3122 E-Z Refuge	Cry1Ab Cry1F mCry3A Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	GT	5% in the bag (RIB)
Agrisure Viptera 3220 E-Z Refuge	Cry1Ab Cry1F Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	---	GT	5% in the bag (RIB)
Agrisure Duracade 5122 E-Z Refuge	Cry1Ab Cry1F mCry3A eCry3.1Ab	BCW ECB FAW SB SWCB WBC *CEW*	RW	GT	5% in the bag (RIB)
Agrisure Duracade 5222 E-Z Refuge	Cry1Ab Cry1F Vip3A mCry3A eCry3.1Ab	BCW CEW ECB FAW SB SWCB TAW WBC	RW	GT	5% in the bag (RIB)
HERCULEX					
Herculex 1 (HX1)	Cry1F	BCW ECB FAW SB SWCB WBC *CEW*	---	LL RR2 (most)	20% structured-½ mile
Herculex RW (HXRW)	Cry34/35Ab1	---	RW		20% structured-w/in, adj
Herculex XTRA (HXX)	Cry1F Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW		20% structured-w/in, adj
OPTIMUM					
TRIsect	Cry1F mCry3A	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	20% structured-w/in, adj
Intrasect	Cry1F Cry1Ab	BCW ECB FAW SB SWCB WBC *CEW*	---	LL RR2	5% structured-½ mile
Intrasect Leptra	Cry1F Cry1Ab Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	---	LL RR2	5% structured-w/in, adj
Intrasect XTra	Cry1F Cry1Ab Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	20% structured-w/in, adj
Intrasect XTreme	Cry1F Cry1Ab mCry3A Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	5% structured-w/in, adj
AcreMax (AM)	Cry1F Cry1Ab	BCW ECB FAW SB SWCB WBC *CEW*	---	LL RR2	5% in the bag (RIB)
AcreMax RW (AMRW)	Cry34/35Ab1	---	RW	LL RR2	10% in the bag (RIB)
AcreMax1 (AM1)	Cry1F Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	10% in the bag *(RW)* & 20% structured-½ mile *(CB)*
AcreMax TRIsect (AMT)	Cry1F Cry1Ab mCry3A	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	10% in the bag (RIB)
AcreMax Xtra (AMX)	Cry1F Cry1Ab Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	10% in the bag (RIB)
AcreMax XTrem (AMXT)	Cry1F Cry1Ab mCry3A Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	5% in the bag (RIB)
YIELDGARD / GENUITY					
YieldGard CB (YGCB)	Cry1Ab	ECB SWCB *CEW FAW SB*	---	RR2	20% structured-½ mile
YieldGard VT Rootworm	Cry3Bb1	---	RW	RR2	20% structured-w/in, adj
YieldGard VT Triple	Cry1Ab Cry3Bb1	ECB SWCB *CEW FAW SB*	RW	RR2	20% structured-w/in, adj
Genuity VT Double PRO (or as RIB complete)	Cry1A.105 Cry2Ab2	CEW ECB FAW SB SWCB	---	RR2	5% structured-½ mile (or 5% in the bag (RIB))
Genuity VT Triple PRO (or as RIB complete)	Cry1A.105 Cry2Ab2 Cry3Bb1	CEW ECB FAW SB SWCB	RW	RR2	20% structured-w/in, adj (or 10% in the bag (RIB))
Genuity SmartStax RIB Complete	Cry1A.105 Cry2Ab2 Cry1F Cry3Bb1 Cry34/35Ab1	BCW CEW ECB FAW SB SWCB WBC	RW	LL RR2	5% in the bag (RIB)
OTHERS					
Smartstax (or as Refuge Advanced)	Cry1A.105 Cry2Ab2 Cry1F Cry3Bb1 Cry34/35Ab1	BCW CEW ECB FAW SB SWCB WBC	RW	LL RR2	5% structured-w/in, adj (or 5% in the bag (RIB))

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G2082

Soybean Stem Borers in Nebraska

Robert J. Wright, Extension Entomologist
Thomas E. Hunt, Extension Entomologist

Identification, life cycle, injury symptoms, and cultural and chemical management of soybean stem borer.

The soybean stem borer, *Dectes texanus texanus*, is a long-horned beetle (Family Cerambycidae) native to the central U.S. It has a wide host range, including soybeans, sunflowers, and several broadleaf weeds, including cocklebur, ragweed, and wild sunflowers.

Soybean stem borer injury can be found in some south central Nebraska soybean fields. This beetle has been moving into Nebraska from north central Kansas over the last decade. It was first documented as a soybean pest near Hardy in Nuckolls County in 2000, and has been moving into south central Nebraska since then. Soybean stem borer injury has been reported on soybeans in Fillmore, Clay, and Saline counties and surrounding areas to the west, east, and south.

Figure 1. Adult soybean stem borer, *Dectes texanus texanus.*

Figure 2. Larval soybean stem borer, *Dectes texanus texanus.*

Description and Life Cycle

The adult is a gray, elongate beetle about 1/2 inch long with antennae that are longer than the body (*Figure 1*). The antennae have alternating black and gray bands. Females lay eggs singly from late June to August on various plants, including cocklebur, giant ragweed, sunflower, and soybean. On soybean, eggs are primarily laid in the leaf petioles.

Larvae feed within the petiole and tunnel down into the main stem. Each of four larval stages tunnels up and down the stem. Larvae are cream-colored, legless, and widest at the head with the body gradually narrowing to the tail end (*Figure 2*). Larvae are 1/2 to 5/8 inch long at maturity. The larvae are cannibalistic and only one larva will survive per plant. Larvae overwinter at the base of the plant in the stem. Pupation occurs in early summer and adult emergence begins in late June. Adults are active from late June through August. There is one generation per year.

Injury Symptoms

Initial injury is seen when larvae tunnel down the leaf petiole and enter the stem. The leaf tissue above this point wilts and dies (*Figure 3*). If you split the leaf petiole, you can see the tunneling and may still see the larva. The appearance of individual dead leaves in an otherwise healthy canopy can be an early indication of the presence of *Dectes*. Split the stems of these plants to confirm the presence or absence of *Dectes* larvae.

Larvae tunnel up and down the stem, and end up at the base of the plant at plant maturity. Mature larvae girdle the inside of the stem to make a cell for overwintering. This weakens the stem and may lead to stem breakage or lodging. Economic damage is caused primarily by lodging and

Figure 3. Dead leaf caused by Dectes larval tunneling in leaf petiole *(Photo by Greg Carpenter, Pioneer Hybrids).*

subsequent harvest difficulties. Girdling is most severe in earlier maturing varieties, and lodging is most severe in earlier planted soybean. In the absence of harvest losses from lodging, direct yield loss from larval feeding has been limited or absent.

Management

Cultural Controls

Several cultural practices can be implemented to reduce potential loss from stem borers.

- Weed control to reduce alternate hosts of soybean stem borers, such as wild sunflower, ragweed, and cocklebur, can help reduce soybean stem borer populations.

- Research at Kansas State University indicates that *Dectes* prefers commercial sunflower to soybeans. Sunflowers may be used as a trap crop to protect adjacent soybean fields.

- Research from North Carolina has found that burying borer-infested stubble after harvest can reduce soybean stem borer populations the next year; however, this practice may not be desirable where soil erosion is a concern.

- The adults are not strong fliers and crop rotation may reduce damage in areas where soybean acreage is limited.

- Field observations in Kansas suggest that early planted, short-season varieties may be more likely to have harvest losses from lodging. Longer season varieties mature later in the year, allowing more time to harvest before lodging is likely.

- Entomologists at Kansas State University have been studying this insect as a pest on soybeans for several years. They have not identified resistance in any commercially available soybean cultivars.

Chemical Controls

Chemical treatment of larvae is ineffective because the larvae are in the stem; effective chemical control of the adults is difficult due to the extended adult emergence period. Research in Kansas indicates that multiple foliar insecticide applications are needed to significantly reduce adult populations and larval injury, and may not be economically justified unless harvest is late and lodging losses are high.

Recommendations for Harvest

Fields with a history of injury or with injury symptoms this year should be carefully watched during August and September. Fields with extensive stalk tunneling (greater than 50 percent of plants) by the soybean stem borer are most at risk for lodging and harvest losses, depending on weather conditions. Those fields should be targeted for harvest first to minimize harvest losses due to soybean stem borer injury. In the absence of lodging losses, this insect does not usually cause noticeable yield reductions.

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File under: Insects & Pests
Field Crop Insects
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Applying Pesticides Safely

Clyde L. Ogg, Pesticide Safety Educator and Ben Beckman, 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 G1219*
- *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:

http://facebook.com/UNLPSEP — Facebook

http://twitter.com/UNL_PSEP — Twitter

http://youtube.com/UNLExtensionPSEP — YouTube

NebGuide

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Know how. Know now.

G479
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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, certification, 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 certified 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 defines noncommercial applicators in order to address those individuals who do not commercially apply pesticides, and do not meet the definition of private applicator.

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 classified 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 specific 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 first 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 applicator.
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 buyer.
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 buyer.

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.

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Index: Pesticides, General Regulations

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G1219
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Worker Protection Standard for Agricultural Pesticides

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This NebGuide describes the Worker Protection Standard, helps you, the owner or operator of an agricultural operation, determine if it applies to your business, and provides information on how to comply with it.

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 OSHA (Occupational Safety and Health Administration), WPS strives to provide employees with a safe workplace, with the obligation for safety falling on the employer. WPS requires employers to protect two types of agricultural employees: *agricultural workers* and *pesticide handlers* (see definitions below). WPS is part of the pesticide label and is enforceable when a pesticide with a label that references WPS is used to produce an agricultural crop or commodity.

An 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. The manual is available in paperback or CD format from the Nebraska Department of Agriculture (NDA) at no cost, or can be viewed online at *www.epa.gov/agriculture/htc.html*.

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

- **Agricultural establishment —** any farm (including vineyard), forest, nursery, sod farm, or greenhouse.
- **Agricultural owner —** any person who possesses or has interest (fee, leasehold, rental, or other) in an agricultural establishment.
- **Agricultural plants —** crops or plants grown or maintained for commercial or research purposes. Examples include food, feed, or fiber plants; trees; turfgrass; flowers; shrubs; ornamentals; and seedlings. Horticultural plants grown for future transplant are included.
- **Agricultural workers —** those who perform tasks related to the cultivation (pruning, rouging, detasseling, etc.) and harvesting of plants or crops on agricultural establishments who may work in areas where pesticide residues are present.
- **Pesticide handlers —** those who mix, load, and apply agricultural pesticides; clean or repair pesticide application equipment; or may have direct contact with concentrated pesticides or tank mixes.
- **Crop advisors —** those who assess pest numbers or damage; pesticide distribution; or the status, condition, or requirements of agricultural plants. Crop advisors include crop consultants, crop scouts, and integrated pest management (IPM) monitors.
- **Immediate family —** includes spouse, children, step children, foster children, parents, stepparents, foster parents, brothers, and sisters. It does not include nieces and nephews.

WPS Labeling

All pesticide products affected by the WPS carry a statement in the *Agricultural Use Requirements* section on the label. 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 commodity, you must follow WPS requirements. WPS requirements are not in effect if an agricultural pesticide is used as labeled for a nonagricultural use.

Who Are the Affected Employers?

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

- Managers or owners of an agricultural establishment
- Labor contractors for an agricultural establishment
- Custom pesticide applicators
- Crop consultants hired by the owner of an agricultural establishment

Most provisions of the Worker Protection Standard 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 *How to Comply with the Worker Protection Standard for Agricultural Pesticides–What Employers Need to Know* manual, listed in the Resources section, for details).

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

1. **Wear appropriate personal protective equipment (PPE)** The personal protective equipment 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. 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 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.
2. **Restrictions during pesticide applications** During the application of pesticides, handlers and/or their employers must make sure that:
   - All label requirements are followed,
   - Pesticides are applied so that they do not contact anyone either directly or through drift, and
   - Everyone is kept out of treated areas during the treatment.

   In most cases, handlers who have been trained and wear the appropriate personal protective equipment are allowed to be in treated areas.
3. **Restrictions during restricted entry intervals (REIs)** WPS has established specific restricted re-entry intervals for all pesticides covered by the Standard. The restricted entry interval (REI) is the amount of time that must pass after a pesticide application before anyone may enter the treated area. The amount of time required is based on the toxicity of the compound and the tasks involved during the product's use. In most cases, REIs are in 4-, 12-, 24-, 48-, and 72-hour intervals. When the pesticide formulation or application is a mixture of active ingredients, the REI is based on the active ingredient that has the longest restricted re-entry period. During the REI, do not enter or allow any members of your family or hired handlers or workers to enter a treated area or contact anything treated with the pesticide(s) to which the interval applies.

Basic Duties of Employers of Pesticide Handlers and Agricultural Workers

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

Information at a central location. Employers must provide current and specific information about the pesticides being applied for the benefit of their employees, whether they are handlers or workers. The following information must be displayed and made accessible at a central location on the agricultural establishment where it can be seen and read easily.

- WPS Safety Poster
- Name, address, and telephone number of the nearest emergency medical facility
- Facts about each pesticide application, including:
  1) Product name,
  2) EPA registration number and active ingredients,
  3) Location and description of the treated areas,
  4) Time and date of the application, and
  5) Restricted entry interval (REI) for the pesticide.

Employers must tell workers and handlers where the information is posted and allow them access. Posted information must be kept legible and current.

Pesticide safety training. Unless handlers and workers are state-certified pesticide applicators or possess valid EPA-approved training validation cards, the employer must provide safety training before employees begin work. Training may be conducted by a certified pesticide applicator or by someone who has completed a train-the-trainer program. The training must be conducted in a manner and language that the employees can understand, using EPA-approved training materials or the equivalent. The trainer also must be on hand and able to answer questions after the training. The NDA stocks a variety of WPS training materials for both workers and handlers that are offered at no cost to agricultural employers.

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 a quarter mile of all workers and handlers and must include:

- Enough water for routine and emergency whole-body washing and eye flushing (about 1 gallon for each worker and 3 gallons for each handler),
- Plenty of soap and single-use towels, and
- A clean change of coveralls for use by each handler (this is not required for workers).

Water for emergency eye flushes must be immediately available if the pesticide label calls for protective eyewear. Employers also must provide water that is safe and cool enough for washing, eye flushing, and drinking. Employers may not use tank-stored water that also is used for mixing or diluting pesticides.

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

Nurseries and greenhouses. There are many special requirements for greenhouse and nursery owners or operators. These include special application restrictions, ventilation criteria, early entry restrictions, and additional handler protection. Consult the EPA *How to Comply* manual, the *Worker Protection Standard in Greenhouses* video on the UNL Extension PSEP YouTube channel (*http://bit.ly/NnPQQM*), and the pesticide label for specifics.

Additional Duties for Employers of Workers

Restrictions during application. Employers must prohibit worker entry into treated areas. Only handlers who have had the appropriate training and are wearing the required equipment may enter the area during application. See the EPA *How to Comply* manual for special restrictions for employees who work in nurseries or greenhouses.

Restrictions after applications. Employers must notify workers about pesticide applications on the establishment and the product's 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 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. All notifications regarding greenhouse applications must be posted.

Posted warning signs. Warning signs must be:

- posted 24 hours or less before application and removed within three days after the end of the REI, and
- Posted so they can be seen at all normal entrances to treated areas, including borders adjacent to labor camps.

If no employees come within a quarter mile of the treated site, *no posting is required*.

Oral warnings. Oral warnings must be delivered in a manner understood by workers, using an interpreter if necessary. Oral warnings must contain the following information.

- Location and description of the treated area
- The length of the REI
- Specific directions indicating that workers must not enter 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. 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.

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 personal protective equipment 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 personal protective equipment for each task. Employers must not allow any handler to wear or take home any used personal protective equipment. They must make sure PPE is worn and used correctly, and make sure respirators fit correctly.

Employers must take steps to avoid heat illness. Employers must take necessary steps to help employees prevent heat illness, especially while PPE is being worn. Train handlers to recognize, prevent, and treat heat illness. There are a number of key elements to keep in mind.

- Drink enough water to replace body fluid lost through sweating.
- Gradually adjust to working in the heat.
- Take periodic breaks in a shaded or air conditioned area whenever possible.
- Supervisors should monitor environmental conditions and workers.

More details about heat illness are available from the EPA publication, *A Guide to Heat Stress in Agriculture* (EPA 750-B-92-001).

PPE cleaning and maintenance. 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 areas.

Replacing respirator purifying elements. 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 each day's work period 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; or at the end of each day's work period 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. Federal, state, and local laws must be followed when disposing of PPE that cannot be cleaned correctly.

Instructions for people who clean personal protective equipment. Employers must inform people who clean or launder personal protective equipment that it may be contaminated with pesticides. They must inform them of the potentially harmful effects of exposure to pesticides and show them how to protect themselves and how to clean the equipment correctly. Further information is available in the EPA *How to Comply* manual.

Employer/Commercial Applicator Information Exchange

To protect the agricultural owner/operator and his or her family, 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
- Time and date of application
- Product name, EPA registration number, active ingredients, and REI
- Whether postings at the treated area and/or oral warnings are required
- Entry restrictions and other safety requirements for workers or other people

The owner/operator is responsible to share the above information with members of his/her immediate family.

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

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 an appropriate medical facility. Information about the medical facility must be posted at a central location. In addition, the employer must provide the victim and medical personnel with the following information.

- The product name, EPA registration number, and active ingredients (listed on the label and posted at the central location)
- All first aid and medical information from the label
- A description of how the pesticide was used
- Information about the victim's exposure

Exemptions

The WPS does not cover pesticides applied:

- On pastures, rangeland, or livestock;
- On the harvested portions of plants or on harvested timber;
- For control of vertebrate pests, such as rodents;
- 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 the WPS;
- On plants intended only 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; or
- For research uses of unregistered pesticides.

Agricultural Owner Exemptions

Owners of agricultural establishments and members of their immediate family are exempt from some of the WPS requirements while performing 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 may hire.

- Pesticide information at a central location
- Pesticide safety training
- Decontamination sites
- Emergency assistance
- Notice about pesticide applications
- Monitoring of handler's actions and health
- Specific handling instructions
- Duties related to early entry: training and instructions and decontamination sites
- All the specific duties related to the need, use, management, and inspection of personal protective equipment

Exceptions to REIs

In general, you, your family members, hired handlers, and hired workers must stay out of a treated area during the restricted entry interval. This restriction has two exceptions:

- Early entry with no pesticide contact; or
- Early entry with contact for short-term, emergency, or specially exempted tasks.

No contact early entry means just that: **no contact**! You, your family members, hired handlers, or hired workers may enter a treated area during an REI if no one will touch or be touched by any pesticide residues, and if the required early entry personal protective equipment is worn. There must not be any exposure to pesticides or residue, even if PPE is worn.

Early entry with contact allows you, members of your family, hired handlers, or hired workers to enter a treated area during a restricted entry interval in only three work situations.

1. Short-term tasks that last less than one hour per 24-hour period and do not involve hand labor
2. Emergency tasks that take place because of an agricultural emergency recognized by the Nebraska Department of Agriculture
3. Specific tasks approved by EPA through a formal exception process.

For early entry short term tasks with no hand labor, one must:

- Wait at least four hours after the pesticide application is completed before entering,
- Enter and work for only one hour during a 24-hour period,
- Wear the personal protective equipment specified on the pesticide label for early entry tasks, and
- Follow any other restrictions specified on the pesticide label or in any special exception under which the early entry takes place.

Crop Advisor Exemptions

Crop advisors are exempt from many WPS provisions in Nebraska if they have met the pesticide safety training requirements. To meet the training requirement, they must either be state-certified pesticide applicators or receive approved WPS pesticide handler training.

As pesticide handlers under the WPS, crop advisors or those under their direct supervision may enter treated areas during pesticide application and the REI if they follow the product labeling PPE requirements. Crop advisors with approved safety training can determine the appropriate protection to be used while performing crop advising tasks in treated areas after the pesticide has been applied.

Individuals under the direct supervision of a crop advisor are exempt from WPS provisions except for the pesticide safety training requirements (see pesticide safety training). These people must be trained as agricultural workers under WPS provisions. The exemption applies only after the pesticide application is completed and while performing crop advising tasks.

The crop advisor must provide people under their direct supervision with information on the pesticide product and active ingredient(s) applied, method and time of application, and the REI. Also, advisors must provide individuals under their supervision with information regarding the tasks to undertake and how to contact the crop advisor.

Resources

Nebraska Department of Agriculture. For WPS regulatory interpretation and compliance guidance, call 402-471-2394.

Ogg, C.L., Bauer, E.C., Hygnstrom, J.R., Hansen, P.J. (2012) Protective Clothing and Equipment for Pesticide Applicators, NebGuide G758.

U.S. Environmental Protection Agency. 2005. How to Comply with the Worker Protection Standard for Agricultural Pesticides−What Employers Need to Know, EPA/735-B-05-002.

This publication was peer reviewed.

UNL Extension publications are available online at *http://www.ianrpubs.unl.edu/epublic/pages/*.

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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 re-use 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 (*Figure 1*). 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:

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 lanldfill, or by incineration, or by other procedures approved by state and local authorities.

Figure 1. Example of label language on a nonrefillable container

- 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"); there also should be minimal dripping outside the container.

