FOREWORD

New technologies are changing the way we grow food, feed and fiber crops and the impact of crop production on the broader environment. The University of Nebraska–Lincoln Extension is pleased to present the 5th Annual Crop Production Clinics to bring you unbiased, research-based information that will help you understand how new technologies can improve the profitability and safety of your operation.

The *2013 Proceedings* contains articles that summarize the information presented at all 9 Clinics. It is intended to be a workbook for you to use during the clinic, and a reference after the clinic. In addition, many of the presentations will be recorded and made available following the Clinics at our website: http://cpc.unl.edu.

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

The Clinics are the primary recertification venue for Commercial Pesticide Applicators. Private Pesticide Applicators may also recertify by attending the Clinics.

We want this program to meet your information needs. Please share with us how we can make the Clinics and Proceedings more valuable for you, and how what you have learned at the Clinics has benefitted your operation. If you have questions about what you read, please contact the author. Author and presenter contact information is listed just before the table of contents. We look forward to hearing from you.

2013 Crop Production Clinics Schedule

January 8, Adams County Fairgrounds, Hastings
January 9, Sandhills Convention Center, North Platte
January 10, Gering Civic Center, Gering
January 15, Atkinson Community Center, Atkinson
January 16, The Auditorium, York
January 17, Armed Forces Reserve Center, Beatrice
January 22, Younes Conference Center, Kearney
January 23, Lifelong Learning Center, Northeast Community College, Norfolk
January 24, Midland University Event Center, Fremont

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After the Drought: Crop Insurance and Risk Management in 2013

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The summer of 2012 saw record-setting drought across Nebraska and other parts of the Midwest. Crop yields were hit hard, especially dryland yields. Where does this leave us, as we review the effects of 2012 and consider our risk management needs and options for 2013?

How Bad was 2012?

This analysis of the effects of the 2012 drought will consider several factors. First, what was the general financial status of Nebraska crop producers heading into the 2012 season? Second, how did yields and prices perform in 2012? Third, how did risk management tools like crop insurance mitigate the effects of low yields?

The beginning financial picture

Most Nebraska crop producers began 2012 in relatively strong financial condition as a result of strong crop prices and generally decent crop yields in the preceding years.

Net farm income in Nebraska, as estimated by the Economic Research Service of USDA, reached a record $7.5 billion in 2011. The previous record was $4.7 billion in 2010. As a point of reference, Nebraska net farm income averaged $3.4 billion over 2006-09 and $2.9 billion over 2002-05.

Record-setting farm incomes were a reflection, first and foremost, of strong prices for the major farm commodities produced in Nebraska. Higher demand for corn from the ethanol industry has driven corn prices higher, and soybean and wheat prices have followed suit. Cattle prices have also been generally strong over this period. While higher feed costs have sometimes made cattle feeding unprofitable, cow-calf producers have enjoyed higher calf prices.

The pattern of higher crop prices over the past several years is a familiar one to those familiar with Nebraska agriculture. USDA's annual average price received by farmers for corn averaged $2.20/bushel over 2001-2005 and $4.01/bu. during 2006-09, but reached $5.18/bu. in 2010 and $6.22/bu. in 2011. Average prices received by farmers for soybeans over this period were $5.73/bushel during 2001-05, $9.02/bu. during 2006-09, $11.30/bu. in 2010 and $12.50/bu. in 2011.

With strong farm incomes, land prices have risen during this period, and farm debt has also been relatively low. While exceptions can certainly be found, the overall financial status of Nebraska farmers tended to be strong heading into the 2012 drought.

Lower yields, higher prices in 2012

The only official USDA estimates for 2012 Nebraska yields are preliminary state-level yield estimates. The November 2012 Crop Production report by the National Agricultural Statistics Service puts Nebraska's overall corn yield at 139 bushels/acre and the soybean yield at 41.0 bu./acre. Measured at the state level, the 2012 corn yield is down about 13 percent from 2011, and the 2012 soybean yield is down 24 percent from the 2011 level.

These state-wide averages combine irrigated and dryland yields, and irrigated land represents a significant portion of Nebraska acreage. According to NASS, about 58-60 percent of corn acreage in Nebraska has been irrigated in the most recent years, while about 46 percent of soybean acreage has been irrigated.

Thus, we can expect that dryland yields in 2012 suffered greater losses than the declines mentioned above. Perhaps more importantly, some individual producers experienced even greater losses which are not apparent when considering only state-wide averages.

Crop prices, on the other hand, rose significantly once the drought settled in. CBOT December corn futures were trading in the $5.00-5.50 range in the late spring and early summer, in response to the news of record plantings. Starting in mid-June, corn prices began rising, reaching more than $8.00 in August before dropping back to the $7.00-7.50 range after harvest. Soybeans followed a similar path, with the November CBOT price rising from $12.50-13.00 range in mid-June to more than $17.50, then falling back to the $14.50-$15.00 range after harvest.

Regarding prices received by farmers, USDA estimates farmers will receive corn prices in the range of $6.95 to $8.25 for their 2012 corn crop, and $13.90 to $15.90 for their 2012 soybeans. This compares to average farm prices of $6.22 for their

2011 corn and $12.50 for their 2011 soybeans (November 2012 WASDE report). Using the midpoints for the 2012 price ranges, this represents a year-to-year increase of about 22 percent for corn prices and 19 percent for soybean prices.

Crop insurance in 2012

Multiple-peril crop insurance (MPCI), provided by USDA's Risk Management Agency through local insurance agents, provided significant relief for the crop losses experienced in Nebraska in 2012. According to RMA, about 15.6 million acres of Nebraska crops were insured in 2012, with a total dollar protection of $8.7 billion.

A majority of Nebraska acres were insured in 2012 for the major crops. Of 9.95 million acres of corn planted, 8.98 million were insured with some form of MPCI, indicating a participation rate of 90 percent. For soybeans, 5.05 million acres were planted and 4.58 million acres were insured, for a participation rate of about 91 percent. For wheat harvested in 2012, there were 1.38 million acres planted and 1.24 million acres insured, meaning about 90 percent of wheat acres were in the MPCI program.

Total farmer premiums paid in Nebraska for 2012 crops amounted to about $271 million, along with a premium subsidy from the Federal government of about $396 million.

Indemnity payouts are still being made and a final payout figure is not available for 2012 crops. However, an estimate can be made using the loss ratio, calculated as total indemnities divided by total premiums (= farmer premiums + premium subsidy). With total premiums of about $667 million, a loss ratio of 1.5 would mean indemnity payments would total about $1.001 billion. The highest loss ratio in recent Nebraska history came with the drought of 2002, which produced a loss ratio of 2.01. If losses reach this level, total insurance payments to Nebraska farmers would reach about $1.341 billion. To put this in perspective, $1.341 billion would be roughly 18 percent of 2011's record net farm income.

Insurance issues for 2013

Producers may consider a variety of issues as they plan their insurance decisions for 2013. First, how do 2012 yield results affect their expectations for 2013? Related to this is the effect of lower 2012 yields on their APH yield history. Some alternatives are available to reduce the effects of low yields. Other issues include the choice or yield or revenue coverage, and the direction of premiums in 2013.

Yield expectations

The drought experience of 2012 could affect producers' decisions in a number of ways. Should one expect lower yields more often? Besides the use of insurance, what production steps could be taken to mitigate yield risk, particularly regarding the selection of crop hybrids or varieties?

Regarding the frequency of low yields, it may be difficult to infer much from one year's observation. Serious droughts have occurred every several years in Nebraska, and even though the 2012 drought is the most serious one since 2002, expectations may not change radically unless the drought extends into the 2013 planting period.

A more important lesson on production risk from the 2012 drought may be the improvement it highlights in crop breeding, particularly in the area of drought tolerance. In spite of some record-breaking drought conditions this past year, Nebraska crop yields suffered but in most cases did not fail, even for most dryland crop producers. These difficult conditions actually highlighted the differences among crop varieties under severe stress. One of the most important risk management decisions for 2013 may be the selection of hybrids which performed well and the elimination of those that didn't.