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, and a lot number identifying the batch.

Refillable Containers

Both registrants and independent refillers (repackage but are not the product registrant) must comply with re-

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

quirements for stationary tanks, repackaging, and portable refillable containers *(Figure 2)*.

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, bi-annually, 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
   - 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 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)*.

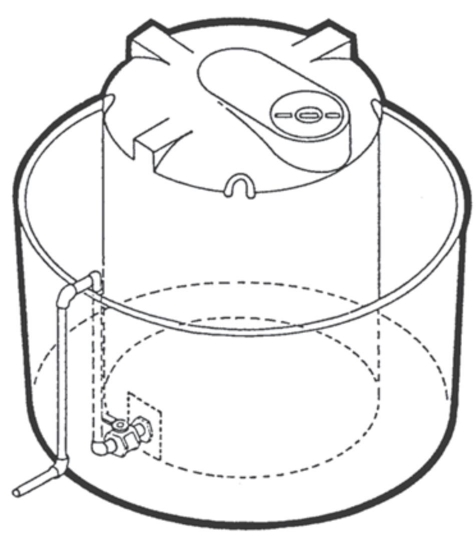

Figure 3. Secondary containment

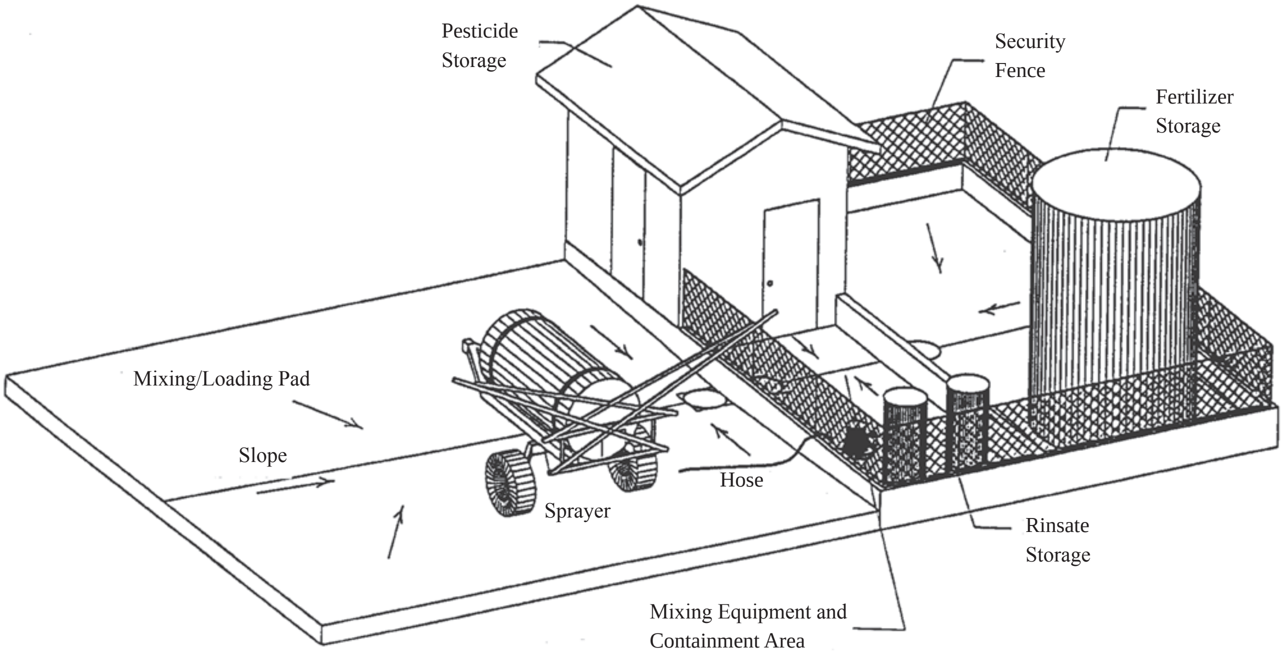

Figure 4. A load-out pad

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://www.deq.state.ne.us/RuleAndR.nsf/Pages/198-TOC.*

The Nebraska Department of Environmental Quality (NDEQ) also makes appropriate minor adjustments to Title 198 to comply with new EPA standards from the PCC Rule. If you are responsible for bulk quantities of liquid pesticides and fertilizers, you may be required to use secondary containment and/or load-out facilities.

According to the NDEQ, 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 Nov. 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 Oct. 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://www.deq.state.ne.us/.*

Resources

Are Environmental Regulations becoming a Pest?, Nebraska Department of Environmental Quality. *http://www.agr.state.ne.us/division/bpi/pes/ndeq_title198.pdf*

Fertilizer and Pesticide Containment in Nebraska, 2004, Nebraska Department of Environmental Quality. *http://www.deq.state.ne.us/.* Search for the publication title.

Title 198: Rules And Regulations Pertaining To Agricultural Chemical Containment, Nebraska Department of Environmental Quality. *http://www.deq.state.ne.us/RuleAndR.nsf/Pages/198-TOC*

Pesticide Container and Containment Rule, Environmental Protection Agency. *http://www.epa.gov/pesticides/regulating/containers.htm*

A snapshot of the EPA Pesticide Container and Containment Rule, Environmental Protection Agency, 2009. *http://www.epa.gov/pesticides/regulating/ccrule-brochure.pdf*

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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;
- classification statement;
- directions for use;
- re-entry statement, if necessary;
- harvesting and/or grazing restrictions; and
- storage and disposal statements.

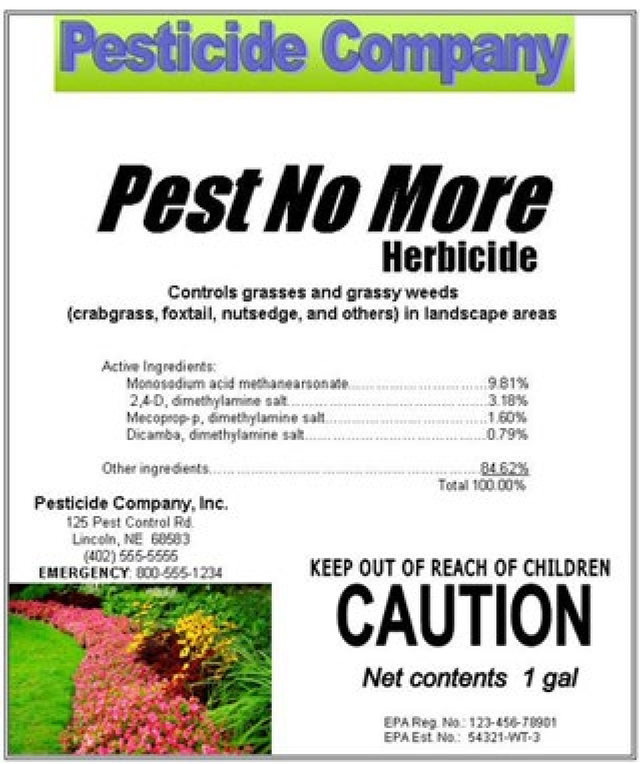


Figure 1. An example of pesticide label.

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 (fluid ounces, pints, quarts, ounces, pounds, etc.).

Use Classification Statement

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 certified *(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.) identifies the specific 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* identifies the way(s) in which a particular pesticide may enter the body and gives specific 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 specific 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 specific to the product. For example, "spray solutions of this product should be mixed, stored, and applied, using only stainless steel, aluminum, fiberglass, plastic, or plastic-lined steel containers" and "this gas mixture could flash 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 specific 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 specific 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

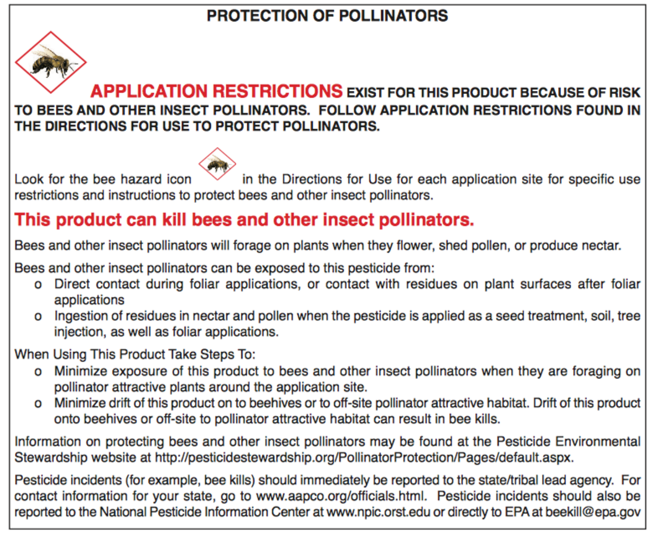
Each pesticide label has general storage and disposal instructions. Keep pesticides stored in a secure location, away from food and feed supplies, and in the original containers. When disposing of pesticide containers, **triple- or pressure-rinse and puncture containers to avoid re-use**. State and local 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 specific 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.

Disclaimer

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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

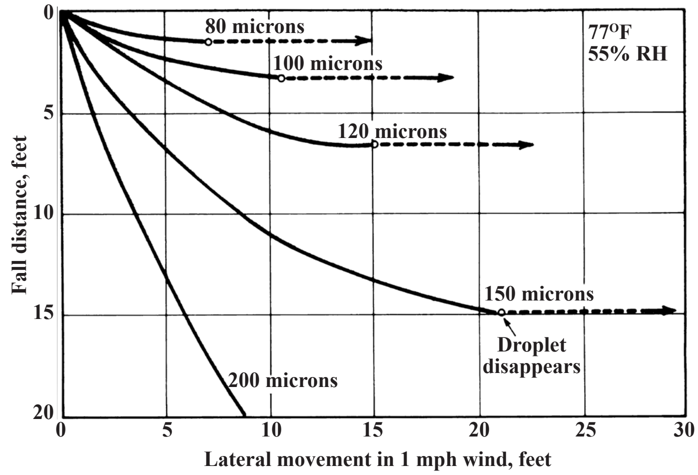

Figure 1. Lateral movement of water droplets. (Hofman and Solseg, 2004)

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 efficacy, 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 orifice with a circular motion and aids the droplet formation with a spinning force.
- An *air inclusion nozzle* has one orifice to meter liquid flow 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 Carrier 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 flat-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 influences 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).

	Volume Median Diameter, microns		
Nozzle Type	*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 Height, inches			
	20-inch Nozzle Spacing		*30-inch Nozzle Spacing*	
Spray Angle Degrees	*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. Specifically, 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)

	Drift	
Droplet Diameter	*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 fire *(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.

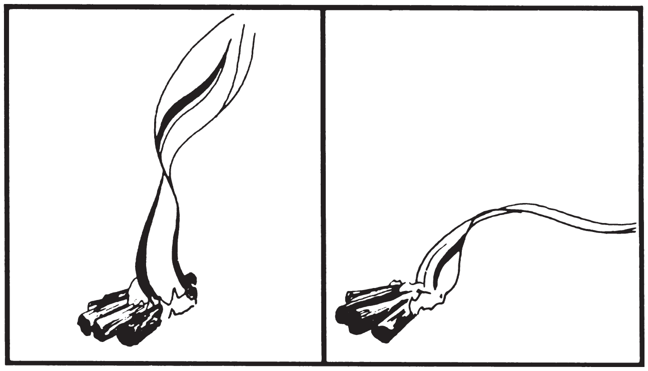

Figure 2. Smoke rising with wind velocity below 5 mph.

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.

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Index: Pesticides, General Equipment

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.

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 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
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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.

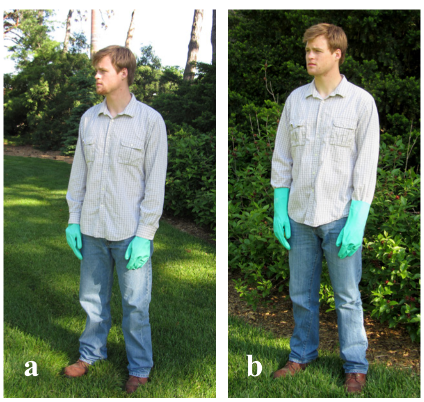

Figure 1. Wear a long-sleeved shirt, long pants, shoes plus socks, and chemical resistant gloves when applying pesticides. We recommend wearing gloves inside sleeves (1a), but wearing gloves outside sleeves may work equally well (1b).

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.

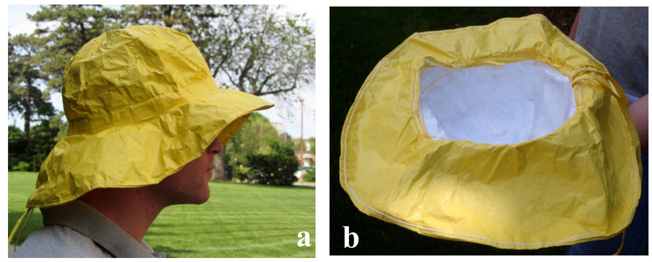

Figure 2. Example of protective hat that can be worn when applying pesticides.

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.

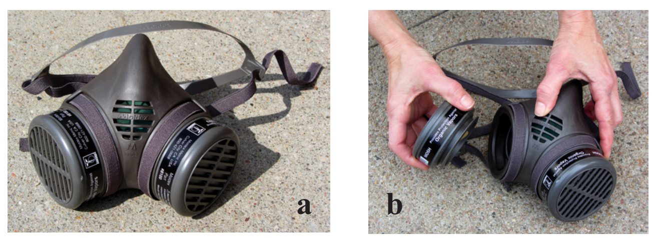

Figure 6. Half-face cartridge respirator with cartridges attached (6a) and cartridge detached (6b).

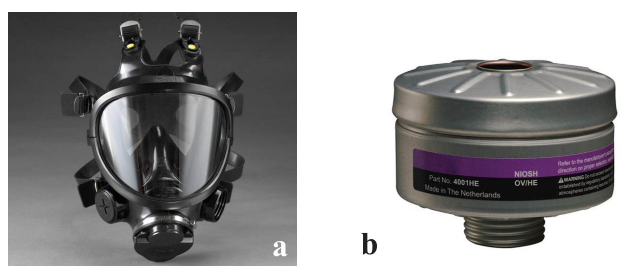

Figure 7a. Full-face canister respirator (no canister) (Photo courtesy of 3M); 7b. Close-up of canister. (Photo courtesy of North by Honeywell)

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.

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University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
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G2083

Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications

**Erin C. Bauer, Extension Associate; Clyde L. Ogg, Extension Educator;
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

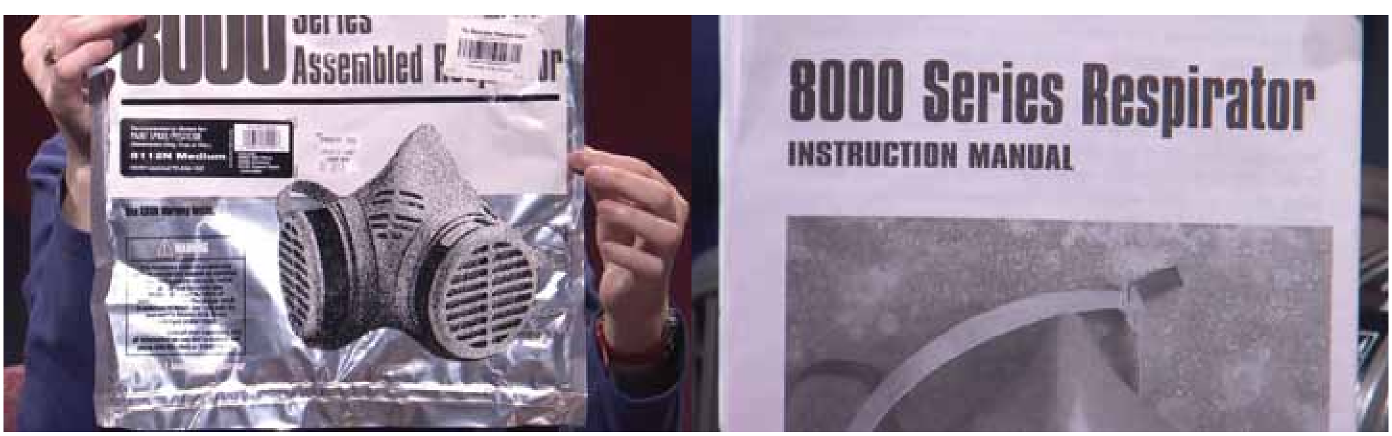

Figure 1. Examples of respirator packaging and instruction manual.

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 properly *(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 operability.

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 filter.

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 filter. 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

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NebGuide

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

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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 sufficiently, 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 finishing 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.

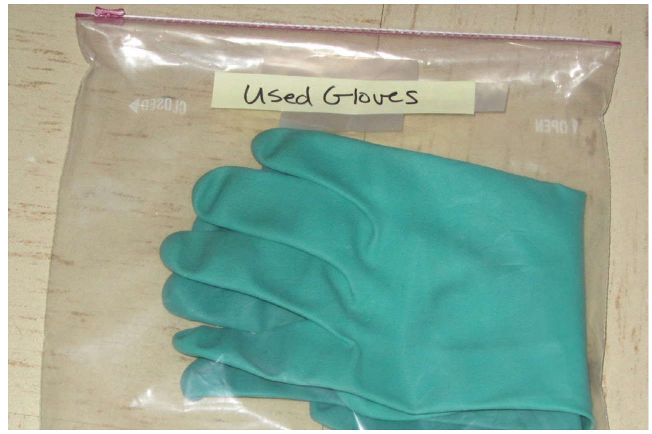

Figure 5. Properly store used gloves in a plastic bag or bucket labeled as such. Photo: University of Nebraska–Lincoln.

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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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, fiber, 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

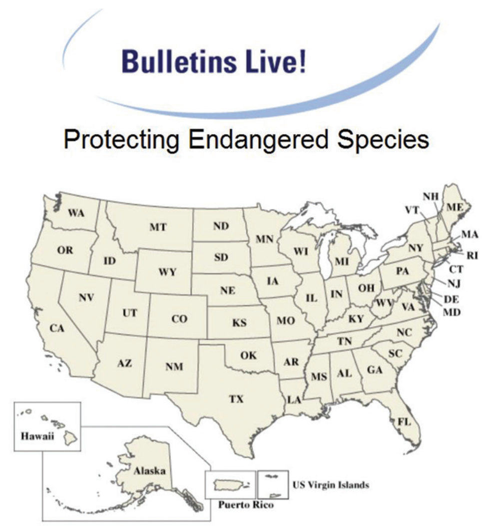

Figure 1. Bulletins Live! map on U.S. EPA website.

"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, fish, 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 survey.

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, fish, 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.

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) 437-5080

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*

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Index: Environmental & Natural Resources Conservation

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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, fluroxypyr, 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 notifications 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.
    - Dow AgroSciences 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 flowering 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 efficacious 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 efficacy 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 Certification 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 Office of Pesticide Programs *www.epa.gov/pesticides/*

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

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University of Nebraska–Lincoln EXTENSION

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EC301

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

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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 co-operation 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 under-standing of honey bee behavior, and know which materials and application practices are the most hazardous to bees. It is unlikely that all bee poison-ings can be avoided, but in most cases, bee losses can be reduced by under-standing 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.

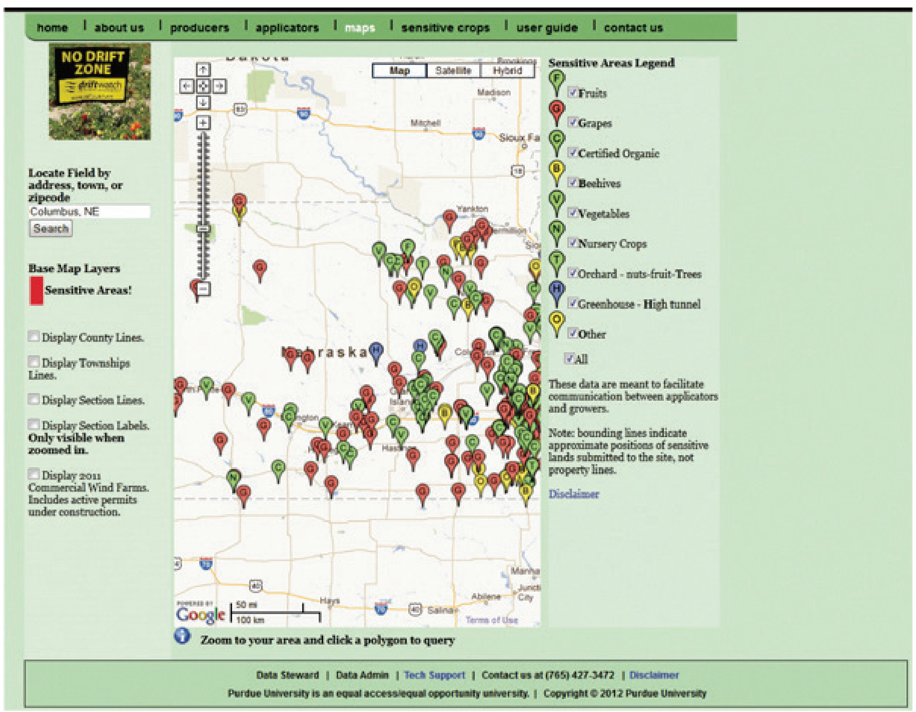

Figure 4. DriftWatch encourages commercial producers to register locations of beehives.