Updating APH yield history

Adding a lower yield from 2012 to their yield histories will reduce producers' APH average yield and consequently their 2013 guaranteed yields. A number of options are available, however, to limit this effect.

First, recall that MPCI coverage is based on each farmer's own "Actual Production History." Each producer's yield history consists of from four to ten years of actual yields. If producers have fewer than four years of their own yields, they must use a "transition yield," or T-yield, to complete the minimum four years of history. T-yields are based on the 10-year historical county average yield.

Once such a yield history has been compiled, the APH average is simply the average yield from this series. Producers can then select coverage from 50 percent to 85 percent of their APH average yield.

Adding a low yield to the APH record will have the greatest effect on shorter yield histories. One APH rule which limits this effect is called a yield cup. This means than the APH average yield cannot decline more than 10 percent from year to year when another yield is added to the series (there is a similar limitation on the upside, called a yield cap, which requires that the APH cannot increase more than 20 percent in one year). The actual low yield from 2012 will still go into producers' histories, but a "cupped" value of 90 percent of last year's APH average will be used instead if the 2012 yield drives the actual average yield below 90 percent of its former value.

Another set of APH rules which may be of some use are those which set a "floor" under the overall APH average. For producers with only one year of their own yields, the APH must be at least 70 percent of the T-yield. Producers with two, three, or four years of records get a floor of 75 percent of the county T-yield, and producers with five or more years of records have an APH floor of 80 percent of the county T-yield.

These rules should be most helpful for those producers with shorter yield histories – for example, those who have just started renting a particular piece of ground – from having their APH yield drastically reduced by a crop failure.

Finally, producers should also remember to have their yields adjusted by their county trend adjustment factors. This process raises the APH average to account for progress in crop yields over time; a 10-year-old yield probably understates one's current yield potential, so the APH can be adjusted to reflect this. Each county has its own trend adjustment factors assigned by RMA, but they will be around 2 bushels per year for corn and about 0.4 or 0.5 bushels per year for soybeans.

Producers are urged to check with their insurance agents on these rules, as qualified agents should be familiar with them and able to update yield histories accordingly.

Crop insurance premiums in 2013

Can we expect crop insurance premiums to increase significantly after the widespread loss experience in 2013? Crop insurance premiums consist of three components: the insurance rates themselves, which reflect the risk of loss, and the crop price elections and the guaranteed yields, which reflect the value of production being insured. How might each of these components change for 2013?

Insurance rates are set to reflect the pattern of crop losses that might be experienced over a period of many years. Thus, one year's losses must be considered in light of yields observed over a much longer time, and one bad year alone may not have much effect. Nebraska's loss experience with major crops over the past 20 years, as measured by the loss ratio over time, suggests that rates are generally adequate to cover occasional large losses such as the 2012 experience. While rate changes may still occur, one would not expect any changes to be large ones.

Premiums are also determined by crop prices and guaranteed yields, which reflect the value of the crop being insured. Higher crop prices in recent years have produced correspondingly higher premiums. This year's relatively high prices will have a similar effect.

Crop prices for insurance coverage on the major crops are established using a month-long average of futures prices prior to planting. This value is considered a simple and useful estimate at planting time of the crop's expected price at harvest. For corn, the coverage uses the average price during February for the December CBOT corn futures contract. For soybeans, it uses the February average of the November CBOT soybeans contract.

In 2012, the crop prices established at insurance sign-up were $5.68 for corn and $12.55 for soybeans. As of this writing (mid-November 2012) the December 2013 corn contract was trading in the $6.00-6.50 range, and November 2013 soybeans were trading just under $13.00 per bushel. Much can happen before the end of February, but the best estimate at this point indicates the prices used for insurance in 2013 may be similar to or slightly higher than those from 2012.

The final component for calculating premiums is the guaranteed yield, which is simply a percentage of the APH average yield. As discussed earlier, average yields will decline for most producers, as adding lower 2012 yields to their history will have a negative effect. The extent of this decline will depend, as discussed above, on the extent of 2012 losses and whether any of the APH cup or floor rules can mitigate this decline. Producers with longer yield histories should be affected less than those with short histories.

The net effects of these three factors are ambiguous. Guaranteed yields should be down slightly, crop prices may be up slightly, and rates will probably change little, if any. Overall, 2013 premiums should be fairly close to those seen in 2012.

Coverage type and coverage levels

Producers have several options when selecting the type and level of coverage. Type of coverage in this sense refers to insurance which covers only yield losses or insurance which guarantees a minimum level of revenue. Coverage can also be based on either one's own farm yields or the county average yield.

The farm level coverage which guarantees yield losses only is called Yield Protection, or YP. The guaranteed yield is simply the APH average yield times the level of coverage, ranging from 50 percent to 85 percent of the APH average. For example, a producer with an APH average corn yield of 160 bushels per acre would have a guaranteed yield of 120 bushels if he/she selected the 75 percent coverage level. Any loss is calculated as the number of bushels that actual yield falls below this guarantee level, times the indemnity price established at sign-up. If the producer in the example above had an actual yield of 100 bushels per acre and an indemnity price of $6.00/bushel, the indemnity would be (120-100) x $6.00 = $120 per acre.

Two types of revenue coverage based on farm yields are commonly used. One is called Revenue Protection, or RP, and an indemnity can be triggered not only by low yields but also low prices.

RP establishes a guaranteed revenue equal to the guaranteed yield times an indemnity price. The indemnity price is the higher of the sign-up price (the February average futures price) or the harvest price (the October average futures price).

Actual revenue under this plan is calculated as the actual farm yield times the harvest price. If actual revenue falls below the guaranteed revenue, the insurance indemnity is equal to the difference.

The second revenue insurance program, called Revenue Protection with a Harvest Price Exclusion, or RP-HPE, establishes the revenue guarantee using only the sign-up price. That is, if crop prices rise during the season, the revenue guarantee is unchanged (in contrast to the result under RP). Actual revenue is still calculated as actual yield times the harvest price.

Other forms of coverage based on county yield results are also available. These programs are the Group Risk Plan (GRP) and Group Risk Income Protection. Producers can select a coverage level as high as 90 percent of county average yield, but relatively few acres are insured under these plans.

Revenue Protection most popular

RP is far and away the most popular form of coverage in Nebraska. In 2012, 81.3 percent of insured acres in Nebraska were covered by RP, followed by 10.6 percent of acres insured under YP. Another 3.6 percent of acres were insured under RP-HPE, and the remaining 4.5 percent of acres were insured under all other plans.

Revenue coverage has long been the most popular form of crop insurance protection, but enrollment in revenue coverage is even higher now than in years past. Back in 2002, the acres covered under the old Crop Revenue Coverage (CRC) plan, which functioned similarly to RP, amounted to about 64.3 percent of insured acres, while the old APH plan (which functioned like YP) covered about 35.1 percent of insured acres. All other plans combined to cover the remaining 0.6 percent of insured acres.

The RP experience of 2012 provides some insight into the popularity of this form of coverage. Although it is the most expensive policy, it provides higher coverage in the event of rising prices, which often occurs in years when poor crop yields are widespread. In 2012, harvest prices were significantly higher than sign-up prices for both corn and soybeans, as markets responded to the drought conditions (from $5.68 to $7.50 for corn and from $12.55 to $15.39 for soybeans). Consequently guaranteed revenues rose a corresponding 32 percent for corn and 23 percent for soybeans. Some producers could have experienced little or no yield loss and still received an indemnity payment under these circumstances.

RP is likely to remain a popular choice in 2013. Carry-over grain stocks will be low due to the poor 2012 crop, so any yield shortfall at a national level in 2013 could produce another large run-up in the harvest prices. Prices at sign-up should also be attractive, producing higher guaranteed revenues under RP and RP-HPE. If prices decline in 2013 in the face of a large national crop, the revenue guarantees may also result in indemnity payments with only shallow yield losses.

Preferred guarantee levels have changed little

As mentioned earlier, crop insurance based on farm yields can select guaranteed yields ranging from 50 to 85 percent of the APH average. Premium subsidy rates decline as coverage levels get higher, but the 85 percent guarantee level still receives a 38 percent premium subsidy when basic units are used to organize land parcels for calculating the APH yield.

The most popular coverage level in Nebraska has long been the 70 percent guarantee level. In 2012, 36.9 percent of all insured acres were covered at the 70 percent level, followed by 31.7 percent of acres covered at the 75 percent guarantee. Only 12.1 percent of acres were insured at the 65 percent guarantee level. In 2002, 19.1 percent of acres were covered the 65 percent guarantee, 33.3 percent of acres at the 70 percent level, and 28.8 percent of acres were insured at the 75 percent level.

Although overall coverage choices have gradually crept higher over time in Nebraska, they are well below those seen in Iowa, where about 34 percent of insured acres are covered at the 80 percent guarantee level and about 17 percent of acres are covered at the 85 percent level in 2011.

Other risk management issues for 2013

Of course, crop insurance isn't the only risk management issue that will be important to producers in 2013. At least two other topics deserve brief mention here.

The first of these is the risk-related provisions in any new Farm Bill. Similar programs proposing additional revenue protection were developed by both the House and Senate in their Farm Bill deliberations in 2012. While the Senate passed the bill sent forward from its Agriculture Committee, the full House did not take up debate of the Farm Bill sent up from its Agriculture Committee before the November 2012 elections. As of mid-November 2012, the final provisions of any Farm Bill are still unknown.

The risk-related programs proposed in both House and Senate versions are similar in the sense that they would provide "shallow loss" protection that is not covered under current crop insurance programs. The maximum guarantee level under YP, RP, and RP-HPE plans is 85 percent. The House and Senate proposals would offer higher coverage still, with various combinations of farm and county yield criteria to trigger any farmer payments. One might say that these programs sit on top of a producer's MPCI coverage and provide protection for that segment of revenue that falls under the crop insurance "deductible." Other notes in these proceedings should discuss the various Farm Bill proposals in much greater detail.

A final and most obvious risk management issue is the question of overall yields and prices for 2013. On the upside, with low expected ending stocks after the smaller 2012 crops, low yields in 2013 could produce another price surge like the one witnessed in 2012. On the downside, relatively high crop prices in early 2013 should lead to very large plantings and create the potential for a huge crop in 2013 if yields are normal or higher. As always, producers need to revisit their marketing plans through the year as conditions warrant.

Farm Bill Options, Impacts, and Outlook

Bradley D. Lubben
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After the 2012 elections, Congress returned to Washington, DC for a lame-duck session to address the "fiscal cliff", the simultaneous challenge of expiring tax legislation and pending budget sequestration. This dual threat has been dubbed the fiscal cliff for the obvious danger ahead if either is neglected before the end of the year. Expiring tax legislation would raise tax rates on millions of Americans beginning January 1 and would predictably harm the slow economic recovery, but any extension of current tax policy to avoid the higher rates would also costs billions in terms of federal budget scorekeeping. Similarly, automatic budget sequestration would make substantial cuts to numerous domestic and defense programs starting January 2, but any effort to avoid those cuts would also cost billions on the federal budget sheet.

That the farm bill would be addressed during the lame-duck session was largely assumed as of mid-November. Statements during the campaign season promised it would be on the agenda. The focus on the fiscal cliff and any legislative solution could involve budget savings promised in proposed farm bill reforms. And, perhaps most significantly, the looming possibility of permanent farm bill legislation from 1949 taking effect on January 1 added the necessary sense of urgency to get something done, whether a full reauthorization or at the least, a temporary extension of then-expired 2008 Farm Bill legislation.

While this analysis was written prior to any farm bill deliberation in the lame-duck session of Congress, it was written with expectations that the principal farm bill proposals as passed in the Senate or in the House of Representatives Agriculture Committe will form the basis of any final compromise. The major differences between the two farm bill proposals were largely constrained to a price-vs.-revenue debate for the commodity program and a question of the size of spending cuts for food assistance programs. While the food assistance spending question became the real political sticking point leading up the election, the commodity program debate is of relevance here.

Farm Bill Research

On-going research at the University of Nebraska is focused on an analysis of farm income, policy, and risk management decisions that impact Nebraska producers. The research model and analysis was initially developed through grant support of the Nebraska Soybean Board, while on-going research is currently funded by the Nebraska Corn Board. The research essentially addresses the question of price, yield, and revenue risk for Nebraska producers, building on historical price and yield distributions and correlations. Model farms, one for each agricultural statistics district in the state, provides a representative sample of crop acreage, crop mix, yield levels, and yield variability throughout the state for analysis. The model includes a representative mix of wheat, irrigated corn, nonirrigated corn, irrigated soybeans, and nonirrigated soybeans across the state. Figure 1 shows each representative farm and county in each district across the state.

The model has been used to analyze various policy and risk management questions, ranging from early proposed changes in the ACRE program to preferred risk management strategies for producers under current farm program and crop insurance options. Each analysis is based on a simulation of 500 draws or possible outcomes for each representative farm based on the price and yield distributions and correlations. The averages and distributions of those 500 draws provide the basis for the following analysis of the alternative commodity program proposals and related crop insurance language and provide a comparison of the House and Senate farm bill proposals and impacts for Nebraska producers.

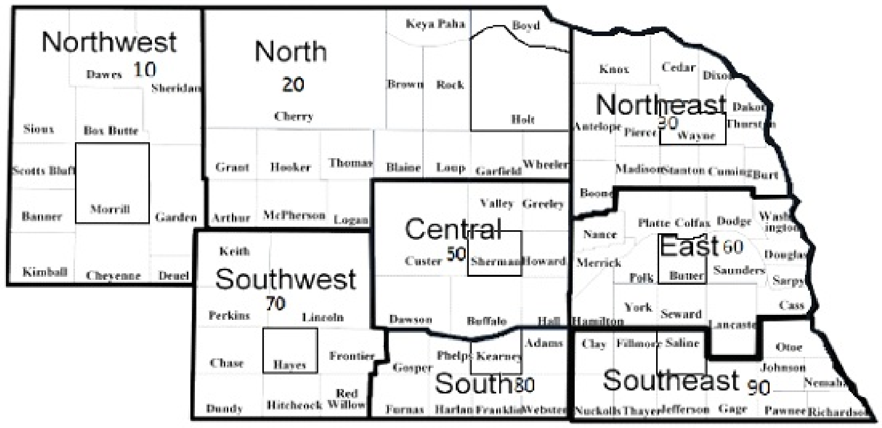

Figure 1. Nebraska Farm Income and Risk Model Representative Farms

Farm Bill Proposals

The current farm bill proposals differ primarily in whether the offer just an average revenue-based safety net (Senate) or an average revenue vs. fixed price-based safety net (House). Whether the farm bill was completed in the lame-duck session of Congress or was pushed off to the new year and the new Congress, these basic options and differences should frame the decision for producers.

In the Senate proposal, the program is called ARC, or Agricultural Risk Coverage. It would provide a revenue-based safety net based on 5-year average yields and average prices. It is a shallow-loss program that would start paying on losses below 89% of the average revenue benchmark, but would only pay on losses down to 79% of the benchmark. There is a proposed option to base the coverage on either farm-level revenue or county-level revenue. Farm-level protection would be expected to pay more often based on more yield variability at the farm, but the payment rate is lower, creating at least some offset.

In the House proposal, the choice is between Revenue Loss Coverage (RLC) or Price Loss Coverage (PLC). RLC provides shallow-loss revenue protection similar to the Senate ARC proposal at the county level, but the trigger starts at 85% of the benchmark and pays on losses down to 75% with a different payment rate. Alternatively, PLC provides traditional counter-cyclical income support if season-average market prices drop below target prices. The proposed target prices are substantially increased relative to existing target prices in 2008 and earlier legislation.