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.

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NebGuide

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Know how. Know now.

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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 efficiently 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 difficult 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 difficult 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.

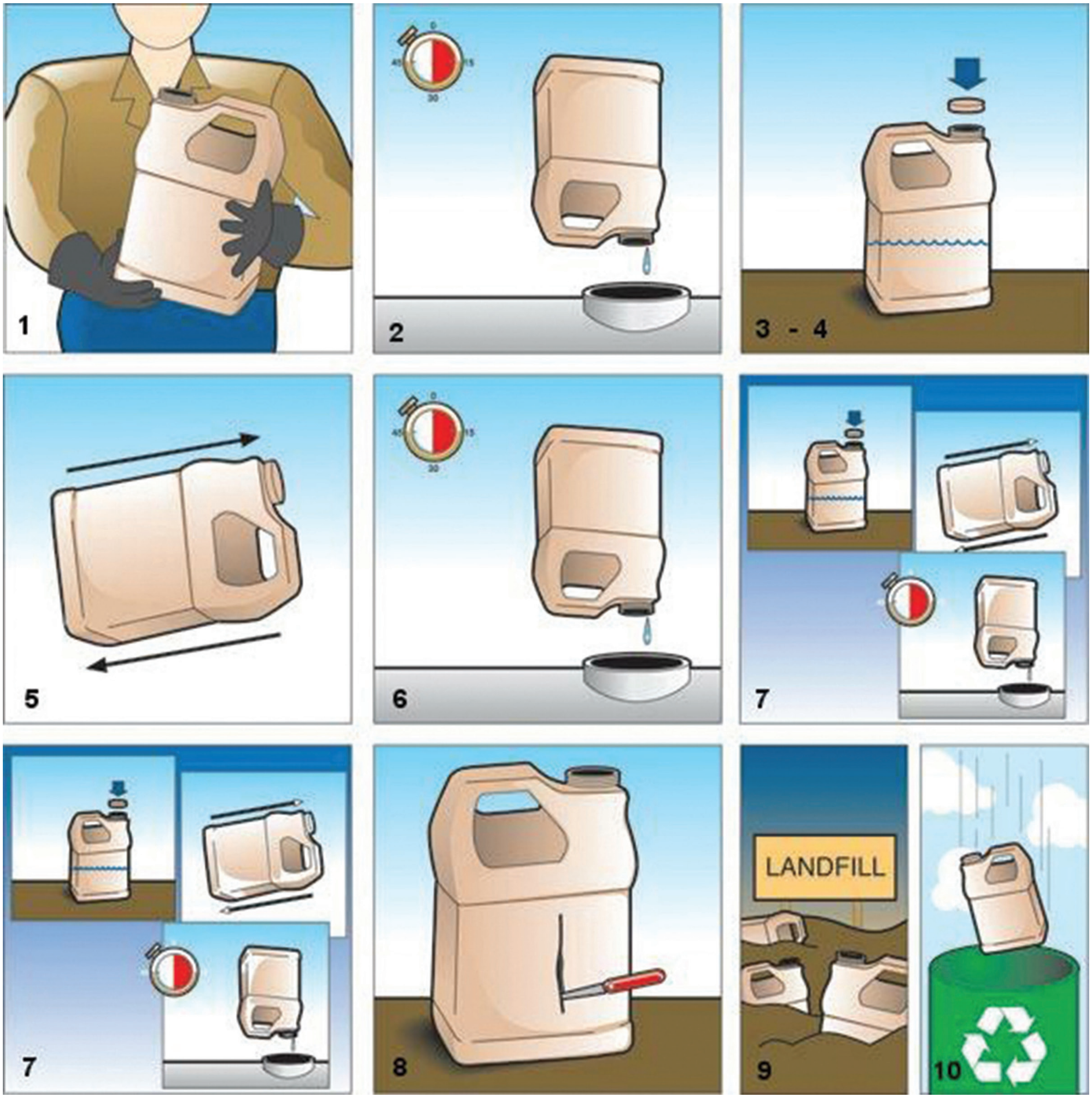

Figure 1. Triple-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.

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 difficult 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 flush 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 flows out. Allow the container

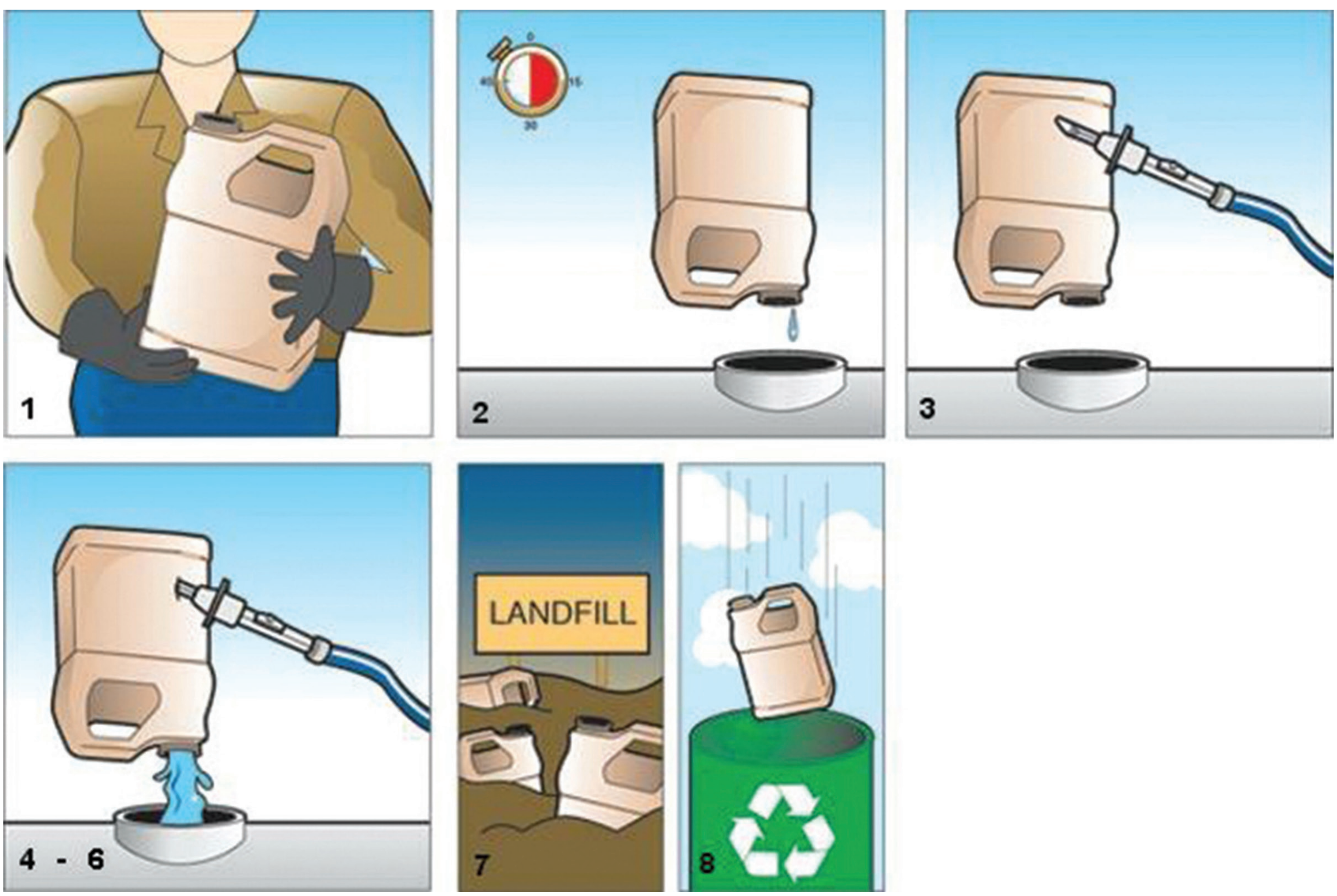

Figure 2. Pressure-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.

to drain for 30 seconds. Begin the rinsing procedure immediately or the product may be difficult 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 flow 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 flow 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 backflow prevention device when filling 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 specific setbacks from wells regardless if the well is active or not.

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Index: Pesticides, General Safety

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NebGuide

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

Know how. Know now.

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(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 finish 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 baffles
- 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.

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Index: Pesticides, General
Safety

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G2038

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”:

- Emergency telephone numbers (see next page)
- Copies of all labels and Material Safety Data Sheets (MSDS) 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 MSDS 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, 2007.

Pesticide Environmental Stewardship, *Pesticide Spills, http://pesticidestewardship.org*

Safe Transport, Storage, and Disposal of Pesticides, EC2507, *http://www.ianrpubs.unl.edu/sendIt/ec2507.pdf*

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.

It is imperative to contact the appropriate state agencies when a spill occurs. Refer to the numbers listed below 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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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.

University of 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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Erin C. Bauer, Extension Associate
Pierce J. Hansen, Extension Assistant

IANR

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Managing Pesticide Poisoning Risk 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.

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.

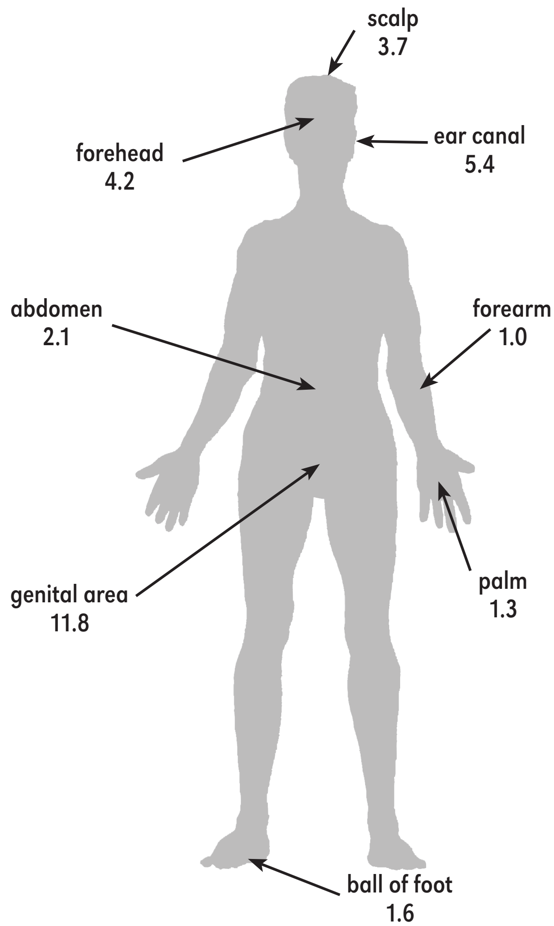

Figure 1. Absorption rates of the different parts of the body based on the absorption rate of the forearm.

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:

$$\text{Risk} = \text{Toxicity } x \text{ Exposure.}$$

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 nonemergencies 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.**

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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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SAFE Transport, Storage, and Disposal of Pesticides

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IANR

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.

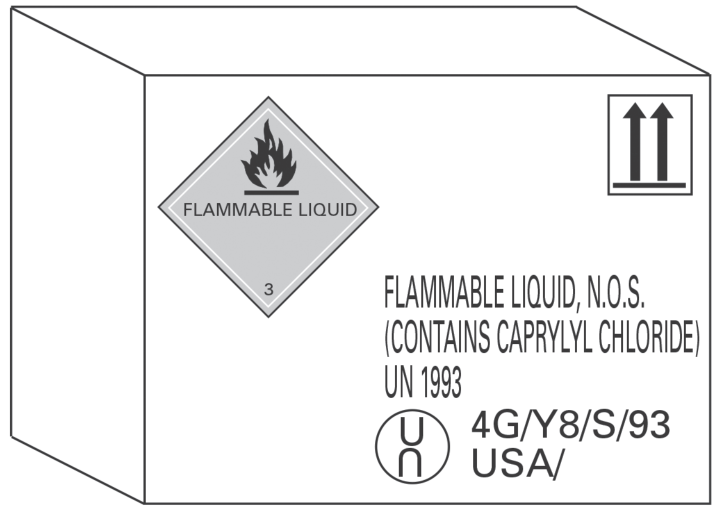
The U.S. Code of Federal Regulations is available online by searching for US Code of Federal Regulations.

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.

Storing Pesticides

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°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.

Fungicide Application Timing and Disease Control

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Introduction

Wet weather that persisted during much of the 2015 growing season proved to be very favorable for disease development in several crops across Nebraska. In particular, diseases caused by fungi were favored by repeated rainfall events and high relative humidity, fog, etc. that supported the production of more spores and continuous plant infection. On some susceptible varieties and hybrids, diseases developed early and quickly eventually reaching moderate to severe levels. Foliar fungicides were applied one or more times to some crops in an effort to mitigate losses due to disease. However, low crop prices and narrow profit margins made foliar fungicide application decisions more difficult as producers weighed the application costs versus the potential protection fungicides can provide from some diseases.

One of the most important factors to consider when making a foliar fungicide application is the timing of the application and how long can you expect protection from the product. In general, most strobilurin fungicides are expected to provide about 21-28 days of protection from infection. And, triazoles are systemic and have curative activity, but only for infections that have just occurred. These fungicides can't restore diseased, necrotic leaf tissue. And, unfortunately, gaining a return on the foliar fungicide application is determined by several additional factors that impact the anticipated disease severity making the decision more difficult, such as:

- Disease history (for those pathogens that overwinter here),
- Susceptibility of the hybrid or variety
- Weather forecast
- Availability of irrigation
- Crop stage
- Crop rotation vs. continuous cropping
- Tillage regime

The protection provided by fungicides applied too early could leave crops vulnerable to increased disease severity once they've worn off. Although, applications made too late in disease development will likely not provide the desired level of control This may also be impacted by the seeming delay in development of disease symptoms from earlier infections (latent period). Some pathogens may require up to three weeks for symptom development after infections that often occurred during an earlier period when weather conditions were more favorable. Fungicides applied during this time period won't likely be able to stop most lesions from developing. And, the development of disease lesions after product application may give producers the impression that the products didn't work as expected. Listed below are specific examples of disease control with foliar fungicides in several crops.

Corn Diseases

Gray Leaf Spot

Gray leaf spot was more severe in 2015 in some areas of Nebraska than it has been in several years and was probably the most significant disease threat to corn across much of the state. The fungus causing gray leaf spot, *Cercospora zeae-maydis*, requires periods of high relative humidity of at least 95% for at least 11 hours for spores to germinate and infect. Conditions during 2015 were very favorable for an extended period of time for gray leaf spot development, thus the severity increased rapidly. The rectangular lesions that are typical of gray leaf spot start on the lowest corn leaves and continue to progress higher on the plant as long as weather conditions are favorable. We often use leaf number (relative to the ear leaf) as a measure of disease severity when monitoring its progress. Because gray leaf spot does not develop sporadically in the canopy, but instead methodically progresses up the plant from the lowest leaves, some people use its height on the plant as an indicator when making a fungicide application timing decision. It's important to keep in mind, though, that gray leaf spot lesions can take 14-21 days to develop after infection and so, leaves may already be infected one to two leaves above the highest leaf with obvious lesions. Gray leaf spot lesion progression up the plant is important to monitor since the ear leaf and those above it contribute 80% of the yield and protecting them is a priority. So, some people prefer to spray fungicides on susceptible hybrids when the gray leaf spot lesions are one or two leaves below the ear leaf, if other high risk factors for disease development apply. High risk factors for gray leaf spot development include:

- Disease history
- Susceptible hybrid
- Favorable weather forecast (including warm and damp conditions)
- Irrigated fields (with more moisture available and greater yield potential than rainfed fields)
- Disease development during early crop stages (especially prior to tassel emergence)
- Continuous corn
- Minimum or no-till fields with more infected crop residue on the surface

2015 was also a difficult year for disease management in some fields because of the long-term development of gray leaf spot. While some producers chose to protect high yield potential with two fungicide applications, others sought to maximize protection from a single well-timed fungicide application. A late flush of gray leaf spot lesion development also led many people to question, "How late can a fungicide be applied and still be economical?" When considering late season fungicide applications we need to consider the plant's grain fill activities at various stages and the potential for disease lesions on leaves to disrupt photosynthetic activity and grain fill. In Table 1, Abendroth et al. (2011) provide estimates on dry matter accumulation in kernels (test weight) during the dent (R5) substages, as well as grain moisture (%), average GDD, and the average number of days at each substage for 110-115 day relative maturity hybrids in Iowa. Overall yield, especially test weight, could be affected by disease during the dent stage when more than 50% of dry matter is left to accumulate in kernels indicating that late season stresses could significantly affect test weight. Thus, under severe disease conditions, late season fungicide applications may be economical during some years with high disease pressure, but are much less likely to provide a yield response than those made earlier. Note that these data do not represent all of the corn relative maturities that are grown in Nebraska (especially in western Nebraska).

Table 1. Dry matter accumulation, grain moisture and growing degree days (GDD) during dent (R5) substages.

Corn Dent (R5) Substage	% Moist-ure	Dry Matter (% of Total Dry Weight)	Avg. GDD	Avg. Number of Days
5.0	60%	45%	75	3
5.25 (1/4 milk line)	52%	65%	120	6
5.5 (1/2 milk line)	40%	90%	175	10
5.75 (3/4 milk line)	37%	97%	205	14
6.0 (Physiological maturity)	35%	100%		
TOTAL			575	33

These estimates of late season dry matter accumulation may help to explain why yield increases occurred in some late treatments in some fungicide trials. At the UNL South Central Agricultural Laboratory in 2008 a fungicide trial was conducted on two hybrids varying in susceptibility to gray leaf spot at two planting dates. Gray leaf spot severity was greater in the susceptible hybrid (rated "fair'), especially in the later planting date (data not shown). Likewise, treatment differences for yield only existed in fungicide treatments applied to the more susceptible hybrid with higher disease severity (Figures 1 and 3). In that trial, the later planted susceptible hybrid experienced the highest disease severity and was also where the most treatment differences existed compared to the non-treated control (Figure 3). Yield in treatments applied as late as the dent stage (R5) were statistically greater (consistently across the six replications), although the increase was not always enough to pay for the fungicide application at current corn prices. Although the likelihood of experiencing similar results is less common for very late fungicide applications, there is some possibility to see economic returns, especially in corn grown at elevated risk for disease development (susceptible hybrid, late planting, continuous corn, etc.).

Figures 1-4. Yield results from corn fungicide trials (2008 UNL South Central Agricultural Laboratory) showing yield (bu/A) following application of 1 of 2 foliar fungicides at various timings to two planting dates of two hybrids. Each treatment combination was replicated six times.

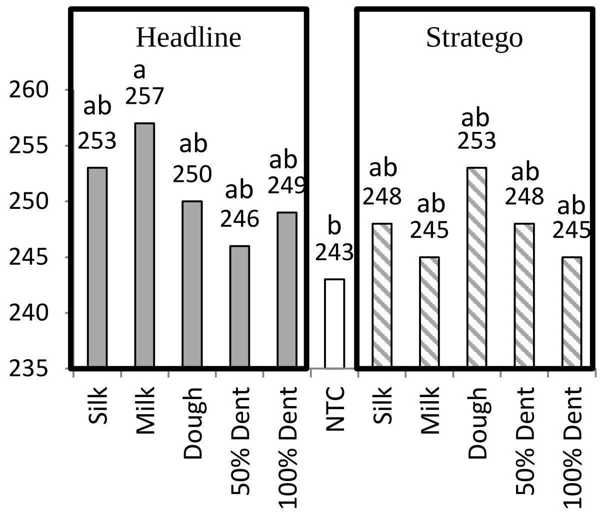

Figure 1. Hybrid DKC 60-18 (GLS Rating=7/Fair) Planted 4/30/2008.

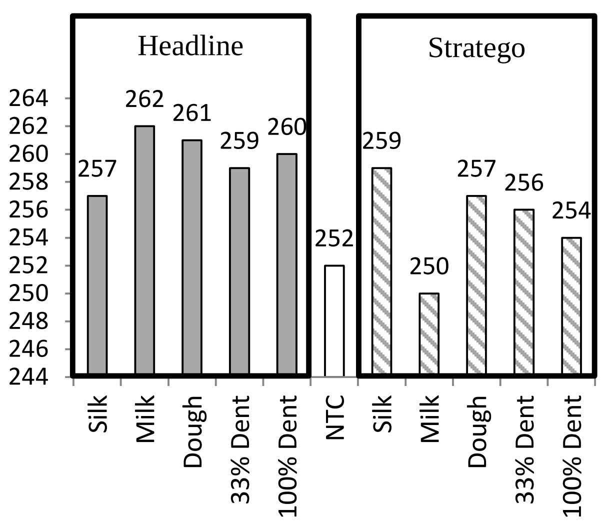

Figure 2. Hybrid DKC 61-69 (GLS Rating=5/Good) Planted 4/30/2008.