Both Senate and House revenue safety net proposals only cover shallow losses and presume that farmers will purchase individual crop insurance as the foundation of their risk management plan. Another component of the proposed safety net is a Supplemental Coverage Option (SCO) that would provide producers the option to purchase a subsidized area-based revenue insurance policy on part of their crop insurance deductible. The availability of this option varies between the Senate and House versions, but essentially it could cover the gap of losses that are not covered by either the revenue safety net program or the individual crop insurance purchase.

Table 1 provides an overview of the mechanics of each of the farm program options and establishes the “scenarios” for analysis in the research model. The first scenario is not participating in any program or purchasing any insurance to produce a crop revenue only result for comparison. The second scenario considers only the purchase of SCO, which would be possible under the Senate proposal if not participating in the ARC program, coupled with Revenue Protection (RP) crop insurance at the 70% protection level, the most common protection and level purchased in Nebraska. The third and fourth scenarios consider the ARC plan from the Senate at either the farm or county level. Under these proposals, ARC pays on losses from 89% to 79% of 5-year Olympic-average revenue. As a result, SCO is only available below 79% down to the 70% RP policy. Scenario 5 includes the RLC coverage from 85% down to 75% of 5-year Olympic average revenue as proposed in the House. This option specifically excludes eligibility for SCO, so there is a gap in protection down to the 70% RP coverage. Finally, Scenario 6 considers the PLC option in the House proposal, which provides counter-cyclical payments based on a revised target price as noted in the table. Importantly, this option was written in the House proposal as allowing SCO at 90%, so the scenario considers SCO from 90%-70% and RP at 70%.

Table 1. Farm Program Options, Supplemental Crop Insurance and Revenue Protection Scenarios

Scenario	Commodity Program		Supplemental Coverage Option	Crop Insurance
	Program	Coverage Level		
NP-NSCO-NI	No program	-	No SCO	No crop insurance
NP-SCO-RP	No program	-	SCO (90%-70%)	RP (70%)
ARCF-SCO-RP	ARC-Farm	89%-79% of 5-year average farm revenue	SCO (79%-70%)	RP (70%)
ARCC-SCO-RP	ARC-County	89%-79% of 5-year average county revenue	SCO (79%-70%)	RP (70%)
RLC-NSCO-RP	RLC	85%-75% of 5-year average county revenue	No SCO (not available)	RP (70%)
PLC-SCO-RP	PLC	counter-cyclical payments below target prices: corn = $3.70 soybeans = $8.40 wheat = $5.50	SCO (90%-70%)	RP (70%)

Farm Bill Analysis

Using the scenarios and farm program options described in Table 1, we can analyze economic impacts on representative Nebraska crop producers. Table 2 provides a per-acre analysis of just the expected commodity program payments for 2013, given trend yield expectations and price expectations as of September 2012.

Based on current price expectations for 2013, the ARC program at the farm level clearly outperforms every other commodity program proposal. Not surprisingly, the farm-level coverage of ARC at the farm pays more often and at higher average levels than ARC or RLC at the county level. PLC in the last column does not pay at all, indicating that at current price expectations, we could not simulate any price drops large enough to trigger any counter-cyclical payments for 2013, even at the proposed higher target prices.

A second important component to consider is the potential premiums and indemnities from SCO. The coverage looks particularly attractive, considering the proposed 70% subsidy rate for premiums. The available coverage also varies between farm program options, meaning that commodity programs and SCO really need to be analyzed together to get a true picture of the potential payments. Table 3 provides that full analysis of expected payments.

Table 2. Average Commodity Program Payments per Acre by Representative Farm

Representative Farm	Risk Management Scenario				
	NP-SCO-RP	ARCF-SCO-RP	ARCC-SCO-RP	RLC-NSCO-RP	PLC-SCO-RP
District 10 Farm	$0.00	$13.32	$0.74	$0.56	$0.00
District 20 Farm	0.00	12.55	0.30	0.22	0.00
District 30 Farm	0.00	20.17	0.01	0.00	0.00
District 50 Farm	0.00	13.03	0.83	0.74	0.00
District 60 Farm	0.00	20.26	0.45	0.32	0.00
District 70 Farm	0.00	10.88	0.77	0.67	0.00
District 80 Farm	0.00	5.96	0.63	0.52	0.00
District 90 Farm	0.00	22.61	1.41	1.18	0.00

Table 3. Average Commodity Program and Supplemental Coverage Net Payments per Acre by Representative Farm

Representative Farm	Risk Management Scenario				
	NP-SCO-RP	ARCF-SCO-RP	ARCC-SCO-RP	RLC-NSCO-RP	PLC-SCO-RP
District 10 Farm	$16.35	$16.94	$4.36	$0.56	$16.35
District 20 Farm	4.97	13.26	1.01	0.22	4.97
District 30 Farm	1.73	20.28	0.12	0.00	1.73
District 50 Farm	6.45	14.09	1.89	0.74	6.45
District 60 Farm	5.87	21.52	1.71	0.32	5.87
District 70 Farm	6.73	12.09	1.99	0.67	6.73
District 80 Farm	5.30	7.16	1.84	0.52	5.30
District 90 Farm	9.55	25.19	3.99	1.18	9.55

When analyzing the combination of commodity program payments and SCO net payments, the picture becomes much more mixed. While ARC at the farm makes the largest commodity program payments (as shown in Table 2), the availability of SCO is substantially limited under ARC (and not available at all under RLC). But, if a producer can and does purchase the maximum SCO coverage (90% down to the assumed 70% RP coverage) by not participating in ARC or by choosing the PLC option, then expected net SCO payments are substantial, particularly in the Panhandle (District 10). Based on expectations, ARC at the farm with limited SCO still appears preferable to the other options for Nebraska producers, but the availability of SCO is an important consideration.

Two graphs complete the analysis and discussion of farm program alternatives. Figure 2 is an illustration of the probability of commodity program and SCO payments on the farm in Southwest Nebraska (District 70). With the inherent yield variability of the region, this representative farm shows a good picture of how payments compare across strategies. The chart is a plot of the Cumulative Density Functions (CDFs) for each of the scenarios in the study. To read the CDF, you read the number on the left axis as the probability that the actual payment will be less than or equal to the number on the bottom axis. For example, the brown line (PLC-SCO-RP) cross the $0 line at approximately 0.4, meaning there is a probability of about 40% that this scenario will result in negative payments (remember there are farmer-paid premiums on SCO). A scenario with a line that is further to the right in the graph is preferred to the others as it indicates greater payments and probabilities. Since the lines cross multiple times, there is not an obvious optimal scenario in this method of analysis, but is clear that either the ARC plan at the farm (ARCF-SCO-RP) or the PLC plan with SCO (PLC-SCO-RP) provide the greatest probability and size of expected payments.

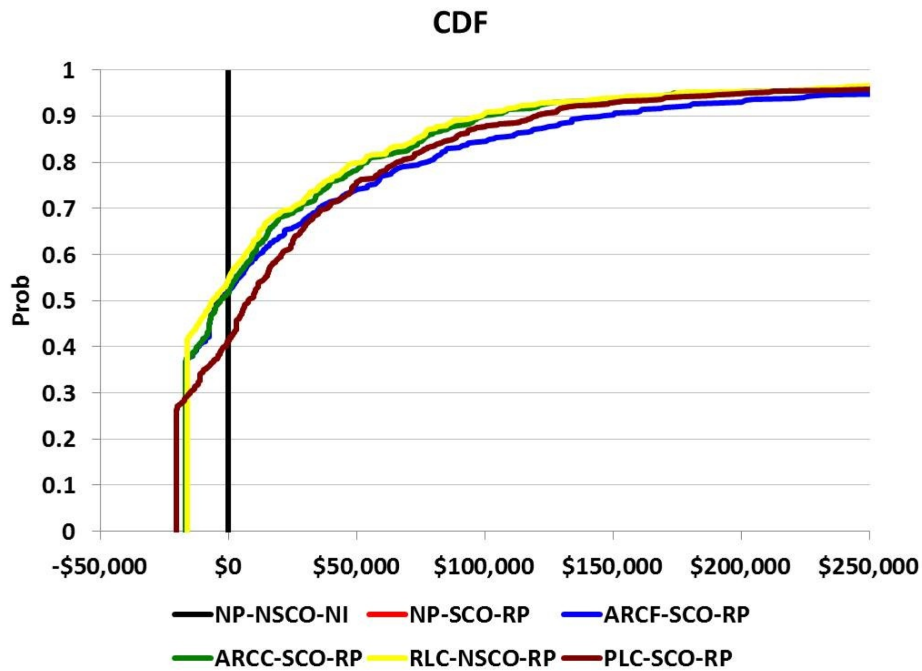

Figure 2. Commodity Program Payments and SCO Net Payments on the District 70 Representative Farm

The second graph is shown in Figure 3 and is a CDF chart of the total adjusted crop revenue on the farm, including actual crop revenue, commodity program payments, net SCO payments, and net RP payments. The graph shows the impact of expected prices for 2013 in terms of expected revenue on representative farm in Southwest Nebraska. The scale of expected crop revenue generally dwarfs the expected payments from commodity programs and crop insurance (SCO and RP), except on the low end of the scale. As compared to the do nothing approach (NP-NSCO-NI), all of the scenarios substantially improve the worst-case outcomes. Buying crop insurance (RP in the study), buying SCO, and participating in the farm program all improve on the bottom line, with differences of nearly $400,000 between the worst-case outcome of doing nothing and the other scenarios of various farm program and insurance combinations. At the 10% probability level, the do nothing scenario has a value just over $900,000, which implies a 10% chance of doing worse than $900,000 in crop revenue. By comparison, adopting one of the other scenarios or strategies improves the 10% probability value to nearly $1.1 million, indicating the strong protection at the low end from the combination of commodity programs, SCO, and RP.

The analysis demonstrates the substantial impact that proposed commodity programs and supplemental crop insurance could have for producers across the state. The analysis shows the largest expected payments from the ARC program at the farm level, although the greater availability of SCO under the PLC plan can greatly offset that advantage. And the probability analysis shows some mixed results between the various scenarios.

It is important to remember again that this is an analysis of farm program alternatives and expectations for 2013 revenue and payments. At current expected price levels, the price safety net of PLC never kicks in and the advantage of an average revenue-based safety net is clear. But, if price levels were to someday return to lower levels and remain lower, then the PLC plan could make substantial payments over several years, even as the average revenue-based plans eventually offer lower protection with lower average prices. The optimal policy option for producers is partly a function of producer expectations for prices over the life of the farm bill. Even the choice between participating in a commodity program tied to average revenue (average yields and average prices) vs. participating in greater purchases of SCO (tied to current-year prices) could vary from year to year based on current prices relative to the 5-year Olympic average price.

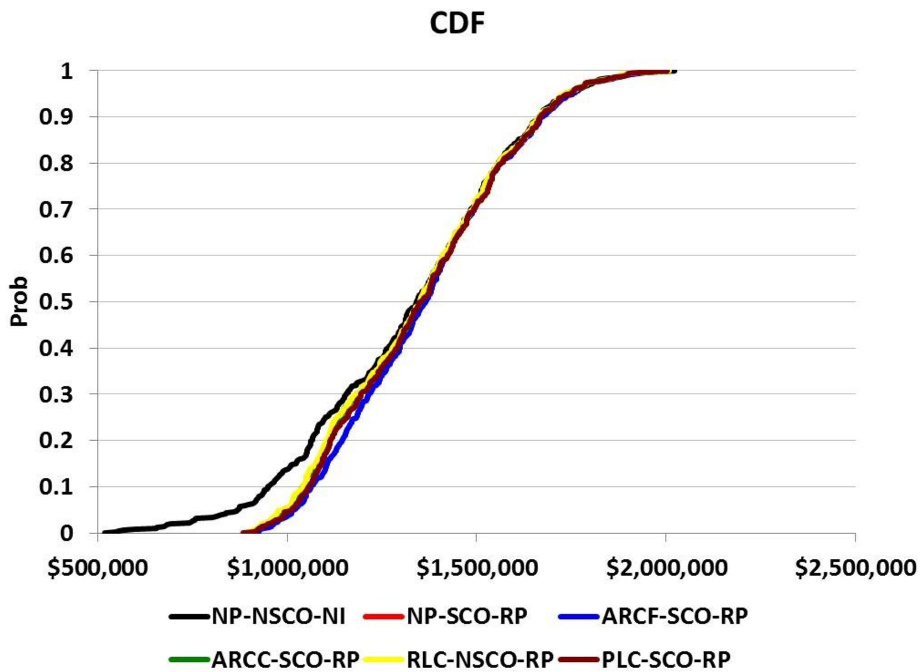

Figure 3. Crop Revenue, Commodity Program Payments, SCO Net Payments, and RP Net Payments on the District 70 Representative Farm

Farm Bill Outlook

As of mid-November, expectations were for Congress to take up the farm bill, likely as part of a broad legislative effort to address the fiscal cliff. If so, the farm bill could well contain both a revenue-based and a price-based safety net in line with the House proposal as a necessary compromise. If the farm bill is not completed in 2012, a short extension to push the debate to a new Congress in 2013 will still leave the same basic framework and options for commodity programs. Thus, the analysis should provide good guidance for producers on how the programs could work and how they could offer risk protection in 2013 and beyond. Expected payments look to be smaller than the direct payments of the past that are essentially guaranteed to disappear, but the risk protection against crop revenue losses could be substantially greater and should merit careful attention and decision-making from producers.

Adjustments for Next Year's Pasture Leases

Allan Vyhnalek, Extension Educator

One of the harder phone calls to deal with in early September 2012 was from a land owner that was concerned that the tenant left their cattle on a pasture too long given the drought and the pasture was turned into a 'road'. The landlord was willing to take less rent and get the cattle off. The tenant, who had a lease valid until October 20th, was unwilling to take the cattle off early, as this meant that the tenant would need to start feeding the cattle with expensive hay. For the tenant, the pasture rent was already paid for and that was cheaper than other alternatives.

It is easy to see how this is difficult for both parties. Everyone understands that leaving the cattle on the pasture too long reduces the long-term health of the pasture. The pasture will basically take a lot longer to recover if it has been severely overgrazed.

Clauses and discussions needed for next year…

The easier way to handle this situation in the future is to include a clause in your written pasture lease for dry conditions. When it is too dry to continue using a pasture, the tenant should be required to take the animals out. In addition, the rent owed should be adjusted lower, accordingly.

Other important clauses should be considered. What if there is a severe hail? What if the pasture burns in a fire? The clause for drought should probably be expanded to include these two disaster situations too.

In addition, it seems to me that discussions should occur about when grazing starts next year. If we get adequate rain and grass starts normally then this is a moot point. But if it doesn't rain, or if the grass is slow starting because of overgrazing in 2012, delaying the start of grazing should be a reasoned approach for 2013 management of the pasture. The rent owed should also be adjusted accordingly.

If we have slow re-growth in 2013, stocking rates should also be adjusted to fit the moisture available and the growing conditions. Having leases priced on an Animal Unit Charge (AUM), and not by the acre, may be a reasoned approach to handle this change in stocking rates.

In most situations, the livestock drinking water is not an issue. But a clause should also be added to include provisions for livestock water if the water source goes dry. Another possibility based on this year's drought, is that pastures which receive moisture could become over-run with weeds. This would never be a problem when the pasture is grazed appropriately. However, when that thatch canopy is opened, seeds which have been in the ground for years now start to grow. A discussion about the expense of weed control is appropriate.

Typically, the weed control of pastures is a landlord expense. But in this case, the tenant over-grazed the pasture causing the weed flush after receiving moisture. Tenants didn't mean to over graze, the 2012 drought was as severe as any in 50 years according to some. Managing the weed control in the next couple of years will be something that clearly needs to be discussed to reach an equitable agreement.