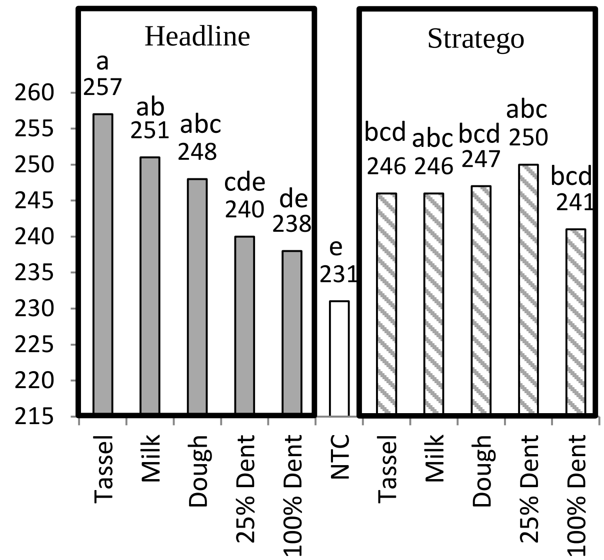

Figure 3. Hybrid DKC 60-18 (GLS Rating=7/Fair) Planted 5/14/2008.

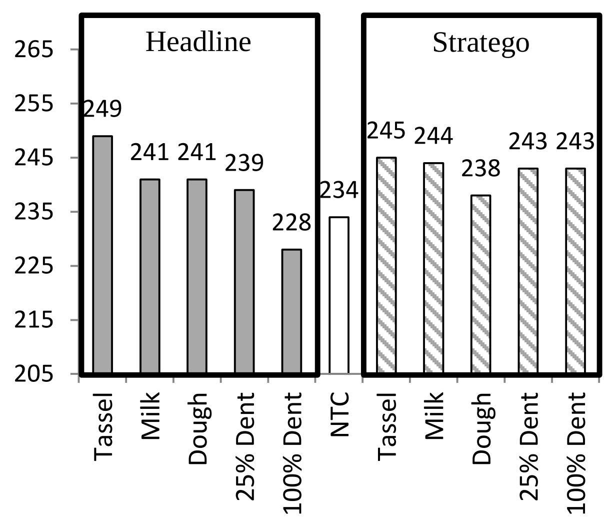

Figure 4. Hybrid DKC 61-69 (GLS Rating=5/Good) Planted 5/14/2008.

Soybean Diseases

*Sclerotinia Stem Rot (White Mold) of Soybean (*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. 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 again in 2015 as we had cool, wet conditions during flowering in many parts of the state.

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).

Wheat Diseases

Stripe rust

The frequency and severity of stripe rust on wheat have increased during the last 10 years, with major epidemics in Nebraska occurring in 2005, 2010, 2012, and 2015. Because of the high risk for substantial yield loss due to stripe rust, it is essential to have management strategies in place and to be prepared to implement management tactics in years when the disease develops to damaging levels. The two main strategies for managing stripe rust are choosing resistant cultivars and having in place an effective fungicide application program. The majority of chemical fungicides registered for control of stripe rust on wheat have excellent efficacy; the rest have very good efficacy. Regardless of the level of efficacy, proper timing of fungicide application is critical in the effective control of stripe rust.

Fungicides are most effective on stripe rust if applied preventively. Optimal timing for fungicide application to control stripe rust depends on the following conditions: 1) stripe rust-favorable weather (cool, wet conditions) is forecast, 2) the flag leaf has emerged, 3) stripe rust has been confirmed in southern states, and 4) stripe rust has been detected in the field. Scouting is critical for early detection and timely fungicide application. If the conditions listed above exist, a fungicide should be applied at first detection of stripe rust in the field. If disease pressure is heavy in southern states and stripe rust appears earlier than flag leaf emergence, a pre-flag leaf fungicide application may be warranted followed by a flag leaf application.

In a stripe rust fungicide trial conducted at the UNL Agricultural Research and Development Center (ARDC) near Mead in 2012, Prosaro at 5 or 6.5 fl oz/A, Headline at 6 or 9 fl oz/A, and Aproach at 6 or 9 fl oz/A significantly reduced stripe rust severity, achieving 76 to 99% control. At label rates, Prosaro, a triazole with two active ingredients achieved 99% control compared to Headline (87% control) and Aproach (76% control), each of which is a strobilurin fungicide with one active ingredient. The biological control products EcoGard at 0.375% or 0.75% and Regalia Maxx at 4 or 8 fl oz/A resulted in stripe rust levels similar to those in the unsprayed check plots. The highest yield was obtained from the Prosaro, Headline and Aproach-treated plots. Yield from the Regalia Maxx and EcoGard treatments did not differ from that in the check treatment.

Fusarium head blight

Fusarium head blight (FHB), also known as scab, is another disease of wheat whose frequency and severity have increased in Nebraska during the last 10 years. Major epidemics occurred in 2007, 2008, and 2015, and varying levels of the disease occurred between 2008 and 2015. Because FHB is favored by excessive moisture before and during flowering, it is most prevalent in the eastern half of the state and in irrigated fields in the southwest. The FHB-causing fungus produces a mycotoxin known as deoxynivalenol or DON. Therefore, in an FHB year, losses to the grower are manifested not only in yield but also in discounts at the elevator if DON levels in grain exceed 2 ppm. Therefore, fungicide applications to control FHB are aimed at reducing disease severity as well as DON.

FHB infections occur on wheat heads mostly during flowering. Therefore, optimal fungicide application timing is at early flowering. FHB researchers in the United States have determined Prosaro and Caramba to be the most efficacious on FHB and DON. The narrow window (early flowering) of fungicide application presents challenges to the grower. FHB researchers are trying to determine if fungicide application later than early flowering can be as effective as an early flowering application. To this end, in 2015 we conducted two field trials (dryland and irrigated) at the ARDC in which we applied Prosaro at early flowering and at 6 and 12 days later to the cultivars Overley (susceptible) and Overland (moderately resistant).

Results showed that in the dryland trial, fungicide applications at 6 and 12 days after early flowering resulted in statistically similar levels of FHB severity and DON in both cultivars, but both variables were significantly higher in Overley than in Overland. In the irrigated trial in Overley, FHB severity and DON were statistically similar in the timings at early flowering and 6 days later. However, the timing at 12 days later resulted in significantly higher FHB severity and DON compared to the two earlier timings. In the irrigated trial in Overland, all three timings resulted in statistically similar FHB severity and DON and both variables were significantly lower than in Overley. These results show that the window of fungicide application to control FHB and DON can be widened from early flowering to 6 days later without loss of efficacy.

Specialty Crop Diseases

Sunflower rust

Rust of sunflower, caused by *Puccinia helianthi*, has been increasing in prevalence and severity within the last decade and, until recently, few labeled fungicides were available for use by the sunflower growers. Because of the development of several new fungicides for managing this disease and the uncertainty for optimal timing for application, on-going studies are being conducted to determine the best time for making applications, and the most effective products for disease management.

To date we have determined that the particular fungicide utilized is not as important as the proper timing of application, although the two strobilurin fungicides, (Quadris and Headline), and the combination product, Priaxor, all produced significantly higher yields compared to the untreated control and two other fungicide treatments (Folicur and Vertisan). The lowest disease severity ratings occurred with any treatment that involved applications at the R5 growth stage, and were additionally significantly better than any application at any other growth stage. Although yield results were not always statistically improved at all sites and years, consistent trends have been seen that indicates this growth stage is the best time for making applications.

Data gathered from more than 5 years of studies have consistently shown that fungicide applications will provide better protection for reducing disease incidence and severity if made in the R4-R6 growth stages. A late season disease rating performed after harvest in 2011 furthermore indicated that the fungicide continued to protect later in the season, compared with the untreated controls. It also suggested that spray applications can help reduce pathogen build-up. This process would also theoretically reduce pathogen inoculum potential, even if yields in the current year may have been unaffected. This is an important point to remember as we know that the pathogen overwinters in Nebraska, making the reduction of inoculum in one year a potentially beneficial technique for managing the disease in subsequent seasons.

Resources

Abendroth, L.J., Elmore, R.W., Boyer, M. J., and Marlay, S. K. 2011. Corn Growth and Development. PMR 1009. Iowa State University Extension, Ames, Iowa.

What's New in Plant Pathology

Anthony O. Adesemoye, Extension Plant Pathologist
Loren Giesler, Extension Plant Pathologist
Robert M. Harveson, Extension Plant Pathologist
Tamra A. Jackson-Ziems, Extension Plant Pathologist
Kevin Korus, Extension Educator
Stephen N. Wegulo, Extension Plant Pathologist

Changes to the Disease Management section of the 2016 Guide for Weed, Disease, and Insect Management in Nebraska

During the past year, several new products have become available for disease management. These products and additional changes have been added or made to the Plant Disease Management Section of the 2016 Guide for Weed, Disease, and Insect Management in Nebraska. Products added to the Weed Guide have been summarized in Tables 1 and 2. Additional updates have also been made to the Plant Disease Management Section. For example, you will now find a table listing Biological Products for Crop Disease Management. In addition, last year we began and have continued to sort and list fungicide products in both the efficacy tables and the product tables by their mode of action. This change was made to raise awareness about product active ingredients and their classes/modes of action. This change will make it easier to compare and select products when rotating modes of action and reduce the selection pressure on pathogens that could potentially lead to fungicide resistance. Be sure to note that products with "Mixed Modes of Action" are listed at the end of each table.

Biological control Products

This year, a new table (page 251) titled 'Biological Products for Crop Disease Management' was added to the Guide for Weed, Disease, and Insect Management in Nebraska. This contains many products that are based on biology and summary information on such products is provided on that page.

Trivapro^{Tm} Fungicide

In 2015 Syngenta registered a new fungicide called Trivapro^{Tm} for use on wheat, corn, and soybean. This product combines three modes of action that include Solatenol, a succinate dehydrogenase inhibitor (SDHI), azoxystrobin and propiconazole. According to the manufacturer, Trivapro will provide broad-spectrum control of many diseases including common rust, Southern rust and gray leaf spot in corn; septoria leaf and glume blotch, leaf rust, stripe rust and stem rust in wheat; and anthracnose, alternaria leaf spot, brown spot, cercospora blight and leaf spot, frogeye leaf spot, pod and stem blight, powdery mildew and rust in soybean.

Priaxor D Fungicide

This fungicide by BASF with EPA registration number 7969-361 became available in the 2015 season for better management of pathogens that may be resistant to fungicides, such as frogeye leaf spot in soybean where it is recommended for application at R3 stage. In addition to fluxapyroxad and pyraclostrobin which are active ingredients in Priaxor, this new product also contains tetraconazole, a sterol biosynthesis inhibitor. The product can be used with soybean, corn and small grains.

Table 1. Foliar products for disease control that were updated in the 2016 Guide for Weed, in Nebraska.

Trade Name	Active Ingredient(s)	Fungicide Class	Change(s) Made
Absolute Maxx	tebuconazole (22.63%) + trifloxystrobin (22.63%)	Mixed Modes of Action	Added to the Corn table
Fortix	fluoxastrobin (14.8%) + flutriafol (19.3%)	Mixed Modes of Action	Added to Wheat table
Propulse	fluopyram (17.4%) + prothioconazole (17.4%)	Mixed Modes of Action	Added to Dry bean and Sugarbeet tables
Prosaro	prothioconazole (19.0%) + tebuconazole (19.0%)	DMI Triazoles Group 3	Added to the Corn table
Quilt	azoxystrobin (7.0%) + propiconazole (11.7%)	Mixed Modes of Action	In Soybean can be applied up to R6 (full seed)
Topguard	flutriafol (11.8%)	DMI Triazoles Group 3	Added to Sorghum and

Table 2. Seed treatment products for disease control that were updated in the 2016 Guide for Weed, Disease, and Insect Management in Nebraska.

Trade Name	Active Ingredient(s)	Fungicide Class	Change(s) Made
Cruiser Maxx Vibrance	thiamethoxam (20.8%) + mefenoxam (3.13%) + fludioxonil (1.04%) + sedaxane (1.04%)	Mixed Modes of Action	Added to Soybean table
ILeVO	fluopyram (48.4%)	SDHI Carboxamides	Added to Soybean table
Inovate Pro	clothianidin (24.03%) + ipconazole (1.203%) + metalaxyl (0.965%)	Mixed Modes of Action	Added to Soybean table
Intego Suite Soybeans	clothianidin (20.0%) + ethaboxam (2.97%) + ipconazole (0.99%) + metalaxyl (0.79%)	Mixed Modes of Action	Added to Soybean table
Mertect 340-F	thiabendazole (42.3%)	MBC Benzimidazoles Group 1	Added to Wheat table
Rancona Crest	ipconazole (0.421%) + metalaxyl (0.562%) + imidacloprid (14.100%)	Mixed Modes of Action	Added to Wheat table
Rancona Pinnacle	ipconazole (0.434%) + metalaxyl (0.579%)	Mixed Modes of Action	Added to Wheat table
Rancona V 100 Pro FS	carboxin (35.52%) + ipconazole (2.22%)	Mixed Modes of Action	Added to Wheat table
Rancona V RTU FS	carboxin (12.58%) + metalaxyl (1.26%) + ipconazole (0.47%)	Mixed Modes of Action	Added to Wheat table

Table 3. Seed treatment nematicide product that was updated in the 2016 Guide for Weed, Disease, and Insect Management in Nebraska.

Trade Name	Active Ingredient(s)	Change(s) Made
Clariva pn	*Pasteuria nishizawae* – Pn1 (15%)	Sugarbeet was added as a labeled Registered Nebraska crop

Specialty Crops Update

Robert M. Harveson, Extension Plant Pathologist Panhandle REC, Scottsbluff

Introduction

This report will summarize some of the major and unusual disease occurrences encountered during 2015 for sugar beets, dry beans, sunflowers, field peas, chickpeas, and fenugreek. Overall, conditions in western Nebraska were similar to those in 2009-2011. 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 to a greater extent than in previous years. Furthermore, the bacterial pathogen, *Pseudomonas syringae* continued to be identified from numerous crops in the region including sugar beets, dry beans, sunflowers, and yellow field peas.

Sugar Beets

Root rots

Root rot diseases in 2015 were generally not as severe as recent years. However, due to the higher rainfall levels, Aphanomyces root rot was observed in greater numbers than over the last 4-5 years. The dry rot canker variant of Rhizoctonia root rot was not identified in 2015, however it has been found occurring widely across Scotts Bluff and Morrill counties in three of the last five years. This is a rarely occurring root rot that is atypical of the well-known Rhizoctonia root rot disease. It causes different symptoms from the Rhizoctonia root rot disease. Little is known about the pathogen due to its seldom-seen status. We have conducted some preliminary studies that have proven that this is a different species of *Rhizoctonia* (known as bi-nucleate) than the "typical" pathogen, *R. solani*, and thus confirming its identity as a distinct root pathogen causing a different disease than the more familiar Rhizoctonia root and crown rot.

Nematodes

Cyst nematodes continue to appear in fields scattered throughout the area, but were not overall damaging in 2014. We also continued investigations focused on managing this pest with the use of a novel biocontrol organism (bacterium) applied as a seed treatment.

Foliar Diseases

The occurance of 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 from several rain events. The most severe damage is generally observed with this disease when night temperatures (midnight to 7 AM) exceed 70 F. However, high humidity or long periods of leaf wetness are also required.

Bacterial leaf spot, caused by the florescent bacterium *Pseudomonas syringae*, was found early and often throughout the region. This epidemic is due to the cool, wet weather, which favors this pathogen and disease. It is fortunate that this problem rarely affects economic yields, but can still appear problematic, causing concern to those unaware of the disease. As temperatures warm, the pathogen is often restricted to lower leaves and the plant essentially "grows out" of the problem.

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 all detected). The cooler weather further resulted in widespread white mold epidemics. Rust showed late in some areas but did not affect yields, as often is the case.

Sunflowers

The primary disease problems in sunflowers in 2014 were due to rust and Phomopsis stem rot. This again was due to the cooler wet weather. These conditions also allowed Sclerotinia (white mold) to cause some issues as both a vascular wilt and stem rot, and a head rot. 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 damage.

A bacterial leaf spot, caused by *Pseudomonas syringae* was also encountered frequently, due to the cool and wet weather. The rust disease was back and present throughout the region, as was Phomopsis. This is a relatively new disease to this area, and can cause very severe damage by inducing lodging of affected plants. We continued to conduct fungicide application studies on both rust and

Phomopsis stalk rot and were able to successfully produce levels of disease.

Another presumed virus-like pathogen of unknown identity was discovered from Scotts Bluff 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 this year, as a result of the weather. Some moderate levels of disease were observed late in the season but they did not affect yields due to the onset of disease toward the end of the season. The conditions required for this disease are similar to that of CLS for sugar beet – warm, but not hot with high humidity. We continue 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.

Other Crops (Field Peas and 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 in 2015 in increasingly high levels compared to previous seasons. They included those caused by *Fusarium* and *Rhizoctonia*. Few other serious potential disease issues have been noted as yet.

A continued large increase in yellow field peas was seen across the region in 2015. A bacterial complex was observed statewide after 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.

Corn Disease Update

Tamra A. Jackson-Ziems, Extension Plant Pathologist

Introduction

The 2015 corn crop was impacted by several corn diseases from the beginning to the end of the season and in all areas of Nebraska. The increased severity and incidence of some diseases was largely due to the extended periods of favorable weather conditions in varying parts of the state that supported the increase in some diseases. In particular, frequent rainfall and high relative humidity were especially favorable for several fungal diseases. Unfortunately, almost all diseases of corn (except rusts) are caused by pathogens that can successfully overwinter in Nebraska. For this reason, making detailed notes on disease development and history for every field will help you both anticipate which diseases will be problematic in the future and better manage them.

Northern Corn Leaf Blight

Northern corn leaf blight (NCLB) was confirmed as early as in V6 corn in mid-June in several fields in Iowa and in eastern Nebraska. Cool to moderate temperatures and moisture favors infection by the fungus causing this disease, *Exserohilum turcicum*. Weather conditions, including cloudy days, moderate temperatures (64-81°F), high humidity and frequent rainfall especially favored further infection and spread of this fungal pathogen that survives well in infected corn residue from recent years. Like most other diseases caused by pathogens that are in the residue, lesions may develop on the lower leaves first and continue to develop on leaves higher up the plant as long as weather conditions are favorable. NCLB lesions can grow to be larger than those of other diseases and are usually cigar-shaped with rounded ends that might be confused with Goss's bacterial blight lesions because of their size. Although, a large amount of microscopic fungal spores may be produced on NCLB lesions making them appear darker and/or dusty in the centers.

Management

Development and spread of NCLB prior to tassel emergence could substantially reduce corn yield later, particularly as lesions develop and expand, killing photosynthetic leaf area that is necessary for grain fill later. It is most important to protect the ear leaf and those above it which contribute approximately 80% of grain fill. In some earlier planted fields, the disease reached leaves 8-9 by the end of June. Early development of NCLB might need a foliar fungicide application to slow disease spread in susceptible hybrids and protect uninfected leaf tissue. Lesions develop in about one to two weeks after infection occurs. Thus, it is possible that many additional leaves are also infected and will develop more lesions in the days following favorable weather. To determine if a fungicide application is economical for you, consider the price of corn, hybrid susceptibility, yield potential, cost of treatment, and disease severity. Efficacy ratings have been assigned to some commercially available fungicides for their disease control by the multi-state Corn Disease Working Group and included in the Disease Management section of the 2016 Guide for Weed, Disease, and Insect Management in Nebraska.

There are no fungicide treatment thresholds for NCLB (or most other diseases). However, you can assess your risk for developing yield-limiting disease severity by considering the high risk factors listed below. Having more of these high risk factors will increase the likelihood of developing severe or yield-limiting NCLB, as well as getting a return on the cost of a fungicide application:

- Poor hybrid disease rating(s) for NCLB (consult seed catalog or company representatives for ratings)
- Early disease development, especially during pre-tassel growth stages
- Continuous corn
- History of severe NCLB
- Substantial corn residue or no-/minimum tillage
- Weather forecast for humid/wet weather and moderate temperatures

Scout fields early and frequently to monitor for development of NCLB and other diseases in areas where it has been a problem. Considering the NCLB rating provided by your seed company for your hybrid(s) will help you to anticipate whether the disease may become severe or not. In fields previously affected by NCLB, it is important to consider this disease in the future when making hybrid selections and other management decisions, especially crop rotation, tillage, etc. that can be helpful to reduce disease severity in subsequent years.

Gray Leaf Spot

Gray leaf spot (GLS) quickly became the most important leaf disease in corn across much of the state as it increased rapidly mid-season during favorable weather conditions. GLS is also caused by a fungus (*Cercospora zeae-maydis*) that survives in infected plant debris from the previous seasons. It consistently begins on the lower leaves and continues to move higher on the plant as long as weather conditions are 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%). GLS 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 GLS, after tasseling when the disease tends to increase in severity more quickly. And, the same high risk factors for NCLB, also apply to GLS development.

GLS 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.

Stalk Rot Diseases

Much of the 2015 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 2015 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 could be 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. 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 2015 are listed below:

Fusarium stalk rot is especially common during damp conditions, but may occur anywhere, including in irrigated fields this past year. The pathogen, *Fusarium verticillioides*, can sometimes be visible as white to pink fungal growth on the outside of stalks at the nodes. Eventually, the disease may cause discoloration of the inside of stalks to pink or salmon.

Anthracnose stalk rot can also cause a leaf disease and is a common cause of top rot or dieback in corn. In more advanced stages of stalk rot the disease can cause the development of black lesions visible on the outside of the stalk and is caused by the fungus *Colletotrichum graminicola*.

Diplodia stalk rot can cause either/both an ear and stalk rot. The fungus causing Diplodia stalk rot reproduces with microscopic spores inside minute raised black structures (pycnidia) that can give the stalk a rough/sandpaper-like feeling.

Physoderma brown spot most commonly causes a leaf disease, but under some conditions can sometimes cause stalk rot disease. The pathogen causing Physoderma needs a lot of moisture and is more common this past year following the frequent rainfall events. Infection at the nodes can weaken them and cause stalk lodging or breakage.

Charcoal rot is one of a few diseases that are more common during drought conditions, and so, is more likely to affect corn in non-irrigated fields or pivot corners. The disease is characterized by the presence of many minute black round structures inside the stalk that can give it a gray to black appearance, like charcoal dust. In addition, the fungus that causes charcoal rot, *Macrophomina phaseolina*, has a wide host range and can cause the same disease in several crops, including soybean, sorghum, and alfalfa.

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.

Other Diseases

Southern Rust

Southern rust was confirmed as early as July in Nebraska. Eventually, southern rust was confirmed in many counties in eastern and southern parts of the state, although its severity was less than expected considering its early development in the state. Warm temperatures and high humidity promote development and spread of the disease and cooler temperatures that developed after its development may have helped to slow its development. Rust diseases produce large amounts of spores that can be easily moved by wind for long distances. The fungus can quickly cause disease during favorable conditions and because most commercial dent corn hybrids have 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. Fields planted later are at highest risk for disease and potentially severe yield impacts because of how early the disease is developing. However, 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.

Goss's Bacterial Wilt and Blight:

Although Goss's Bacterial Wilt and Blight did develop in some areas of the state, overall the severity seemed to be less than that experienced during recent years. The combination of cooler temperatures and increasingly widespread use of resistant hybrids and other management strategies are likely the reason for the apparent reduction of the disease. It's important to remain diligent about selection of resistant hybrids, though, in areas where Goss's wilt has been a problem in the past because the pathogen is likely still viable in infected residue and can develop rapidly on susceptible hybrids, especially popcorn or after hail or wind damage.

For More Information

Nebraska Extension publications:

- Corn Disease Profile I: Foliar Diseases (EC 1867)
- Corn Disease Profile II: Stalk Rot Diseases (EC 1868)
- Common Stalk Rot Diseases of Corn (EC 1898)
- Corn Disease Profile III: Ear Rot Diseases and Grain Molds (EC 1901)
- Disease Profiles: Nematodes of Nebraska Field Crops (EC 1908)
- Rust Diseases of Corn (G1680)
- Gray Leaf Spot of Corn (1902)

Diagnostic videos on the Crop Watch YouTube Channel

- Corn Diseases: Identifying Rust
- Corn Diseases: Gray Leaf Spot
- Corn Diseases: Goss's Bacterial Wilt and Blight
- Corn Diseases: Aspergillus Ear Rot
- Corn Diseases: Nematodes
- Corn Diseases: Hail Damaged Corn
- Corn Diseases: Northern Corn Leaf Blight
- Corn Diseases: Crazy Top
- Corn Diseases: Corn Smut

Wheat Disease Update

Stephen Wegulo, Extension Plant Pathologist

Introduction

Prolonged cool and wet conditions during the growing season in 2015 favored the development of leaf and head diseases of wheat. The most widespread and severe diseases were stripe rust and Fusarium head blight, also known as scab.

Other diseases observed in 2015 were Septoria tritici blotch, tan spot, and bacterial streak and black chaff. Most of these diseases, however, were masked by the early onset and high severity of stripe rust. Some growers reported seeing ergot in their wheat. In the southern Panhandle, isolated fields had severe wheat streak mosaic.

Rainfall or irrigation during grain maturation favored growth of saprophytic fungi on wheat heads in some fields. These fungi caused sooty mold on the heads and invaded the maturing grain causing black point, a disease characterized by discoloration of the embryo end of the wheat kernel. Black point and other grain diseases such as scab lower grain quality and reduce germination.

Due to the widespread occurrence of stripe rust and Fusarium head blight, ratings were taken in state variety trials in Chase, Cheyenne, Furnas, Hitchcock, Keith, Lancaster, Saunders, and Saline Counties. These ratings on a scale of 1 (resistant) to 9 (susceptible) are shown in Tables 1 to 5. Because these two diseases predominated in 2015, the rest of this article summarizes their biology, epidemiology, and management.

Stripe Rust

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 stripe rust in Nebraska occurred in 2010, 2012, and 2015. 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). Rapid desiccation of the entire plant can occur due to utilization of water and nutrients by the stripe rust pathogen. Later in the growing season, dark brown to black telia (fruiting bodies that produce overwintering spores known as teliospores) develop under the epidermis and form streaks on the leaves and leaf sheaths.

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. It is favored by low temperatures and moisture. Optimal conditions for infection are temperatures between 45 and 54ºF and eight hours of free moisture on the leaf surface. Optimal conditions for disease development are a temperature range of 50-59ºF and intermittent rain or dew. Under optimal conditions for disease development, 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.

Yield losses of up to 40% or more due to stripe rust have been reported in susceptible wheat cultivars. Stripe rust can be managed by planting resistant cultivars and fungicide application timed to protect the flag leaf. Cultural practices such as controlling volunteer wheat and avoiding excessive fertilization and irrigation can help to reduce losses.

Fusarium Head Blight

Fusarium head blight (FHB), also known as scab, is caused by the fungus *Fusarium graminearum* (sexual stage: *Gibberella zeae*). *F. graminearum* also causes stalk and ear rots in corn. 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. In Nebraska, recent major epidemics occurred in 2007, 2008, and 2015.

On immature wheat heads, one or more spikelets or the entire head appears prematurely whitened or bleached. Bleached spikelets are sterile or contain kernels that are shriveled and/or appear chalky white or pink. These kernels are often referred to as *Fusarium*-damaged or scabby kernels. They contain a mycotoxin, deoxynivalenol or DON, commonly known as vomitoxin.

F. graminearum overwinters as chlamydospores (resting spores) or mycelia in the soil or in host crop residues. Primary inoculum mainly consists of ascospores produced in perithecia (sexual fruiting structures), which form on crop residues in the spring. Ascospores are released from crop residues and spread by wind and/or splashing water from rain or irrigation. They land on heads and during wet, warm weather they germinate and infect glumes, flower parts, or other parts of the head. Infections occur mostly during flowering.

Most of the commercially grown wheat cultivars are susceptible. A few are moderately resistant and should be considered when choosing cultivars. Fungicide application timed at early flowering to six days later can significantly reduce FHB and DON. Currently the most effective fungicides are Prosaro and Caramba. Both are in the triazole class. Strobilurin fungicides should not be used to control FHB as they have been shown to increase DON. Cultural management tactics include 1) crop rotation with non-host crops such as broad-leaved legumes (e.g. soybean)

– avoid planting wheat after corn or wheat or sorghum, and 2) irrigation management.

Table 1. Stripe rust ratings in state wheat variety trials in southeast Nebraska in 2015.
Rating Scale: 1 = resistant; 9 = susceptible

Entry	Lancaster County	Saline County	Saunders County	Avg
Camelot	9	7	8	8
Everest	8	9	8	8
Freeman	2	4	3	3
KanMark	3	5	4	4
LCH10-13	9	8	9	9
LCH11-1117	4	1	2	2
LCH13NEDH-3-31	5	8	7	7
LCH13NEDH-5-59	7	7	7	7
LCS Mint	4	2	4	3
Mattern	2	2	2	2
McGill	8	9	9	9
NE09517	2	1	3	2
NE09521	5	6	6	6
NE10478	7	6	5	6
NE10507	7	9	8	8
NE10589	2	2	2	2
NE10683	8	9	9	9
NI10718W	7	8	8	8
NW07505 (W)	9	9	9	9
NX04Y2107W	2	2	2	2
NX11MD2337	7	7	8	7
"1863"	2	1	2	1
Overland	7	6	6	6
SY Southwind	1	1	1	1
SY Wolf	2	1	1	1
Scout 66	6	7	8	7
T158	4	1	2	2
Turkey	9	8	9	8
WB-Cedar	2	3	2	2
WB-Redhawk	9	8	8	8
Wesley	6	7	7	7

Table 2. Stripe rust ratings in state wheat variety trials in west central Nebraska in 2015.
Rating Scale: 1 = resistant; 9 = susceptible

Entry	Furnas County	Hitchcock County	Keith County	Avg
"1863"	2	1	1	1
Antero	3	4	2	3
Bearpaw	9	7	8	8
Brawl CL Plus	8	9	8	8
Byrd	9	9	8	9
CO11D174	9	7	8	8
Denali	8	7	9	8
Freeman	3	3	2	3
Hatcher	8	4	4	5
Infinity CL	7	8	5	7
Judee	2	2	3	2
Kanmark	5	8	8	7
LCH10-13	9	8	5	7
LCH13NEDH-3-31	9	8	8	8
LCH13NEDH-5-59	9	8	8	8
LCI13NEDH-14-53W	8	7	6	7
Mace	9	9	9	9
Mattern	3	3	2	3
McGill	9	9	7	8
Mint	6	3	3	4
N11MD2130W	6	5	4	5
N11MD2166W	4	2	5	4
NE09517	2	2	2	2
NE09521	4	5	3	4
NE10478	7	8	3	6
NE10507	8	8	9	8
NE10589	3	3	2	3
NE10683	9	8	9	9
NI10718W	8	8	8	8
NW03666 (W)	9	7	8	8
NW07505 (W)	9	8	8	8
NX04Y2107W	4	2	4	3
NX11MD2337	9	7	7	8
Overland	9	5	6	7
Robidoux	2	5	8	5
Scout 66	9	6	6	7
Settler CL	7	8	8	8
SY 06BC722#25	2	2	3	2
SY 06BC796#68	3	2	2	2
SY Monument	1	1	5	2
SY Wolf	2	3	2	2
Turkey	9	6	8	8
Warhorse	1	1	2	1
WB Grainfield	2	1	2	2
WB Winterhawk	8	7	6	7
WB4458	4	3	2	3
Wesley	9	8	8	8
Wizard	7	8	7	7
T158	2	3		3

Table 3. Stripe rust ratings in state wheat variety trials in Chase and Cheyenne Counties, Nebraska in 2015.
Rating Scale: 1 = resistant; 9 = susceptible

Entry, Chase County	Rating	Entry, Cheyenne County	Rating
"1863"	2	Alliance	9
Antero	3	Antero	2
Anton	7	Bearpaw	9
Bearpaw	9	Brawl CL Plus	8
Brawl CL Plus	8	Buckskin	8
Byrd	9	Byrd	9
Cowboy	9	Camelot	8
Denali	9	CO11D174	7
Judee	1	Cowboy	8
Kanmark	8	Denali	8
LCH10-13	9	Freeman	3
LCH13NEDH-3-31	9	Goodstreak	9
LCH13NEDH-5-59	9	Hatcher	7
LCI13NEDH-14-53W	9	Ideal	7
Mattern	3	Infinity CL	7
Mint	3	Judee	2
N11MD2130W	6	Kanmark	3
NE07531	9	LCH10-13	8
NE09517	1	LCH13NEDH-3-31	6
NE09521	7	LCH13NEDH-5-59	6
NE10478	8	LCI13NEDH-14-53W	4
NE10507	8	Mace	9
NE10589	2	Mattern	3
NE10683	9	Mint	4
NI06736	9	N11MD2166W	2
NI10718W	8	NE05548 (Panhandle)	8
NI12713W	3	NE09517	2
NI13717	9	NE09521	7
NI14732	9	NE10478	8
NI14733	8	NE10507	9
NW03666 (W)	9	NE10589	4
NW07505 (W)	9	NE10683	9
NX04Y2107W	3	NI10718W	7
NX11MD2337	8	NW03666 (W)	9
Oakley CL	1	NW07505 (W)	9
Overland	6	NX04Y2107W	3
Pronghorn	9	NX11MD2337	8
Robidoux	5	Oakley CL	2
Settler CL	9	Overland	6
SY 06BC722#25	2	Pronghorn	6
SY 0BC796#68	3	Redfield	5
SY Wolf	2	Robidoux	5
T158	2	Scout 66	8
Warhorse	2	Settler CL	9
WB Cedar	7	SY Monument	1
WB Grainfield	1	SY Wolf	2
WB4458	2	T158	4
Wesley	9	Turkey	6
Winterhawk	9	Warhorse	2
Wizard	9	WB Grainfield	2
		WB4059CLP	8
		WB4458	4
		Web-Quake	2
		Wesley	5
		Winterhawk	6
		Wizard	8

Table 4. Fusarium head blight ratings in state wheat variety trials in southeast Nebraska in 2015.
Rating Scale: 1 = resistant; 9 = susceptible

Entry	Lancaster County	Saline County	Saunders County	Avg
Camelot	7	8	8	8
Everest	5	5	5	5
Freeman	7	6	7	7
KanMark	9	9	9	9
LCh20-13	7	7	6	7
LCh21-1117	9	7	8	8
LCh23NEDH-3-31	8	8	8	8
LCh23NEDH-5-59	5	5	6	5
LCS Mint	9	7	9	8
Mattern	8	9	9	9
McGill	7	8	8	8
NE09517	8	8	8	8
NE09521	8	7	7	7
NE10478	8	8	8	8
NE10507	9	8	8	8
NE10589	7	8	7	8
NE10683	8	9	8	8
NI10718W	7	7	6	6
NW07505 (W)	8	8	9	8
NX04Y2107W	8	9	9	8
NX11MD2337	6	6	6	6
"1863	8	8	8	8
Overland	4	5	5	5
SY Southwind	8	6	7	7
SY Wolf	9	6	6	7
Scout 66	8	8	8	8
T158	9	8	9	9
Turkey	5	6	5	5
WB-Cedar	9	9	9	9
WB-Redhawk	9	9	9	9
Wesley	8	7	8	7

Table 5. Fusarium head blight ratings in a state wheat variety trials in Hitchcock County, Nebraska in 2015.
Rating Scale: 1 = resistant; 9 = susceptible

Entry	Rating
"1863"	9
Antero	7
Bearpaw	5
Brawl CL Plus	9
Byrd	8
CO11D174	8
Denali	6
Freeman	6
Hatcher	7
Infinity CL	7
Judee	4
Kanmark	9
LCH10-13	7
LCH13NEDH-3-31	8
LCH13NEDH-5-59	5
LCI13NEDH-14-53W	6
Mace	9
Mattern	8
McGill	8
Mint	8
N11MD2130W	8
N11MD2166W	7
NE09517	7
NE09521	8
NE10478	8
NE10507	8
NE10589	5
NE10683	9
NI10718W	7
NW03666 (W)	7
NW07505 (W)	8
NX04Y2107W	8
NX11MD2337	7
Overland	4
Robidoux	9
Scout 66	8
Settler CL	8
SY 06BC722#25	8
SY 06BC796#68	6
SY Monument	9
SY Wolf	6
T158	9
Turkey	4
Warhorse	4
WB Grainfield	8
WB Winterhawk	8
WB4458	9
Wesley	8
Wizard	6

Soybean Disease Update

Loren J. Giesler, Extension Plant Pathologist

Introduction

Although the 2015 production season was good for soybean production and many growers had great yields, we did have our share of soybean disease issues. 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 and Brown Stem Rot were also present in several fields. Stormy conditions resulted in frog eye leaf spot being present in many fields as well. This article will help to identify, differentiate and manage these diseases that occurred in 2015. Additional information on disease identification can be found at the UNL Crop Watch Web Site. At the time of this write up we do not have all yield data summarized from management trials that will be presented as appropriate for specific diseases.

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 2015, Pythium damping off was the most common seedling disease problem due to cooler soil temperatures.

Pythium Damping-off and Root Rot (*Pythium* spp.). Seed and seedling diseases caused by *Pythium* develop early in the season under cool soil temperatures (50 to 60 °F) and wet soil conditions.

More information on seed treatment fungicides and management of these seedling diseases can be found in NebGuide G-1852: “Seed Treatment Fungicides of Soybeans”.

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*)

Phytophthora root and stem rot of soybean, is caused by, a soil borne fungus-like water mold 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 60 °F 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 *Phytophthora 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, 3,6,7. 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.

Brown Stem Rot (*Phialophora gregata*)

The fungus survives in plant residue on which spores are produced from precolonized woody stem tissue. Infected plant residue is thought to be the main source of spread for the fungus. Infections occur through the roots and lower stem early in the season and the mycelium grows upward in the water-conducting xylem vessels. Water and nutrient flow is thus inhibited because the mycelium plugs the xylem vessels. Soybean cyst nematode will increase the risk of brown stem rot damage.

Symptoms

Symptoms of brown stem rot typically do not occur until mid- to late-reproductive stages (R5). Infected plants may not show visible symptoms other than premature death which may be confused with early maturity or dry weather. Brown stem rot can produce both foliar and/or stem symptoms. Split stems of infected plants reveal internal browning of the pith and vascular tissue. Pith discoloration starts at the base of the stem and moves upward to the nodes and progresses into the internodal tissues during the growing season. Later in the season, infected plants may wilt and show external browning on the lower part of the stem. Severely diseased plants may lodge. Leaf symptoms may resemble high temperature "scorch" or drought stress. Leaves on infected plants may develop interveinal chlorotic (yellowish) blotches. Tissue between the veins dies and turns brown, whereas tissue adjacent to veins remains green and is the last to die. This foliar symptom can be confused with sudden death syndrome. Eventually all leaves will curl and die and will remain attached to the leaf stem (petiole). Foliar symptoms will not develop if air temperatures are high (above 85 °F) during the R3-R4 growth stages. Field distribution will typically be patches or packets of plants being affected.

Favorable Environmental Conditions

Cool weather during soybean reproductive stages favors foliar symptom development; irrigation after flowering increase leaf symptoms. Disease development is greatest between 60 ° and 75 °F and is suppressed at temperatures above 80 °F. Wet soils also favor disease development earlier in the growing season and moisture stress later in the season increases disease severity.

Management of Brown Stem Rot

Resistance. Plant resistant varieties whenever soybeans are planted in infested fields. However, the genetic source of brown stem rot resistance is limited. It is not recommended that growers rely only on resistant varieties, but use a combination of management practices to reduce the incidence and severity of this disease. Rotate soybean varieties to preserve the effectiveness of resistance genes.

Rotation. A minimum of two years between soybean crops in fields with a history of brown stem rot will effectively reduce pathogen populations and the risk of brown stem rot. Corn, small grains and forage legumes are all good rotation crop choices. Soybean is the only host for the brown stem rot pathogen. Because the brown stem rot fungus survives mainly on crop residue left on the soil surface, decomposition of the residue is believed to be an important factor in managing this pathogen.

In no-till systems, longer crop rotations and shredding soybean straw may be needed to reduce pathogen populations.

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. In 2015 we did not see as much SDS develop as we did in 2014. 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 symptom 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 the 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. Avoid early planting as it favors SDS infection with cool soil temperatures.

Fungicide application. In 2015 ILeVo© was launched by Bayer Crop Science. This is the first seed treatment that has shown to be effective against SDS. Profitability for this product is still under evaluation.

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. 2015 was the third year in a row that white mold has shown up due to cool conditions during flowering. 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).

Frogeye Leaf Spot (*Cercospora sojina*)

Frogeye leaf spot is a fungal disease that is becoming more common in Nebraska. In 2015, this disease was present 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 are considered the most effective. In 2010, resistance to strobilurin fungicide 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. 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.

Biological Products for Disease Management in Field Crops

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Introduction

Growers' interest to reduce dependence on chemical inputs, the demand for information by growers and what is happening in the market has brought about this section on biological products. Development of resistance to many fungicides, consumers' interest in foods that are free from pesticide residue, and the need for alternative products that can help ensure better and sustainable use of soil resources has been driving the evolution and development of the biological sector in the agriculture industry. Many products based on biology are there in the market currently for the management of crop diseases.

In the biological market, different languages are used including biofungicides, biofertilizers, bioinsecticides, yield bioenhancers, bioherbicide, biorational technology, etc. These words or phrases may be confusing to some growers and the questions from many are – what are these different terms? What is a biological or what is the meaning of biorational technology? Let us look at some of the terms.

Biologicals/biorationals are products derived from naturally occurring microorganisms, plant extracts and other organic materials. These products can be in the form of biopesticides or biostimulants. Biopesticides (or protectors) are those products that protect against or are used to directly control biotic stresses like pathogens, insect pests and weeds and these are described as biofungicides, biobactericides, bioinsecticides, and bioherbicides, respectively.

In this section we will focus more on biological products that are used in crop disease management, most of which are described as biofungicides. Some of the modes of action of biofungicides are (1) to induce systemic resistance in the plants, (2) to compete and reduce toxin contamination produced by pathogens, (3) to eliminate pathogens or (4) to obstruct the growth or reproductive cycles of pathogens.

Biostimulants (or enhancers) are defined as materials that "enhance the plant's nutrient use efficiency, or provide other direct or indirect benefits to plant development or stress response" and they include plant growth regulators, adjuvants, and inoculants. Biostimulants are not nutrients in themselves but they help stimulate a plant's natural physiological processes such as in enhanced nutrient use efficiency. They are applied as a pre-plant seed treatment, in-furrow or as a foliar spray application.