As you can tell, there aren't many concrete suggestions for solutions to these situations. The key point of providing this information is to encourage the tenant and landlord to plan ahead for 2013 in case the drought continues.

I have always maintained on any lease, communications will be the key. So managing the pasture as we move forward from 2012 will also need to be discussed. The tenant should be letting the landlord know about the pasture conditions and the landlord should be communicating their expectations too. The bottom line is: "Hope for the best, but plan for the worst."

Notes:

The 2012 Soybean Management Field Days
Quest For the Holy Grail of Soybean Production: 100 Bushel Soybeans

Greg Kruger, Cropping Systems Specialist
Evan Sonderegger, Graduate Student

In 2012, the Nebraska Soybean Board and the University of Nebraska-Lincoln partnered to better understand soybean yield and yield components in an attempt to ascertain whether or not 100 bushel/acre soybean production was possible. Studies conducted in Minnesota, Wisconsin, Kentucky, Missouri, Arkansas, and other major soybean production states in recent years have concluded that soybeans are versatile but there are certainly some agronomic practices which can be implemented to maximize production. They found narrow row spacing to be the most important practice that growers can adopt to increase yields.

In 2012, replicated research studies were conducted at each of the Soybean Management Field Day sites (Lexington, O'Neill, Platte Center, and David City). At each site, two studies were conducted to better understand the interaction of grower decisions based around row spacing x plant population and maturity group x plant population. For the first study, 15 inch and 30 inch row spacings were compared at 100,000, 150,000, and 200,000 seeds/acre. In the second study, a 2.4, 2.9, and 3.4 relative maturity soybean were planted at 100,000, 150,000, and 200,000 seeds/acre.

Notes were taken from each study including final plant population, yield, and 6 ft. row per plot. From the full plant harvests, the number of soybean seed/plant and seed size were determined. Additionally, at Mean and North Platte, a study was conducted looking at the same relative maturity soybean at 50,000 and 250,000 seeds/acre beyond those in the relative maturity x plant population study. In the study at Mead and North Platte, the plots were seeded near May 1st and June 1st.

In studies conducted in other states in recent years, they concluded that early planted soybean have a greater yield potential than later planted soybean. Our study seeks to confirm if this is true across a wide range of relative maturity groups in Nebraska or if planting date is less of a factor in Nebraska. While none of the treatments, resulted in 100 bushel/acre, valuable information was gained on production practices which could potentially increase yields for Nebraska growers.

Much like the results from other states, narrow row soybeans have had greater yields and, in general, earlier planting date resulted in higher yields. Going into 2013, the results from these studies will be examined in more detail to better understand how growers can maximize soybean yields in Nebraska. Interestingly, studies in Nebraska have shown that management decisions had no impact on soybean seed size. Management decisions did have an impact on the number of seeds/acre though.

As we better understand relationships such as number of seeds/acre and seed size resulting from agronomic practices, we will be better suited for making recommendations to growers.

Notes:

Grain Storage Management to Minimize Mold and Mycotoxins

Thomas W. Dorn, Extension Educator
Tamra A. Jackson-Ziems, Extension Plant Pathologist

Grain Quality Concerns

As most dryland corn producers are aware, the dry and hot growing season in 2012 resulted in reduced corn yields with moderately lower test weights. Along with the reduced test weights are concerns about potential mycotoxin contamination in the drought-stressed grain.

The only way to know for sure if there are mycotoxins in your grain and which specific mycotoxins are present is to collect representative grain samples and have them tested by a certified laboratory.

Many species of fungi can cause ear rot diseases and molding of grain. Most of these fungi become associated with the grain in the field, but may continue to grow and reproduce if grain is stored under favorable conditions of moisture and temperature in the bin.

Harvested corn is NOT necessarily safer in the bin than in the field with regard to maintaining grain quality. If there was a problem with ear rot diseases in the corn in the field, there will likely be grain mold problems in the bin. Even under the best storage conditions, grain mold fungi are likely to continue to grow in the bin, where some can also produce mycotoxins. Under these conditions, it is important to cool and dry harvested corn as quickly as possible – preferably within 48 hours of harvest. It is NOT recommended to store infected grain, particularly for extended periods of time. In addition, grain that is damaged during or after harvest, such as during handling or storage by insects or other mechanical means, is much more prone to fungal infection by grain molds.

Ear rot diseases and grain molds can lead to substantial reductions in grain quality that can ultimately cost producers who may be penalized at elevators or by loss of feed quality.

Grain Moisture

Wet grain (greater than 16 percent moisture) loses quality grade three times faster when it is not being aerated to reduce the heat created by microbial respiration. Grain should be dried as quickly as possible by running the fan(s) continuously (rain or shine) until grain is below 17% moisture to slow mold growth in the grain. When grain is below 17% moisture, run fans even if foggy or raining to carry away heat buildup in the bin <u>at least every 3 days</u> until the moisture content throughout the entire bin is below 15% moisture. When grain is below 15% moisture, you may begin to run aeration fans intermittently when the equilibrium moisture content table indicates additional drying is possible.

If it is likely that fungi that produce mycotoxins are present in the corn, dry the grain to 14% moisture if it will be held for one month and if grain will be stored for over a month, dry the grain down to <13% moisture. If the corn is found to have <u>any</u> level of mycotoxin contamination it is recommended to partially fill the bin(s) initially, such as1/4 of the capacity of the bin, so the fan(s) will produce higher airflow rates (cfm/bu) and therefore dry the grain quicker and reduce mold growth and mycotoxin production and contamination of the grain.

If the bin was equipped with a stirring system, run a couple of rounds each time four or more feet of corn is added to the bin. Stirring will help to equalize the moisture content in the grain and to prevent over-drying the bottom of the bin. However, be careful to not over stir, as the down augers can damage the kernels and small cracks in the seedcoat allow fungal infection of the kernels.

Grain Temperature

In addition to getting the corn dry, you need to cool the grain whenever ambient air temperature allows. This will slow the growth rate of the fungal organisms and will prolong the shelf life of the grain. Run the fans whenever the air temperature is 10 degrees below the grain temperature in the bin to cool the grain. This advice holds even in years when we are not expecting mycotoxin contamination. Continue running fans until the grain is 30 degrees F Reducing the grain temperature down to near freezing will stop mold growth. Nevertheless, check bins at least once a month for any signs of heating.

If your bin is not equipped with a grain temperature monitoring system, you should consider purchasing a grain thermometer *that* can be pushed into the grain. I recommend you buy a grain thermometer that can be pushed at least four feet into the grain. Some suppliers sell the thermometer head without an extension rod, but they have a threaded female socket that accepts a 3/8 inch threaded rod (ready-rod).

When measuring grain temperature, always allow at least five minutes for the thermometer to equalize with the grain before taking each reading. Take readings about every 20 feet around the perimeter of the bin, but maintaining a distance of at least two feet from the bin wall. Then check several places in the center of the bin. If you find a difference of eight degrees or more between the warmest and coldest spot in the bin, run the aeration fan(s) to equalize the grain temperature in the bin. If you detect a musty smell when you turn on the fan or if you see condensation on the inside of the bin roof on a cold day, you might have a hot spot developing in the grain in the bin. Most often, these hot spots develop in the center of the bin directly under the loading auger where the majority of the fines collect. If you detect any of these warning signs you should consider unloading some grain and observe the grain coming out of the auger for signs of heating or spoilage.

If there are confirmed mycotoxins in the grain at harvest, it is safer to avoid storage of the affected grain. It is not recommended to hold the grain in the bin after temperatures begin to warm again in the early spring, Mold spores in the bin will survive harsh winter conditions and continue to grow again once temperatures exceed 40 degrees F. In addition, mycotoxins are temperature stable and their concentrations will not decline in storage, but likely only increase.

Disinfesting Bins

It is important to thoroughly clean out the bin once it is empty, including all grain and grain dust that could still contain pathogens and insect pests. When moldy grain has been removed from the bin, you can use a spray disinfectant on all inside surfaces in the empty bin to kill mold spores.

For example, you may use 1 gallon of 5.25% household laundry bleach to 20 gallons water. Then rinse the bleach off with water a few days later to ensure the bleach does not cause corrosion on the galvanized metal.

Chlorine fumes are dangerous. You will need a lot of ventilation while working in the bin. NEVER mix bleach with ammonia or vinegar!

For More Information

For more information, see the 2013 Crop Production Clinic article and presentation entitled, "Corn Disease Update" in these Proceedings. Additional information on these and other diseases can also be found at the website Plant Disease Central at http://pdc.unl.edu/ or in the following UNL Extension publications:

Sampling and Analyzing Feed for Fungal (Mold) Toxins (Mycotoxins)
http://www.ianrpubs.unl.edu/epublic/live/g1515/build/g1515.pdf

Understanding Fungal (Mold) Toxins (Mycotoxins)
http://www.ianrpubs.unl.edu/epublic/live/g1513/build/g1513.pdf

Use of Feed Contaminated with Fungal (Mold) Toxins (Mycotoxins)
http://www.ianrpubs.unl.edu/epublic/live/g1514/build/g1514.pdf

Corn Disease Profile III: Ear Rot Diseases and Grain Molds
http://www.ianrpubs.unl.edu/epublic/live/ec1901/build/ec1901.pdf

Western Bean Cutworm Update

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Western bean cutworm (WBC) is not a new pest to Nebraska, but in recent years it has expanded its range from a fairly local pest in parts of Colorado, Kansas and Nebraska to a pest of corn and dry beans across the U.S. Corn Belt. 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. 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 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 ponds 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, 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 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.

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 and can be found by typing "Western Bean" into the Apple search box.

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.

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 pheromone 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

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. Damsel bugs, 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*.

Field corn hybrids that contain genes that cause the plants to produce Cry 1F or VIP3A *B. 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 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.

How to Submit an Insect Sample for Diagnosis

Jeff Bradshaw, Entomology Specialist
Sean Whipple, Entomology Postdoctoral Associate

Over the past couple years I have received a number of samples to identify or plant parts with injury in need of a diagnosis. Some of these specimens were not handled well and in some cases made it very difficult or even impossible to identify. My hope is that this document can serve as a reminder as to how best preserve, store, and submit insect or insect-related samples for identification and diagnosis. This publication is not meant as a guide for insect collecting as much as a guide for best practices to have the best chances of having a sample correctly identified.

Killing and Preserving

Insects and mites of all kinds may be killed and preserved in liquid agents; however, some insects may need to be killed in a gaseous agent and then stored dry.

Ethanol (grain or ethyl alcohol) mixed with water (70 to 80 percent alcohol) is usually the best general killing and preserving agent. For some kinds of insects and mites, other preservatives or higher or lower concentrations of alcohol may be better. Because pure ethanol is often difficult to obtain, some use isopropanol (isopropyl or rubbing alcohol).

A high alcohol concentration (95%) may also be used if large numbers of insects are to be killed in a single container, because the insect body fluids will dilute the alcohol. On the other hand, soft- bodied insects, such as aphids and thrips, small flies, and mites, become stiff and distorted if preserved in 95 percent alcohol and should be preserved in alcohol of a lower concentration. Adult bees should not be collected in alcohol because their usually abundant body hairs become badly matted and interfere with identification. Adult moths, butterflies, mosquitoes, moth flies, and other insects with scales and long, fine hairs on the wings or body may be worthless if collected in alcohol regardless of the concentration.

Formalin (formaldehyde) solutions should not be used because the tissues become excessively hardened and the specimens then become difficult to handle.

Larvae of many insects (e.g., caterpillars, grubs, or maggots) should not be collected in alcohol. It is best to either bring in the live specimen or "fix" the specimen in boiling water prior to storing them in alcohol. Boiling the specimen fixes their proteins and prevents them from turning black. Larvae should be left in hot water for 1-5 minutes, depending on the size of the specimens, then transferred to 70-80 percent alcohol. Large specimens or small specimens that have been crowded into one vial should be transferred to fresh alcohol within a day or two (or start with a higher concentration of alcohol as noted above) to reduce the danger of diluting the alcohol with body fluids. If the alcohol becomes too diluted, the specimens will begin to decompose. Water is not a preservative.

Temporary Storage of Specimens

After specimens have been collected, there are several ways to keep them in good condition until they can be properly preserved. The method used depends largely on the length of time that the specimens may have to be stored temporarily.

Medium to large specimens may be left in tightly closed bottles for several days in a refrigerator and still remain in good condition. Some moisture must be present in the containers so that the specimens do not become "freeze-dried," but if there is too much moisture, it will condense on the inside of the bottle as soon as it becomes chilled. Paper towel placed between the jar and the insects will keep them dry. When specimens are removed for preservation, place them immediately on paper towel to prevent moisture from condensing on them.

Insects may be placed in alcohol, as described previously, and kept for several years. However, it has been shown that many insects, especially small ones, can deteriorate in alcohol stored at room temperature.

It is standard practice to place many kinds of insects in small boxes, paper tubes, triangles, or envelopes for an indefinite period, allowing them to become dry. Do not store soft-bodied insects by such methods because they become badly shriveled and very subject to breakage. Flies, for example, should never be dried in this manner because the head, legs, and most of all the antennae become detached very easily and will become very difficult to identify.

Almost any kind of container may be used for dry storage; however, tightly closed, impervious containers of metal, glass, or plastic should be avoided because mold may develop on specimens if even a small amount of moisture is entrapped. Nothing can be done to restore a moldy specimen.

Avoid placing specimens collected at different times or places in the same container. If specimens with different collection data must be layered in the same container, include a separate data slip with each layer. The date and location that a sample was taken can assist in diagnosis and identification.

Liquid Preservation

Preservation of insects, mites, and spiders in alcohol varies a lot by the type of sample. For example, spiders preserve well in ethanol, but not in isopropyl. However, in general, ethanol and isopropanol mixed with water is the most widely used preservation fluids. Most commonly, a mixture of 75% alcohol to 25% water is used. The solution should be thoroughly mixed since alcohols and water do not mix easily by themselves. Additives should be avoided if possible.

For any labels placed into the collection containers, Special care should be taken with labels placed in alcohol.

Paper should be a high quality cotton paper (e.g., resume paper) or it might disintegrate in the alcohol. Some inks (such as India inks) and pencil graphite can withstand exposure to the alcohol the best. Typewritten labels from laser printers will work; however, ink-jet printer ink generally dissolves in alcohol.

Sample Data

To have any scientific value, specimens must be accompanied by a label or labels giving, as a very minimum, information about where and when the specimen was collected, who collected it, and, if pertinent, from what host or food plant.

The indispensable data must answer the questions of where, when, and who, in that order and as exactly as feasible. A detailed submission form can be sent in with you samples can be found at: http://pdc.unl.edu/diagnosticclinics/plantandpest/submissionforms -- This form could be used for submission to the Plant & Pest Diagnostic Clinic or could be used along with your sample to any of your county Extension offices and then forwarded on to the appropriate expert.

Packing Materials

If you can not make it to your local Extension office or would like to send your sample directly to a specialist, adequate shipping procedures will need to be followed. Screw-top mailing tubes are good for most items that you would want to mail. All containers must be large enough to include ample packing material to minimize the effects of jarring-a minimum of 5 cm on all sides. There are a wide variety of packing materials ranging from shaved wood and crumpled newspapers to foam or starch "peanuts". One of the best materials is bubble wrap or blister pack. This is very light weight and has excellent shock-deadening properties.

Shipping specimens in vials

(1) Fill each vial with liquid preservative. Stopper tightly by holding a pin or piece of wire between the vial and the stopper to permit air or excess fluid to escape, then remove the pin or wire. Make certain that cork stoppers do not have defects that will allow leakage. Screw-top vials should be firmly closed and sealed with a turn and a half of plastic adhesive tape or Parafilm around the lower edge of the cap and part of the vial. There is no need to seal with paraffin; it often breaks loose and will not prevent leakage.