A Component of Integrated Input and Pest Management Systems

It is important to emphasize that biologicals do not replace conventional chemistry; rather the interest is for them to be compatible with chemical products that growers are already using. The hope is that the use of biologicals can reduce the need for chemical sprays in an integrated pest and input management (IPIM) system.

The biologicals in the IPIM systems have to be locally adaptable and beneficial to the soil-plant systems in terms of microbial community, overall soil biodiversity, soil structure and health, enhanced nutrient use efficiency, systemic management of biotic and abiotic stresses and induced plant's ability for better physiological potential. The improved system should lead to better crop productivity and confer resiliency and sustainability to the agrosystems in the face of challenges of rapidly changing environmental conditions. The use of biologicals presents these opportunities.

Efficacy and Development of the Biological Sector

In the past, one challenge was the inconsistency of biologicals in different soil conditions, however, efficacy is getting better now with more research. Molecular technology, especially metagenomics, has been evolving and increasing our understanding of the complex interactions that occur in soil-plant systems, especially the root microbiome.

Folks that monitor the Ag industry will notice major investments that have occurred in recent times in the biological/biorational sector, which is an indication of the role that these products will play in crop production going forward. Following many acquisitions, realignments, new ventures and the launch of new product platforms in this sector, it has been projected that the sector will grow to $8 billion by 2020. The investment in research is increasing and no doubt this will improve efficacy. The interests in biology-based technology will continue to expand as it is good for conventional agriculture as well as organic farming.

Residue Harvest Effects on Irrigated, No-Till Corn Yield and Nitrogen Response

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Introduction

Immobilization of applied N is expected when much high C:N crop residue remains in the field as is typical following corn grain harvest. Immobilization of N is expected to be less if crop residue is less. The effect of reduced immobilization on N availability may more than compensate for N removed in residue harvest. Therefore, applied N requirement for a following corn crop may be less if crop residues are reduced through harvest. Residue removal decreased the economically optimal N rate (EONR) by >11 and >17 lb/ac for no-till and strip till, respectively, in southern Minnesota (Sindelar et al., 2013).

Crop residue harvest often affects the yield of the following crop but the direction of the effect depends on production conditions. When soil water deficits are likely to occur, residue removal may cause reduced yield of the following crop (Wilhelm et al., 2004). Residue removal effects on soil temperature, and thereby on rate of crop development, have been well documented (Sindelar et al., 2013). The interactions between tillage practice, N requirement, and residue removal can be important. In Sindelar et al. (2013) crop residue removal resulted in corn yield increases of 6.5 and 9% for tillage and no-till, respectively. Averaged over 10 cropping seasons, irrigated corn grain yields were 7.5 to 8.6% higher for no-till when corn residue was removed compared with no residue removal, while grain yields were similar under tillage in all residue removal treatments (Schmer et al., 2014). In an analysis of 239 site-years across 36 research sites that were primarily in the US Corn Belt, Karlen et al. (2014) found mean corn yields of 156, 161, and 161 bu/ac with no, moderate and high rates of residue removal. This amounted to a 3% average yield increase with corn residue harvest compared with no residue harvest. Corn yield was on average 20% more with no residue removal for tilled compared with no-till management, but there was no tillage effect on grain yield with residue removal.

Therefore, when water is not limiting, crop residue harvest may result in increased yield and less immobilization of applied N. Research was conducted to determine the effect of residue harvest on crop yield and EONR for the following corn crop under irrigated, no-till conditions.

Materials and Methods

Field research was conducted in 2013 and 2014, with continuous irrigated no-till corn from 2012, at two locations of the Agricultural Research and Development Center (ARDC) and one of the Haskell Agricultural Laboratory (HAL). Residue removal rates were 0 and >75%. Sub-plot treatments were six N rates of 0 to 224 lb/ac at ARDC and 0 to 180 lb/ac at HAL.

Observations included canopy reflection at V9-10 for normalized difference red edge (NDRE; NDRE = (780 nm – 730 nm)/(780 nm + 730 nm)) and normalized difference vegetative index (NDVI; NDVI = (780 nm – 670 nm)/(780 nm + 670 nm)) with a hand carried Rapid Scan (Holland Scientific, Lincoln NE). Grain yield and N uptake were determined.

Results and Discussion

More N availability at V9-10 with residue removal compared with no removal was indicated by generally higher NDRE and NDVI. Plant N uptake was 22% and applied N recovery was 43% more with residue removal compared with no removal.

Table 1. Crop residue effects on crop canopy reflectance (NDVI and NDRE), N uptake and applied N recovery.

	NDVI	NDRE	N uptake lb/ac	%N recovery
No removal	0.76	0.31	143	25
Resid. removed	0.82	0.35	177	37

Grain yield averaged 160 bu/ac and was on average 20% more with residue removed (Fig. 1). Yield increases varied by site-year from 2.7 to 71% and were greater following the second compared with the first year of residue removal. Responses included linear and curvilinear responses and the yield peak was often not reached.

The EONR was determined to be 7 to 21 lb/ac, with a mean of 16 lb/ac, less with residue removal compared with no removal.

The results indicate that applied N immobilization was reduced by corn residue removal as N uptake at V9-10 and at physiological maturing were greater with residual removal. The 20% yield increases due to crop residue removal were greater than the average of 3% increase determined from Karlen et al. (2014). The greater effects on yield in this study may be attributed to lack of soil water deficits with irrigation while in many non-irrigated studies, water deficits with residue removal compared to no removal may have caused more yield reduction (Wilhelm et al. 1986; Varvel et al., 2008). The mean reduction in EONR was only 16 lb/ac N and similar to 12 lb/ac mean reduction in EONR with residue removal determined by Sindelar et al. (2013). However, the effect of residual removal on EONR varied greatly by trial and cannot be well predicted pre-plant. To fully capitalize on this potential to reduce N rates likely will require sidedress N application in response to crop canopy color. Higher corn yield with lower N rates associated with residue removal may not be sustainable in the long term due to total soil N decline.

Conclusion

Significant grain yield increase can be expected for irrigated no-till corn following corn by removal of some crop residue. While average applied N recovery and crop N uptake are greater with residue removal and mean EONR is less, there is little justification to adjust the pre-plant N rate due to inadequate predictability of EONR. However, if a significant proportion of N is sidedress applied based on canopy reflectance, mean N application will be reduced by residue removal.

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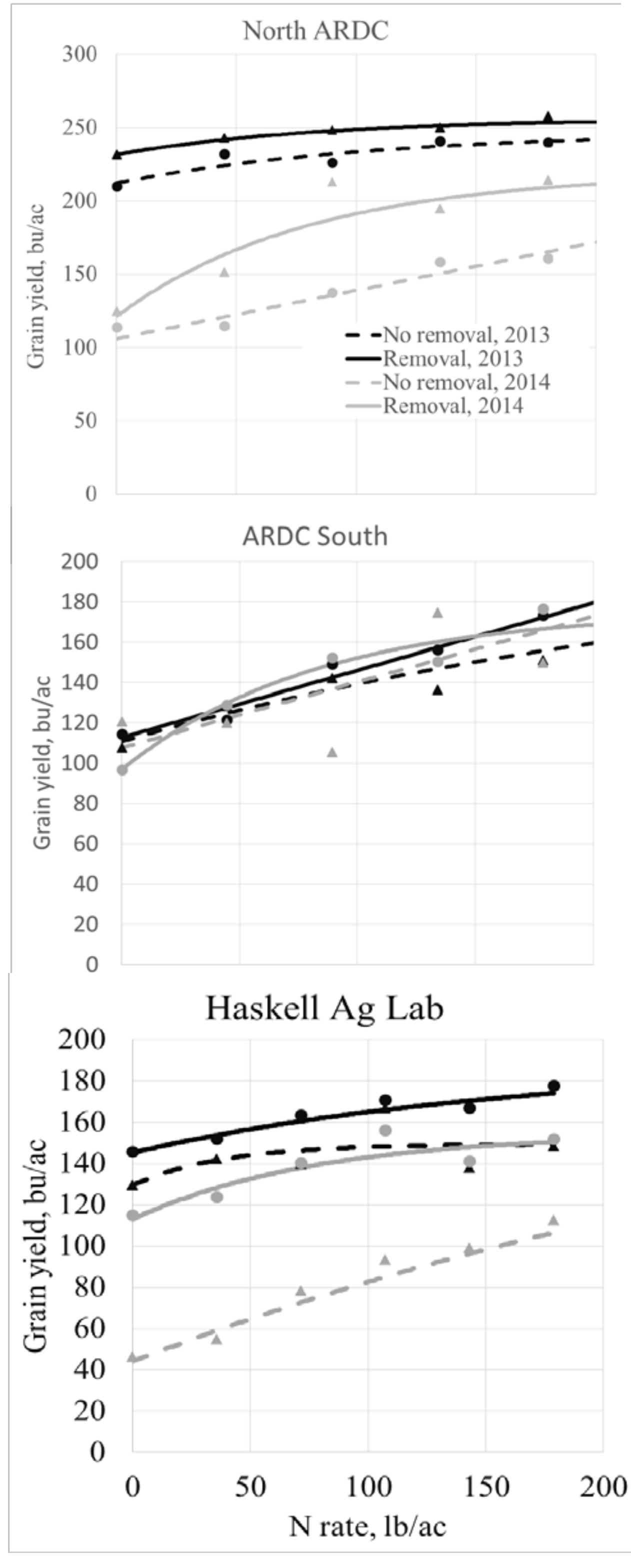
Figure 1. Corn grain yield response to applied N, with and without residue removal.



Where Do Foliar Micronutrient Applications Fit in Corn Production?

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Introduction to Plant Analysis

Plant tissue analysis is a diagnostic technique commonly used to track the nutrient status of plants during the growing season. It is widely used in combination with soil sampling to provide a basis for prescribing lime and fertilizer needs. The two most common objectives of plant tissue analysis are to monitor the nutrient status of crops during the growing season or to verify deficiency symptoms. This analysis helps to determine if soil fertility levels and applied fertilizers are sufficient to meet crop nutritional needs.

Micronutrients are essential to corn growth but are only needed in very small concentrations (*Table 1*). Thus, plant tissue analysis is an excellent tool for assessing the micronutrient status of corn throughout the growing season. This technique has been used for years but recently gained attention because with increasing yields there appears to be temporal shortages of micronutrients during the growing season. Commercially, there are now many micronutrient products available to remedy this problem and ensure quality grain yields.

Table 1. Estimates of micronutrient uptake by crops

Micronutrient	*200 Bu Corn*	*60 Bu Soybean*	*6 Ton Alfalfa*
	lb/acre	*lb/acre*	*lb/acre*
Iron	2.4	1.7	1.8
Manganese	0.4	0.6	0.6
Zinc	0.4	0.2	0.2
Boron	0.2	0.1	0.3
Copper	0.1	0.1	0.06
Molybdenum	0.01	0.01	0.02

Adapted from: *Role of Micronutrients in Efficient Crop Production*, D.B. Mengel, Purdue University AY-239.

The concept of plant analysis is built on Julius von Liebig and Carl Sprengel's "Law of the Minimum" in that plants grow to the limit imposed by the nutrient in least supply. Deficiency of any one of the essential plant nutrients can limit plant growth. Plant tissue analysis makes use of this foundational concept by comparing the elemental concentration of a particular plant part with established critical values or sufficiency ranges of the same plant species. This comparison of the elemental concentration of the sampled plant and established critical values or sufficiency ranges is the basis for accessing the plant's nutrient status (*Table 2*). Generally, a plant sample with a nutrient concentration below the sufficiency range or critical value implies a deficiency of that nutrient indicating that the nutrient is either limiting or unavailable. As illustrated in table 2, there is a range of specific critical levels that is rather broad, indicating that other factors such as growth stage at sampling, genetic, soil, cultural, and environmental factors have an influence on plant nutrient concentrations. These must be taken into consideration when interpreting plant analysis.

Table 2. Published critical micronutrient concentrations and sufficiency ranges in corn (adapted from Escano et al. 1981)

Study	Growth Stage	Mn	Fe	Cu	Zn	B	Mo
		ppm					
1	Plants <12" tall	20-300†	50-250†	5-20†	20-60†	5-25†	0.10-10.00†
1	Prior to tasseling	15-300†	10-200†	3-15†	15-60†	4-25†	0.10-0.30†
1	Initial Silk	20-200†	20-250†	6-20†	25-100†	5-25†	0.10-0.20†
2	Initial Silk	15‡	15‡	5‡	15‡	-	-
3	Initial Silk	34-200†	21-250†	8-20†	50-150†	-	-
4	Initial Silk	20-150†	21-250†	6-20†	20-70†	-	-
5	Initial Silk	-	-	-	15‡	-	-
6	Initial Silk	-	-	-	15‡	-	-
7	Initial Silk	-	-	-	17‡	-	-
Mean Initial Silk§		15‡	15‡	5‡	15‡	-	-
Mean Initial Silk¶		24.7-183†	20.7-250†	6.7-20†	32-106†	5-25†	0.10-0.20†

† Sufficiency Range
‡ Critical Value
§ Average corn nutrient concentration critical value from the above published studies at the initial silk growth stage
¶ Average corn nutrient concentration sufficiency range from the above published studies at the initial silk growth stage

Plant tissue analysis is performed in three basic steps: (1) sampling and sample preparation, (2) laboratory analysis, and (3) interpretation of results to provide a supplementation recommendation. However, the first step involves determining when to sample. This will depend on whether the farmer is trying to catch a deficiency before it is yield-limiting one or if a deficiency has been identified. If the farmer is anticipating problems sampling will occur at an early age. However, when the plant is young there are other factors that might cause an early low reading and a false low reading would be costly since application would not be needed. Additional challenges include having enough representative tissue to sample and having enough leaf area for good contact between the micronutrient spray and the leaves. Most broadcast spray will not be intercepted by small corn plants and will be soil applied. Most of the data in table 2 is for corn at silking. At this stage it might be too late to influence yield.

There are many other factors affecting plant tissue nutrient concentrations such as genetics, disease, insect, and weed pressure, climate (light, temperature, rainfall, humidity), and soil properties (pH, soluble salts, moisture, temperature.) Any one or combination of these factors may reduce the plant tissue concentration even when there is adequate levels of that nutrient in the soil. The plant part sampled is important to a good interpretation of the results. When corn is less than 12in. tall, collect all of the above ground foliage. For corn before tassel, collect 15-20 of the top fully collared leaves at the top of the plant. For corn after tassel, collect 15-20 leaves below and opposite the ear. Sampling of different plant parts will not always correspond with sufficiency values used for interpretation so experience is important

In 2013, we conducted a survey of 45 fields, taking a soil sample and a plant sample at the same time. At most sites, the concentration of the micronutrient in the soil did not correlate with the concentration of the micronutrient in the plant (Figure 1). Graphs a, b, and d show that there is little relationship between the concentration of boron (B), iron (Fe), and zinc (Zn) in the plant and the concentration of the corresponding nutrient in the soil. The concentration of manganese (Mn) in the plant tissue does appear to be a more accurate indicator of the concentration of Mn in the soil as indicated in graph c. In the graphs below, the solid lines indicate critical levels. Since most sites were above the critical level, the supply of the nutrient in question did not limit plant growth. In practical terms, agronomic crops in Nebraska are most commonly constrained from reaching their genetic and environmental potential by the lack of nitrogen and water. However, as crops increasingly achieve sufficient levels of these and other agronomic inputs, micronutrients may become more likely to be the limiting growth factor.

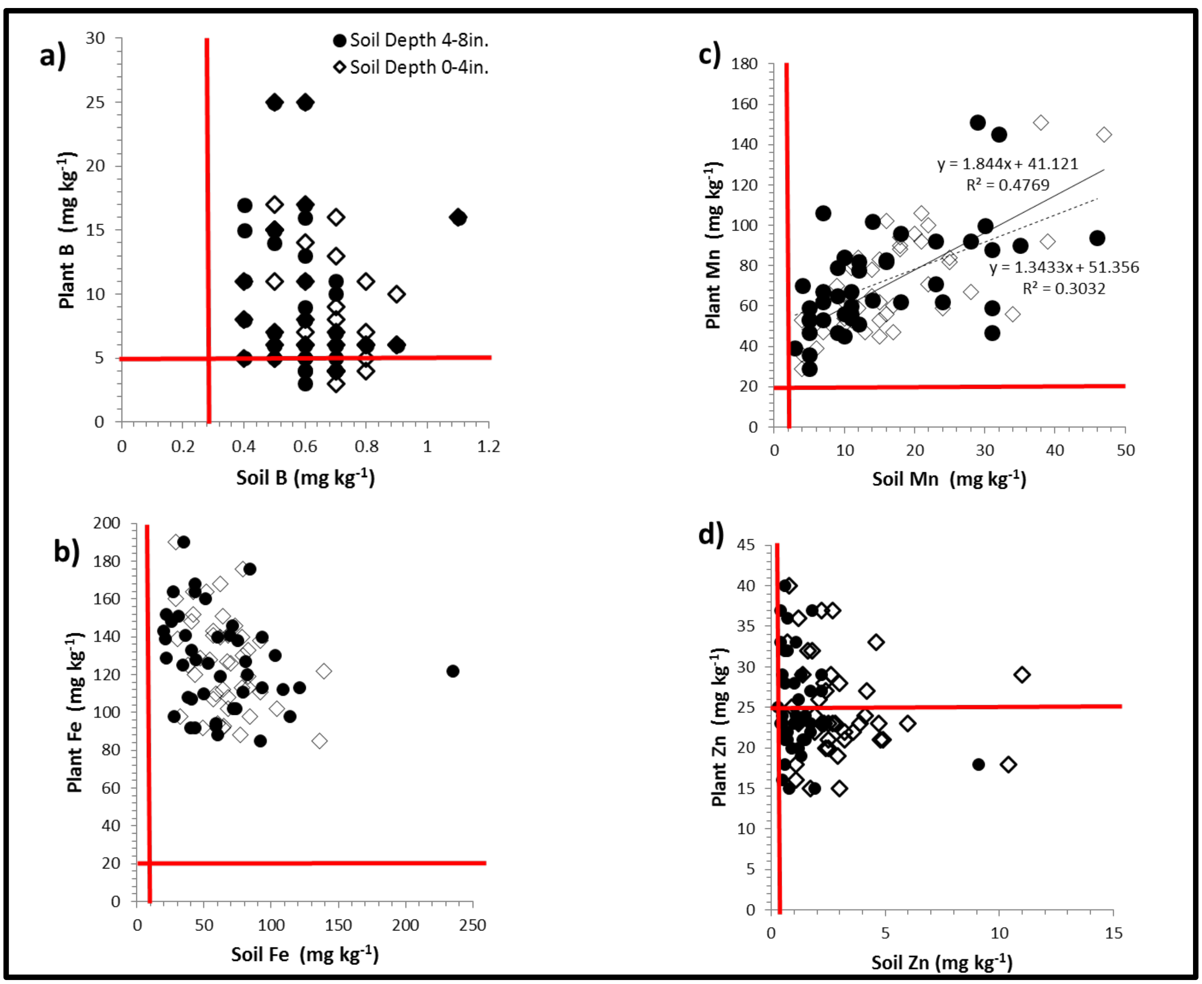

Figure 1 (a-d). Example relationships between soil and corn leaf micronutrient concentrations from 45 locations. Corn critical values are presented as vertical and horizontal lines for leaf samples collected at VT-R5 and soil samples. Soil and leaf samples were collected on the same date. These graphs indicate that B, Fe, Mn and Zn are generally above critical levels in the soil. Zn and occasionally B are below critical levels in plant tissue testing. In most cases, micronutrients concentrations in the soil do not correlate to the micronutrient concentration in the plant tissue.

Introduction to Foliar Micronutrient Supplementation

Micronutrient foliar sprays are widely used in agricultural production and are a complement to soil nutrient amendments. Although plant leaves are specialized in capturing light and CO_2, their ability to regulate absorption of certain nutrients has long been recognized and used in nutrient management. Foliar applied micronutrients have been found to penetrate the leaf surface through the cuticle, cuticular cracks and imperfections, stomata and lenticels (*Figure 2*). This places nutrients at the site of photosynthesis and minimizes disruptions that can occur in movement from the soil to the roots to the leaves. In-depth studies performed in 2014 in Nebraska indicated that approximately 33-50% (depending on the applied nutrient) of the applied foliar micronutrient were taken into the corn leaf. In a second trial, greenhouse results indicate that the foliar applied micronutrients are in large part being taken up through the leaves rather than through the roots. The foliar application of micronutrients to correct or avoid micronutrient deficiencies under conditions where soils provide limited availability is commonly practiced worldwide across agronomic and horticultural crops.

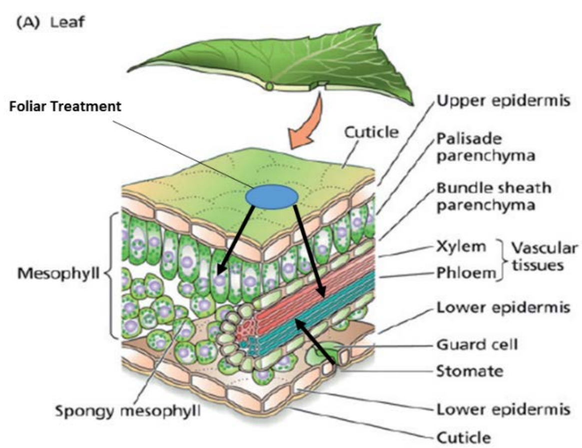

Figure 2. Side view of leaf with a proposed mechanism of foliar micronutrient entry (adapted from Plant Physiology, 4th Edition 2007)

Numerous soil properties can limit nutrient solubility and uptake by plant roots. For example, micronutrients (i.e. Fe, Mn, B, Cu, and Zn) have limited availability in high pH, calcareous soils. Thus, micronutrient foliar sprays are of general interest for use as tools to manage these nutrients and subsequently bypassing soil limitations. Foliar nutrient application is frequently used because plant responses to foliar applied micronutrients are usually more rapid than soil applications and generally have higher recovery rates compared to soil applications.

During the growing seasons of 2013-15, 30 on-farm strip trials and five in-depth studies were performed through a Nebraska Corn Board Grant and in partnership with the Nebraska On-Farm Research Network evaluating the effect of foliar micronutrient (B, Fe, Mn, Zn) application. Trial sites had soil or plant tissue evidence for low micronutrient availability but records of high yield. Though industry parameters reported these sites as deficient to low of the applied micronutrient, very few of the locations had confirmed micronutrient deficiencies. Trial location yields ranged from 140 to 260 bu/ac with most site averaging yields over 200 bu/ac. Though the data is still preliminary and does not include harvest data from 2015, only two sites had significant yield increases. Four study sites had significant yield decreases and the remaining study sites showed no significant yield differences between the control and foliar micronutrient- treated strips. In most scenarios, foliar micronutrients were effective in increasing the concentration of the applied micronutrient in the plant tissue.

See Foliar Micro-Nutrient Studies chapter in the Nebraska On-Farm Research Network 2014 Growing Season Results for more details. http://cropwatch.unl.edu/farmresearch

Where Do Micronutrients Fit in Nebraska?

Nebraska soils are generally fertile and in most cases micronutrient treatments are probably not necessary. However, under limited, prescriptive scenarios, such as low lying, extremely wet, dense soils, foliar micronutrient applications may be beneficial. It should be noted that determining predictable times and locations to apply micronutrients to achieve a profitable yield increase has remained elusive. Without these predictive tools, utilizing foliar micronutrient successfully and consistently will be difficult. As shown in Figure 1, it can be theorized that locations that have both soil and plant tissue samples below critical values may be more likely to see a yield response from micronutrient treatments (this is very rare in Nebraska); whereas locations with plant tissue values below critical values and soil samples at or above critical levels would be less likely to see yield response due to micronutrient applications. In the latter scenario, changes in plant-soil-nutrient interactions may make these soil micronutrients available for plant uptake before micronutrient applications would have any effect such as in the case of Zn and B in Figure 1.

See Micronutrient Management in Nebraska NebGuide G1830 for further information.
http://extensionpublications.unl.edu/assets/html/g1830/build/g1830.htm

Future Research Results

The lead author of this article, Zach Stewart is a Ph.D. candidate at the University of Nebraska and is expected to graduate in the spring of 2016. This article only partially describes the experiments he has conducted on micronutrient management in corn in Nebraska. Though not available at the time of this publication, be on the lookout for articles discussing a survey of micronutrients from approximately 75 locations in and around Nebraska and their relationship with soil, plant, grain, and yield values; an assessment of the effect of foliarly applied B, Fe, Mn, and Zn applied at different rates and timings in corn production and the fate of the applied micronutrients; a combined analysis of three years of foliar micronutrient strip trial yield and plant concentration data; an assessment of the biofortification potential of foliar Zn and Fe on corn; and a greenhouse study comparing the effect of foliarly applied nanoparticle, chelate, and sulfate forms of Zn and Fe.

Cover Crops: What Do We Know?

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Introduction

Maintaining or enhancing benefits that soils provide is a priority for sustaining crop and livestock production, and maintaining overall long-term agricultural productivity. This is particularly important with increased concerns about high production costs, environmental degradation, food insecurity, and increasingly abrupt climatic fluctuations. Integrating cover/forage crops with existing cropping systems is one potential strategy to enhance the beneficial role that soils play in food, fiber, and fuel production, C and other nutrient and water cycling, and soil, water, and air quality improvement.

Cover crops are increasingly associated with qualitative terms such as "soil health" or "soil quality". As these terms are subjective and often nebulous, it is essential to develop a more refined understanding of the impacts of cover crops on basic soil processes and properties and their complex interactions, which are used as indicators for assessing "soil quality" or "soil health". While the use of cover crops is not a new concept, the implications of their re-emerging importance and impacts on soils and crop production deserve further discussion. Many have studied the effects of cover crops on soil and crop production, but few have attempted to discuss or integrate all the potential agricultural benefits that cover crops may provide. A synthesis of existing knowledge based on current published information can be useful for a broader understanding of cover crop impacts on soil ecosystem services and identification of knowledge gaps that deserve further research.

Soil Water Erosion:

Cover crops can reduce losses of sediment and nutrients in runoff by 1) providing protective cover to soil, 2) absorbing raindrop energy, and 3) increasing soil surface roughness to delay runoff initiation, intercept runoff, reduce runoff velocity, and increase opportunity time for water infiltration.

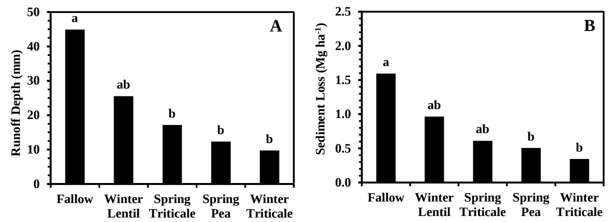

Figure. 1. Effects of winter and spring cover crops on A) runoff and B) sediment loss when cover crops were planted during fallow period in a wheat-fallow system for five years in a semiarid soil in southwestern Kansas.

Soil Wind Erosion

Addition of cover crops to cropping systems may also be an effective management practice to reduce wind erosion. Wind erosion is a major environmental concern in semiarid soils such as those in the Great Plains. Soils are susceptible to wind erosion in late winter and early spring when main crops are absent and winds are high. If winter and spring cover crops are successfully grown during this period in semiarid environments, they can be useful to reduce the risk of wind erosion.

Cover crops are not, however, widely used in semiarid regions because cover crops use water and may reduce plant available water for subsequent crops. Despite the challenges with management, cover crops are still increasingly attractive in water-limited regions to protect soil from wind erosion. Some producers plant cover crops under irrigated conditions to protect soil from erosion after corn stover is baled for livestock to meet forage supply needs. Because baling and removal reduces the amount of stover left to protect the soil surface from erosion, drilling or aerial seeding of cover crops before or after stover baling can provide soil protective cover.

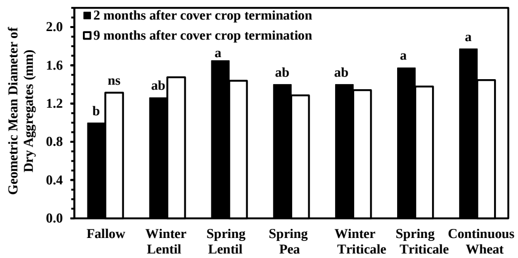

Figure 2. Effects of winter and spring cover on soil dry aggregate stability with time after termination when cover crops were planted during fallow period in a wheat-fallow system in the fifth year in a semiarid soil in southwestern Kansas.

Soil Compaction

Soil compaction is increasingly becoming a concern as farm equipment including tractors, combines, and grain carts have become larger and heavier. Moreover, producers sometimes have to get into fields when the soil is wet and susceptible to compaction to achieve timely weed control and harvest. Problems associated with excessive compaction such as reduced water, heat, and gas flow, reduced nutrient and water uptake, restricted root growth, and thereby reduced crop yields are well documented.

Cover crops can reduce or alleviate soil compaction risks. One of the mechanisms by which cover crops reduce soil compaction includes direct loosening of compact layers through the penetration of deep tap roots, which can act like tillage tools or bio-drills. The extent of this benefit will depend on the cover crop species, length of cover crop time in the field, and amount and characteristics of the below ground biomass input (i.e., length and size of roots). Cover crops with large tap roots including brassicas [radish (*Raphanus sativus* L.), turnip (*Brassica rapa* L.), and others)] have potential benefits for reducing soil compaction.

Another mechanism by which cover crops can reduce soil compaction is by improving soil aggregation, enhancing macroporosity, and increasing soil organic C concentration. For example, accumulation of soil organic C with time under cover crops reduces near-surface soil compactability, which refers to the soil's susceptibility to compaction. On a silt loam in eastern Kansas, the addition of summer cover crops including sunn hemp (*Crotalaria juncea* L.) and late-maturing soybean to no-till winter wheat-grain sorghum reduced near-surface soil compactability by 5% after 15 yr of management. Maximum bulk density, measured using the Proctor test, under summer cover crops was lower in the 0 to 7.5 cm depth than under plots without cover crops. The same study found that the soil critical water content at which maximum compaction occurs was deeper under cover crops, which suggests soils under cover crops may be trafficked at greater soil water contents without causing soil compaction compared with soils without cover crops. In that study, the decrease in Proctor bulk density and increase in critical water content were correlated with soil organic C concentration, indicating that soil compactability decreases as soil organic C concentration increases near the surface layers. Soil organic C has low density and can thus dilute the bulk density of the whole soil, reducing soil compaction risks.

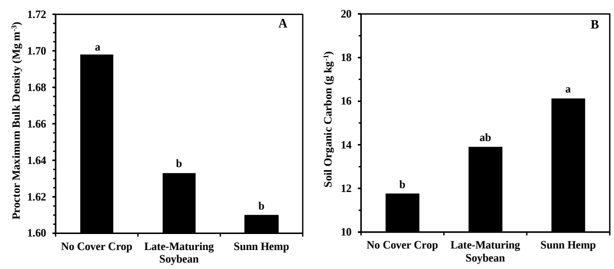

Figure 3. Response of Proctor maximum bulk density (maximum soil compactibility) and soil organic C to the addition of summer cover crops to no-till winter wheat-grain sorghum at 0 kg N ha^{-1} of application for the 0 to 7.5 cm depth after 15 yr in south central Kansas.

Increasing Nutrient Cycling

Including cover crops in intensively managed agroecosystems could affect nutrient recovery, storage, and cycling. Cover crops can scavenge nitrates and other nutrients and convert them to proteins, reducing excess nutrients available for leaching. A global meta-analysis of strategies to control nitrate leaching in irrigated agricultural systems found that inclusion of non-leguminous cover crops may reduce nitrate leaching by about 50% compared with fallow in irrigated cropping systems. Leaching of excess nitrates is a major cause of water pollution and can be particularly relevant in coarse-textured soils. The decreased nitrate leaching with growing cover crops may reduce risks of groundwater pollution. The potential of cover crops for increasing soil fertility can be important in soils with low organic matter content or low fertility. Cover crops when terminated early can supply some of the N needs for the subsequent crops. The beneficial effects of cover crops may be limited in regions with lower precipitation.

Cover crop termination dates can directly affect C and N supply to soil. If cover crops are terminated late or at full maturity, soil N can be immobilized and not readily available for the subsequent crop regardless of cover crop species (legumes and non-legumes). This can result in reduced crop yields if sufficient N is not supplied to the crops. Termination method can also influence soil nutrient availability.

Suppressing Weeds

Cover crops can be a useful means to suppress weeds within agroecosystems. However, there seems to be a great deal of variation in the reported success of using cover crops for weed suppression. This variation is a result of the complexity of agroecosystems. Different weed species in different environments respond differently to cover crops depending on cover crop species planted. Moreover, how and when the cover crop is grown, the method of its termination, and other management practices influence its potential impact on weed populations.

There are two ways that cover crops can influence weed populations. One is through direct competition with growing weed species. This kind of cover crop is generally referred to as a smother crop or living mulch. The second approach uses indirect suppression resulting from physical or chemical suppression, or manipulation of nutrient cycles.

Cover crops planted with the main crop will generally provide weed suppression through competition for light, soil water, and nutrients. A potential negative effect is that the cover crop will also be competing with the main crop. As such, the goal is to identify a cover crop species that is short-lived, grows actively, but is also short enough not to compete with the crop for light. Adequate soil water supply is necessary to minimize competition for water. Leguminous cover crops are often used because they will compete less for soil nitrogen.

More commonly, cover crops are planted during a fallow period. In such cases, the cover crop provides weed suppression via the residue left after termination or by out-competing weeds that would otherwise produce seed and increase potential for weed-crop competition in the succeeding cropping cycles. The residue can affect weeds by physically modifying the microenvironment, by releasing leachates from residue that chemically interfere with weeds or soil microbial populations that benefit weedy species, or by affecting nutrient cycling (see above) in such a way to make nutrients temporarily unavailable to emerging weeds. A growing cover crop during what would otherwise be a ‘fallow’ period can potentially produce nitrogen for later cereal crops or replace weeds that would contribute to an undesirable weed seedbank.

Impacts on Crop Yields

Cover crop impacts on subsequent crop yields are often variable. Cover crops may increase, reduce or have no effects on subsequent crops yields.

Precipitation amount is one of the leading factors that affects performance of cover crops and their impacts on subsequent crops. In regions with high precipitation, cover crops may increase crop yields, but in water-limited regions such as the semiarid central Great Plains, cover crops may reduce crop yields.

Research studies in the Great Plains have revealed that cover crops may or may not reduce subsequent crop yields, depending on site-specific conditions including precipitation amount, evapotranspiration rate, and tillage management.

Studies from semiarid regions suggest that, while cover crops may not always reduce crop yields, they do not increase crop yields in this region. Thus, economic return from cover crops may be limited in semiarid regions unless cover crops are grown as forage crops for haying or grazing. It is important to note that, in some semiarid environments, cover crops may not always reduce crop yields in normal years but in years with below normal precipitation (i.e., drought years) they will most probably reduce crop yields. Evapotranspiration rate is another factor that can influence cover crop effects on crop yields in the Great Plains. Under the same amount of precipitation, cover crop performance will decrease with an increase in evapotranspiration rates in semiarid regions.

Regions with higher precipitation amounts indicate that cover crops can increase crop yields. For example, in south central KS, sunn hemp and late-maturing soybean as summer cover crops when managed under no-till winter wheat-grain sorghum rotation increased crop yield. Precipitation appears to be the main factor that determines cover crop effects on subsequent crop yields. The variable effects of cover crops on crop yields warrant more comprehensive research under different climatic conditions not only related to short-term benefits to crop yields but also in regards to long-term benefits of cover cropping to soil conservation, soil and environmental quality, weed management, and sustainable agriculture.

Potentials for Animal Feed

While cover crops by definition are not intended to be grazed or harvested, interest is growing in the potential side benefits of cover crops when used as double cropping for forage production in integrated crop-livestock systems, especially when forage supply is limited. For example, increased conversion of grasslands to croplands has increased pressure on crop residues or silage for animal feed. Cover crops may provide supplemental forage to meet the livestock production demands. The interest in integrating cover crops with livestock production is not new, but current interest is driven by increasing demands for feed and variable climatic conditions.

Feed quality of pasture plants can be low, depending on the time of the year. Forage or cover crops may provide feed of high nutritional value to enhance livestock performance. Under favorable precipitation or soil moisture conditions, growing cover crops can fit for fall, winter, and spring grazing. Oats and turnips, and mixtures of radishes, forage rapeseed, cowpeas (*Vigna unguiculata* L.), lentils, sunflowers (*Helianthus annuus* L.), millets (*Pennisetum glaucum* L.), and sorghum-sudangrass are some of the potential cover/forage crop species. While cover/forage crops could reduce available water for the subsequent crops in years with lower precipitation than normal in semiarid regions, summer annuals can provide forage for baling or grazing.

Findings from the few published studies suggest that grazing or haying of cover crops may be feasible with proper management while still providing additional soil ecosystem services such as erosion control and maintenance of soil fertility. Cover crops may create a synergy between crops and livestock in these systems for increasing nutrient cycling and enhancing resource use efficiency. Under moderate grazing, cover crops can contribute to the diversification of integrated crop-livestock production systems while increasing economic benefits and improving soil ecosystem services. Animals can also contribute to nutrient distribution and cycling within the whole field via manure input. Grazing cover or forage crops may be feasible under controlled stocking rates to reduce overgrazing. The reduced grazing intensity can enhance cover crop recovery, regrowth, biomass accumulation, and most importantly nutrient cycling, while maintaining desirable soil properties.

Conclusions

Cover crops can provide a number of soil ecosystems services such as reduction in water erosion, wind erosion, and soil compaction risks, improvement in soil properties, and increase nutrient cycling. Cover crops may increase, reduce, or have no effects on subsequent crop yields. The extent to which cover crops improve soil properties and affect crop yields are, however, highly site-specific and depend on precipitation. The adverse effects on crop yields may increase with a decrease in precipitation since cover crops use water and can reduce available water for the main crops. Early termination, selection of cover crop species, and other improved practices may reduce, to some degree, the negative effects of cover crops on yields in water-limited regions. Other factors that affect cover crop success include initial soil fertility conditions, cover crop species, and length of time in the field. Inclusion of cover crops after crop residue removal or during fallow periods is a potential practice to provide soil surface residue cover and to conserve soil. The few studies conducted to date suggest that grazing or haying cover crops may not negatively affect soil ecosystem services such as soil properties. There may be trade-offs between soil ecosystem benefits provided by cover crops and cover crop production costs, which warrant a more detailed economic analysis. While it is unlikely that a cover crop can provide all the N needed for subsequent crops, it may reduce inorganic fertilizer requirements. A more systematic and quantitative assessment of all soil ecosystem services provided by cover crops is needed for different soil types, climatic conditions, and cropping systems. It is also important to further discern the implications of grazing or haying cover crops on soil ecosystem services. Cover crops offer the potential for improving soil ecosystem services, but more systems approach based studies are needed to characterize cover crop performance and delivery of soil ecosystem services.

Resources

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Potential Uses of Unmanned Aerial Systems in Nebraska Crop Production

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Introduction

There is substantial interest in the use of unmanned aerial systems (UAS) for crop production in Nebraska. Unmanned aerial vehicles – usually termed "drones" – have been in the news a lot over the past year. Popular press articles frequently express concern about safety, citing "near misses" with manned aircraft, or privacy, with questions such as whether it is legal to shoot down drones over one's property. The relatively low cost and ease of use of UAS has allowed an increase in use among hobbyists, as well as those with an interest in commercial use, while the regulatory framework has lagged behind. However, once regulatory issues are resolved and in place allowing widespread commercial use, the Association for Unmanned Vehicle Systems International (AUVSI) has predicted there will be an $75 billion economic impact in the US (revenue and job creation) between 2015 and 2025 (AUVSI Advocacy, 2015), and that the greatest use for UAS will be in agriculture.

Current Regulations

Currently, the Federal Aviation Administration (FAA) has circulated draft regulations for public comment on commercial use of small UAS (< 55 lb). Key aspects of the proposed rules are line-of-sight operation, daytime flights only, maximum altitude of 500 ft, operation in Class G airspace only without ATC permission. Operators must pass an aeronautical knowledge test at an FAA-approved center, obtain an unmanned aircraft operator certificate, and be vetted by the Transportation Security Administration. Final approval and implementation of small UAS rules, which could be amended from the above components based on public comment, is expected in 2016 or 2017.

Another route for commercial use of UAS is a Section 333 exemption for small UAS commercial use, which is granted case-by-case prior to finalization of the small UAS rule. Generally such exemptions have used a lower altitude restriction (often 200 ft), and the use of a licensed pilot as the operator. As of September 2015 there had been 1,732 Section 333 exemptions granted, with a number of those for commercial agricultural use (FAA 2015).

Crop Scouting

Initially the easiest and most common use of UAS for crop production in Nebraska will be crop scouting – assuming regulations are not so restrictive as to make scouting use impractical. There is much to be gained from an elevated view of a field. Problem areas or man-made patterns can be more visible with some height perspective rather than a ground level view.

Figure 1. Ground level view vs aerial view from 200 ft.

Figure 1 is an example of a ground level view of a Nebraska corn field after planting compared to an aerial view.

There are evident gaps in plant stand from the ground, with some apparent repetition that is hard to discern. The aerial view clearly shows a repeating gap in plant stand – in this case resulting from preplant anhydrous ammonia, applied at a slight angle to the planted row direction. Anhydrous ammonia was applied at too shallow depth, resulting in germination damage whenever the planted row intersected the preplant ammonia fertilizer band. Figure 2 is an image of a University of Nebraska research study at the Brule Water Resources Laboratory in 2013. The most significant patterns are man-made – the result of nitrogen fertilizer and irrigation water rate treatments imposed on blocks throughout the growing season. However, the image illustrates other patterns in the field – planter or cultivator gaps in stand, and differences in crop color which reflect underlying soil properties – primarily soil texture and organic matter patterns.

It is likely that UAS will become a routine tool for crop consultants and many growers – allowing scouts to quickly scan over a field for problems – again assuming regulations are conducive to such use. Unmanned aerial systems for crop scouting need only have standard cameras, which record in visible (red, green, blue) wavelengths – and which may easily send a video image to the operator in real time. Such systems exist that are easy to use and relatively inexpensive ($800 - $3000). The low cost and ease of use will allow operators to rapidly survey fields for atypical areas in a matter of minutes as a routine practice. It will be very easy for crop consultants to survey fields aerially on a weekly basis, for example, to identify areas to scout more closely on the ground.

Multispectral and Georeferenced Imagery

Quantitative use of UAS for crop production generally requires multispectral sensors collecting georeferenced data. Multispectral sensors detect crop reflectance in specific wavelengths that provide information about crop status, in visible and near-infrared (NIR) spectra. Often multispectral information reveals issues which are not visible to the human eye. Reflectance from two or more wavelengths can be combined in a formula, called a vegetation index (VI), which is correlated to specific crop properties, such as nitrogen (N) status. The most commonly known VI is the Normalized Difference Vegetation Index (NDVI), which uses reflectance in red and NIR wavelengths. However, for high biomass crops such as corn, NDVI is less sensitive to N stress than some other VI's. Consequently, sensors that use Normalized Difference Red Edge (NDRE) or Chlorophyll Index (CI) indices, which are not as limited by biomass, are commonly used for corn. One challenge with UAS has been a lack of lightweight multispectral sensors which are within the payload capacity of small UAS. Figure 3 illustrates one of the University of Nebraska-Lincoln's UAS with a 5 band multispectral sensor used in research. Currently there is considerable interest in sensor development for UAS, and several companies have recently introduced multispectral sensors designed specifically for UAS and agricultural use.

Figure 2. Aerial image of study at the Brule Water Resources Laboratory, August 2013.

Figure 3. Multirotor UAS (Octocopter XL) with five band Tetracam MCA multispectral sensor, with incoming radiometer correction.

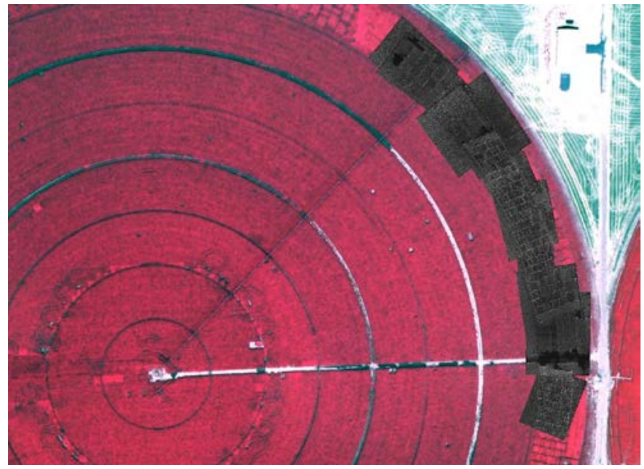

Figure 4. Grayscale Chlorophyll Index (CI:(NIR880/VIS530)-1) developed from UAS imagery, on background NIR image from manned aircraft, July 2012, West Central Water Resources Laboratory, Brule, NE.

To properly use multispectral aerial imagery, data should be calibrated for incoming radiation. The amount of light reflected from a crop canopy will depend on incoming light, which is influenced by atmospheric properties, sun angle, clouds, etc. Several multispectral sensor systems for UAS are now equipped with incoming radiometer sensors allowing internal radiometric correction of imagery. Multispectral sensors for UAS today cost from $6,000 to more than $20,000. Sensors capable of sensing wavelengths beyond NIR, specifically in thermal bands, are also becoming available for UAS, and may be particularly useful for irrigation management.

To be useful for spatial crop management, aerial imagery generally must be georeferenced – assigning spatial coordinates to the image – so one can measure and manage based on image information, and then relate image information to other layers of geospatial information, such as yield maps, grid soil sample information, etc. Sophisticated aerial imaging systems used on full size aircraft have the capacity to collect data which is georeferenced by the system at collection. Smaller sensor systems used by UAS do not yet have that capacity, so images must be georeferenced after collection. This process requires expertise in use of Geographic Information System (GIS) software, and can be time consuming. Systems marketed for agriculture now often include the airframe, sensors, and image processing software to create accurate VI maps without significant GIS skill.

Research conducted by UNL in recent years on using UAS for detecting N stress has focused on small plot studies, which in many cases can be covered in one image from relatively low altitude. Multirotor UAS are ideal for such research. For larger scale studies, multiple images must be collected, due to legal and operational limits on height of UAS use. Figure 4 illustrates one such study, conducted at the West Central Water Resources Laboratory near Brule in 2012. The background image is false color NIR collected from a manned aircraft. Multiple UAS images, in this case used to produce grayscale Chlorophyll Index (CI) images, are stitched together to cover the entire study (which evaluated drought tolerance of corn inbred lines for breeding purposes).

In order to use UAS imagery to cover entire fields of 160 acres, given the likely FAA height limit of 500 ft, it will require the UAS to collect many images which can then be combined to cover the field.

Given the cost of equipment and the technical nature of processing multispectral imagery, it is likely that most crop producers will contract with a service for use of UAS to collect such information. It may be that companies will develop offering these services directly to growers, or to crop consultants who can package this data with other information and advice on use. Again, development of such services will be substantially influenced by requirements of final FAA regulations.

Opportunities

Most UNL research to date with UAS sensing has focused on detecting nitrogen and water stress. There is great potential for such systems to improve N and water management in irrigated systems with timely geospatial information throughout the growing season. Figure 5 is of a study evaluating the use of an active crop canopy sensor on a UAS. In this case, NDRE values were highly correlated with N rate treatments. Active sensors use an internal light source, and thus are not influenced by atmospheric conditions – they can be used day or night.

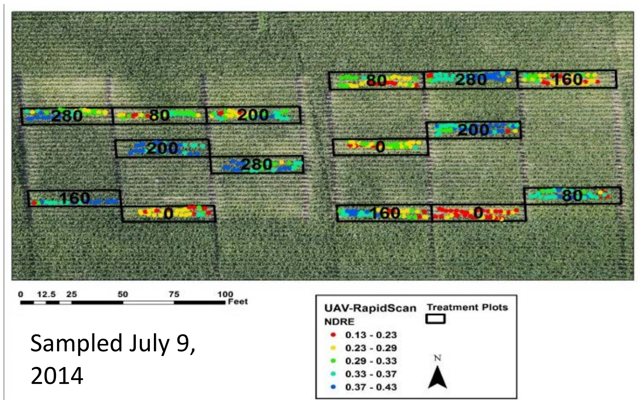

Figure 5. Active crop canopy sensor data collected from a UAS, overlaid on a natural color UAS image.

The sensor collected geospatial data, and thus did not require georeferencing. Such systems may be useful in the future for regular monitoring of crop N status, and controlling spatial fertigation.

Imagery from UAS has several advantages over manned-aerial or satellite platforms. UAS imagery can be collected more quickly and inexpensively. Manned-aerial must be scheduled according to the availability of the aircraft and pilot, and weather and clouds can interfere with both satellite and manned-aerial. Image resolution can be much higher with UAS. Use of satellite or manned-aerial imagery is not particularly useful for scouting, since images may be several days old before they are available to the consultant or grower. However, it is unlikely that UAS imagery will replace satellite or manned-aerial data. Instead, UAS imagery, obtained at higher temporal and spatial resolution, will complement imagery from other platforms. Use of unmanned aerial systems is also likely to go beyond imagery collection. Such systems may become useful for collection of physical samples, such as leaf samples, for on-board or laboratory analysis. They may also be useful for intervention, such as pesticide application. Single rotor, relatively large UAS (100 kg) produced by Yamaha have been used for several years for pesticide application to rice fields in Asia. The current Yamaha model, RMAX, has been studied for vineyard pesticide application at the University of California-Davis (Giles and Billing, 2015).

There has been less research to date on use of UAS for detecting and managing other stresses, such as insect, disease or weed pressure. It is likely that UAS imagery or other data will be useful for managing these challenges as well as nutrients and water. It is also likely that UAS use will become common for Nebraska crop production over the next few years. Details on capacity, cost, availability of services, etc. will depend largely on final regulations set by the FAA and evidence of improved management and profitability to crop producers.

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Herbicide Update 2016

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Corn Herbicides

Acuron™ [Atrazine (10.93) + Mesotrione (2.6%) + S-metochlor (23.4%) + Bicyclopyrone (0.65%)]. Acuron may be used pre-emergence or post-emergence (up to 12 inches tall) in field corn, seed corn, and silage corn. It can be used in sweet corn and yellow popcorn, but only pre-emergence. Acuron contains the safener benoxacor. If organic matter content of the field is less than 3%, apply Acuron at 2.5 qt/Acre, and if ≥ 3% then at 3 qt/Acre. Do not exceed 3 qt/Acre of Acuron per year. EPA Reg. No. 100-1466. Modes of Action: 5, 15, 27.

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™ [Dicamba (56.6%)]. DiFlexx includes exclusive CSI™ Safener technology which enables corn plants to better withstand herbicidal activity and provides better crop safety. DiFlexx may be used for pre-emergence or post-emergence selective control of broadleaf weeds in corn and fallow croplands. The application rates of DiFlexx vary with weed type and growth stage. Do not apply more than 16 fl oz/Acre per application and a total of 24 fl oz/Acre per year. Apply maximum of two applications per growing season, separated by two weeks or more. EPA Reg. No. 264-1173. Modes of Action: 4.

Solstice™ [Fluthiacet methyl (2.2%) + Mesotrione (38.52%)]. It contains two active ingredients possessing both contact and systemic activity that can be applied post-emergence for selective control of broadleaf weeds in field corn, seed corn, yellow popcorn and sweet corn. It can be applied up to V8 corn growth stage or until corn is 30 inch tall. Application rate is 2.5 to 3.15 fl oz/A. If atrazine is mixed with Solstice, do not apply to corn that is more than 12 inches in height. EPA Reg No. 279-3461.

Soybean Herbicides

Afforia™ [Flumioxazin (40.8%) + Thifensulfuron methyl (5%) + Tribenuron-methyl (5%)]. This is for burndown and preplant residual control of broadleaf weeds and partial control of annual grasses in soybean. It has two modes of action and rapidly inhibits the growth of susceptible weeds. It can be applied at 2.5 oz/A a day before planting soybean or 2.5 to 3.75 oz/A if applied before 7 days of planting soybean. Crop injury may occur from applications made to poorly drained soils under cool, wet conditions. EPA Reg. No. 352-889.

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.

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.

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.

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.

Rovel™ [Flumioxazin (51%)]. It can be applied to soybeans prior to planting or pre-emergence application must be made within 3 days of planting soybean. Application after soybeans have begun to crack, or are emerged, will result in severe crop injury. Do NOT apply more than 3 oz/Acre per growing season. EPA Reg. No. 59639-99-524. Mode of Action: 14.

Ransom™ [Flumioxazin (12.92%) + Metribuzin (56%)]. It is a selective herbicide for pre-emergence control or suppression of susceptible broadleaf weeds and certain annual grass weeds in soybeans. It also offers control of certain emerged broadleaf weeds when applied as part of a burndown treatment. EPA Reg. No. 66222-260. Mode of Action: 14, 5.

Rovel™ FX [Flumioxazin (30%) + Chlorimuron (10. 3%)]. It is a selective herbicide for pre-emergence control of broadleaf weeds and suppression of certain annual grasses in soybeans. Do NOT apply more than 5 oz/Acre during a single growing season. EPA Reg. No. 59639-117-524. Mode of Action: 2, 14.

Surveil™ Co-Pack [Surveil™ V (Flumioxazin 51%); surveil™ FR (Cloransulam-methyl 84%)]. This is multi-pack for pre-emergence control of certain weeds in soybeans. Read herbicide label to know Co-Pack load chart. EPA Reg. No. 59639-131-62719. Modes of Action: 14, 2.

Trivence™ [Chlorimuron ethyl (3.9%) + Flumioxazin (12.8%) + Metribuzin (44.6%)]. Trivence is a burndown as well as residual herbicide that may be applied preplant or pre-emergence to soybean. It has three modes of action and rapidly inhibits the growth of susceptible weed species. It can be applied at 6 to 9 oz/A depending on soil texture and soil pH. EPA Reg. No. 352-887. Mode of Action: 2, 5, 14.

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.

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.

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.

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.

Autumn Super™ [Iodosulfuron-methyl (6%) + Thiencarbazone-methyl (45%)]. Autumn Super is an herbicide from Bayer for burndown of existing vegetation and residual weed control. It can be applied to field after fall harvest and early spring at least 30 days prior to planting field corn, cereals, and grain and forage sorghum or at least 60 days prior to planting soybean, sweet corn, popcorn or corn grown for seed. It cannot be applied more than 0.5 oz/A in a year. EPA Reg. No. 264-1134.

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.

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.

Finesse® Cereal and Fallow [chlorsulfuron (62.5%) + metsulfuron (12.5%)]. Finesse Cereal and Fallow is for use in wheat, barley, triticale, fallow and CRP grasses. Use rates are 0.2 to 0.4 oz/a in small grains and fallow. Consult the label for rotational crop restrictions. EPA Reg. No. 352-827.

Panoflex™ [Tribenuron-methyl (40%) + Thifensulfuron-methyl (10%)]. It is used for selective post-harvest burndown, fallow, and pre-plant burndown weed control. Apply 0.3 to 0.6 oz/A as a burndown treatment prior to planting any crop, or shortly after planting wheat (including durum), barley or triticale (prior to emergence). Sequential treatments can be made but the total amount should not exceed 0.6 oz/A. EPA Reg. No. 352-876.

Piper [Flumioxazin (33.5%) + Pyroxasulfone (42.5%)]. For control and/or suppression of certain weeds to maintain bare ground non-crop areas. EPA Reg. No. 59639-193. Modes of Action 14, 15.

Always refer to herbicide product labels for complete details and directions for use.

Using the Guide (EC130) to Improve Pesticide Efficacy and to Manage Spray Drift

Robert N. Klein, Western Nebraska Crops Specialist

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 you cannot control all the variables, achieving goals such as these is a real challenge.

Pesticide and Drift

Pesticide and drift ratings are influenced by:

- Spray characteristics
  - Chemical
  - Formulation
  - Additives
- Weather, etc.
  - Air movement (direction and velocity)
  - Temperature & humidity
  - Air stability/inversions
    Topography
- Equipment & application
  - Nozzle type
  - Nozzle size
  - Nozzle orientation
  - Nozzle pressure
  - Nozzle height
  - Technology
  - Sprayer speed

Two Kinds of Drift

There are two kinds of drift:

1. **Particle drift** is off-target movement of the spray particles.
2. **Vapor drift** is the volatilization of the pesticide molecules and their movement off target.

A Mississippi State University study analyzed data from more than 100 studies involving drift from ground sprayers. Of the 16 variables considered, three were most important.

1. **Wind speed**. When the wind speed was doubled, there was almost a 700 percent increase in drift when the readings were taken 90 feet downwind from the sprayer. Hence the recommendation of spraying in 10 mph winds or less.
2. **Boom height.** When the boom height was increased from 18 to 36 inches, the amount of drift increased 350 percent at 90 feed downwind. (See Figure 1)

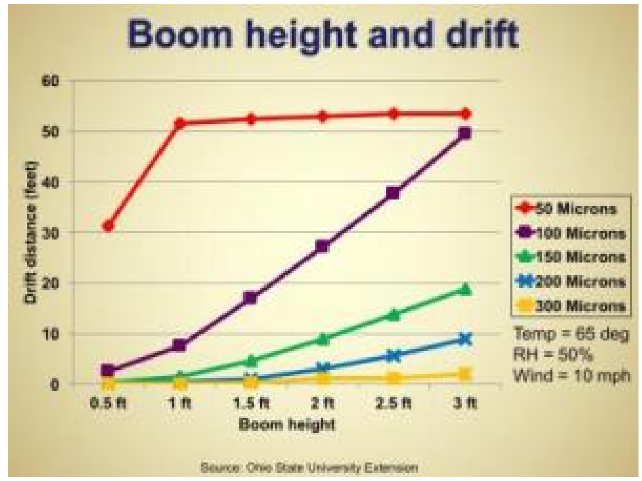

Figure 1. Downwind drift distance for various spray droplets released from different boom heights. (Scott Bretthauer, University of Illinois Extension)

3. **Distance downwind.** If the distance downwind is doubled, the amount of drift decreases five-fold. Therefore, if the distance downwind goes from 100 to 200 feet, you have only 20 percent as much drift at 200 feet as at 100 feet and if the distance goes to 400 feet, you only have 4 percent of the drift you had at 100 feet. Check wind direction and speed when starting to spray a field. You may want to start spraying one side of the field when the wind is lower. Also, it may be necessary to only spray part of a field because of wind speed, wind direction, and distance to susceptible vegetation. The rest of the field can be sprayed when conditions change.

Pesticide drift also can be reduced by using one of the new types of tips and by adjusting spray pressure. Higher spray pressures produce smaller droplets which are more susceptible to drift. If using a rate controller, be careful of increased speed. Since most rate controllers increase the pressure to maintain the same gpa when the speed increases, try to maintain the speed within +10 percent. For example, if you're applying 20 gpa at 8 mph at 40 psi and you increase the speed to 11 mph, the pressure will now be 75.5 psi which will produce a lot of small particles prone to drift. Also, this pressure will be above the operating range of most tips. Drift reduction agents may be helpful.

New spraying technology such as the "blended pulse" can decrease the risk of drift by allowing flow rate to be controlled independently of spray pressure.

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.

- One star – 25-49% reduction
- Two stars – 50-74% reduction
- Three stars – 75-89% reduction
- Four stars – 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 on Pesticide Labels as Early as Fall of 2015; Look for Information About Use of DRT in the Directions for Use

Trying to manage spray drift with only spray particle size may result in reduced pesticide efficacy. For instance, on spray droplet size, Kirk A. Howatt, Associate Professor at North Dakota State University, made the following statement: "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."

Drift Reduction: Recommended Techniques

1. Follow label directions.
   - Read label; use the nozzle manufacturer's guide for nozzle and pressure combinations.
2. Select a nozzle to increase droplet size.
   - Large droplets-less prone to drift. Use largest droplets that provide necessary coverage.
3. Increase nozzle size resulting in higher application volumes.
   - Larger capacity nozzles can reduce the amount of spray deposited off-target.
4. Consider using new technologies.
   - Certain nozzles (air-induction and venture nozzles) may help reduce drift.
5. Keep nozzle close to the target. (Boom height is #2 in Spray Drift Management).
   - When using hand-held equipment, keep nozzle close to reduce the potential for drift.
   - For spray rigs, lower boom height.
6. Maintain appropriate travel speed.
   - High travel speeds may result in an unstable boom, higher boom, and increased drift potential.
7. Avoid applying when wind speeds are high. (Wind speed is #1 in Spray Drift Management).
   - More spray moves off-target as wind increases.
8. Do not spray during a temperature inversion.
   - Temperature inversions prevent the dissipation of spray particles.
9. Consider using buffer zones/no-spray zones near sensitive areas.
   - Leave a buffer zone/no-spray zone if sensitive.
10. Use a drift-control additive when needed.
    - Increases average droplet size. Additives must not become your only drift-reducing technique. They do not make up for poor spraying practices.

Some new pesticides like Dow Agro Sciences Enlist Duo have a chart that details nozzle and pressure that are allowable when applying Enlist Duo herbicide. It goes on to state that "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

2016 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 BCPC specifications and in accordance with ASABE standard S572.1. Following are charts in the guide.

First page of 4 in Guide (ED 130)

Pesticides listing the recommended or required spray droplet size and carrier rate on the label. Always check label before applying.

Herbicides

Herbicides	*Drop Size Classification*	*Ground Application GPA*
2,4-D amine	C	8 to 20+
2,4-D ester #4	C	10+
2,4-D ester #6	C	10+
AAtrex 4L	C	Minimum 10
AAtrex Nine-O	C	Minimum 10
Accent Q	M - C	Minimum 15
Acuron	M to C	Pre-Emergence 10 - 80 & Post-Emergence 10 - 30
Affinity BroadSpec	Largest Droplet Size*	Minimum 5 to 20
Agility SG	Largest Droplet Size*	Minimum 5 to 20
Aim EC	Min Amt of Fine Spray Droplets	Minimum 10
Ally Extra SGW/ TOTSOL	Largest Droplet Size*	Minimum 5 to 20
Ally 60XP	Largest Droplet Size	Minimum 3 to 20
Alluvex	M (C if spray vol is increased)	Min 15; Min 5 to 10 w/ Glyphosate

Herbicides	*Drop Size Classification*	*Ground Application GPA*
Broadaxe	Minimal Amts of Fine Spray	Minimum 10
Bronate 6.3	No Mention	No Mention
Butyrac 200	C-but nozzle types that will provide adequate coverage	Minimum 10
Cadet	M - C	Min 15; up to 40 for dense canopy or weeds
Callisto 4SC	M to C	PRE:10 to 60 & POST: 10 to 30
Callisto XTRA	M to C	10 to 30
Canopy DG	C to VC	Minimum 10
	M	Minimum 15
Canopy EX	M, C	Minimum 20
Capreno	M to C	Minimum 10
Capstone	C	Minimum 10
Chapparal	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


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

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]					Soybean yield[b]	
				14 DAP	28 DAP	42 DAP	90 DAP	At harvest	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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