(2) Wrap each vial with cotton, tissue, paper toweling, or similar material. Allow no piece of glass to come intocontact with another piece of glass. Several vials may be wrapped together or held with tape or rubberbands as a unit, or they may be placed in a small cardboard box with enough packing to insure that they are not shaken around.

Note that some shippers have restrictions concerning the shipping of hazardous materials. Because alcohol is flammable and considered hazardous, some shippers will not ship material in alcohol (e.g., USPS), while others may require some level of hazardous shipping permit. An alternative (besides shipping dead, but unpreserved or live specimens, see below) is to decant off the all of the alcohol, leaving only the sample. Then, gently pack some cotton into the vial or container until there is limited room for the sample to move.

Shipping Live Specimens

Most insects and mites intended for a collection or submitted to experts for identification should not be shipped alive. To protect American agriculture, Federal law prohibits the importation and movement of live pests, pathogens, vectors, and articles that might harbor these organisms unless the shipments are authorized by the U.S. Department of Agriculture. If it is necessary to ship live material, be sure to comply with all Federal, State, and local regulations. Shipments of live insect material without valid permits may be seized and destroyed by plant quarantine inspectors. In addition to meeting Federal laws, the shipment of some species must be approved by State officials. For most questions regarding most federal regulations, contact the Animal and Plant Health Inspections Service (APHIS) within the U.S. Department of Agriculture.

Pupae or larvae shipped to be reared elsewhere should be placed in tightly closed containers without vent holes. These insects require a minimum of air and will not suffocate. Pupae preferably should be packed loosely in moist (not wet) moss or similar material. Larvae should be packed with enough food material to last until their arrival. Most beetle larvae and some caterpillars, especially cutworms, should be isolated, since they are can be cannibalistic. To prevent excessive accumulation of frass (fecal material) and moisture, do not overload containers. Plant material held without ventilation tends to become moldy, especially when kept in plastic bags. For this reason, pieces of the host plant bearing such insects as scale insects (Coccoidea) should be partially or completely dried before being placed in a container, or they should be packed in a container such as a paper bag, which will permit drying to continue after closure. Live Heteroptera and other small, active insects are killed easily by excessive moisture in the container. Therefore, it is advisable to provide several tiny vent holes or place a fine mesh screen over one end of the container when shipping such insects.

Some containers designed to hold living insects are strong enough to be shipped without additional packing, but generally the containers should be enclosed in a second carton with enough packing material to prevent damage to the inner carton. In all cases, affix a permit for shipping live insects in a conspicuous place on the outside of the shipping container.

In recent months, regulations concerning the shipment of dead specimens has changed markedly. This is largely in response to concerns about trade in rare or endangered species and "wildlife". Previously, most insects were excluded from the category of "wildlife", but recent rules have been expanded to include insects in this definition. However, it is still possible to ship dead insect without special permits within the U.S.

2012 Crop insect concerns

Jeff Bradshaw, Entomologist

Similarly to last year, 2012 had continued reductions in grasshopper numbers with sporadic populations throughout western Nebraska. Due to the very warm winter during 2011-2012 and the addition of a dry growing season, there were some specific insect species that broke out with large populations.

The Good

Beneficial insects. The beneficial insects that were in high numbers in last year's sunflower fields were reduced this year following the decline of grasshoppers. Other beneficial insect numbers also seemed to be reduced, perhaps in part because of the extreme drought and high temperatures.

Reduced pest numbers. Mexican bean beetle numbers were again low this year. They had low populations going into the winter of 2011 and due to the extreme heat this summer eggs survival in June was substantially reduced.

The Bad

Grasshoppers. Although conditions were favorable for high grasshopper numbers in the Spring (dry and warm), there numbers declined over the season as the high heat and extreme lack of moisture provided very little forage for grasshoppers. During the adult survey (July 2-Aug. 30) the only counties with $\geq 15/yd^2$ on average were Scotts Bluff, Morrill, Sheridan, Goshen, Deuel, and Grant. Depending on conditions over the next few months, these counties could see high grasshopper numbers again next year.

Potato pests. Potato psyllids were very low in the western panhandle; however, fields in Morrill and Box Butte colonies did see large psyllid numbers. Fortunately, the potato psyllid numbers did not increase until close to vine kill.

Wheat insects. Early in the season brown wheat mites (Fig. 1) were abundant at isolated locations. Sawflies continue to substantial lodging to isolated fields from Cheyenne to Box Butte. Counties in the West Central District continue to escape this particular insect pest.

Figure 1. Brown wheat mites on wheat.

Dry bean insects. While Mexican bean beetle and western bean cutworm numbers continue to be reduced, the hot and dry weather brought on other issues, thrips. I received numerous reports and samples of thrips in dry beans. The predominate species was the onion thrips, which cause some wilting in furrow-irrigated dry beans.

Sunflower insects. Sunflower head moths (Fig. 2) were very abundant this year. Early-planted fields were hit hard by this insect and its associated head rot. Additionally, stem borers and stem weevils were also abundant. Some dryland confection sunflowers lodged due to insect feeding leaving 1,000s of pounds of grain in the field.

Figure 2. Adult sunflower head moth

The Bizarre

Beet armyworms. This year we faced a major outbreak of beet armyworms, particularly in sugarbeet fields. These insects were reported in dry bean, alfalfa, corn, and sugarbeet this year. This is, supposedly, a migratory species and this is the first time a major outbreak of this insect has been reported in western Nebraska in at least 20 year. Let's hope that this insect does not become a regular problem.

2012 Crop Insect Issues

Robert Wright, Extension Entomology Specialist

Beet armyworm on corn

We received reports of beet armyworm (*Spodoptera exigua*; Lepidoptera: Noctuidae) caterpillars in south central Nebraska on seedling and whorl stage corn. It is relatively uncommon to find beet armyworms on corn in Nebraska. They do not overwinter in Nebraska, but moths can migrate from the south with the proper frontal systems. Newly hatched beet armyworm larvae scrape the green leaf surface producing a window-pane effect, similar to feeding by fall armyworms (*Spodoptera frugiperda*). As larvae grow larger, they begin feeding within the whorl, producing ragged holes in the leaves as they emerge, similar to feeding by corn earworms. Later in the summer beet armyworms were also found damaging a variety of crops in southwestern and western Nebraska, including corn, sugar beets, and soybeans. Beet armyworm larvae can reach 1.25 inch in length at maturity, are smooth skinned, light green-dark green in color, usually with a small dark spot on the side of the second thoracic segment.

One concern to be aware of is that beet armyworm populations in the deep south have been reported to be resistant to many pyrethroid insecticides, and apparently the beet armyworms in Nebraska were not easily controlled with pyrethroid insecticides, although we do not know if this was because of resistance or high temperatures at the time of application. Other potential active ingredients for control that are not pyrethroids, depending on crop, include chlorantraniliprole, indoxacarb, methoxyfenozide, methomyl, or *Bacillus thuringiensis*.

Millipedes on corn and soybeans

There were reports of millipedes damaging corn and soybeans in eastern Nebraska and Iowa in 2012. Typically, millipedes are most common in fields with heavy crop residue on the surface, for example in a field after several years of corn, in a no-till or minimum till system. Often there is some confusion about these close relatives of insects, because people often refer to them as wireworms, which entomologists recognize as the name for immatures stages of click beetles (Coleoptera: Elateridae). There are no research reports to suggest what insecticides would be good at controlling millipedes in these situations. Longer term management practices which reduce the amount of crop residue (rotation, tillage) may make the environment less favorable for millipedes.

Aster leafhoppers

We received several reports of Aster leafhoppers (*Macrosteles*) (Hemiptera: Cicadellidae) in small grains and turf in southeastern Nebraska in early summer. There were widespread reports of these leafhoppers across a very large area of the mid-west in 2012, from southeastern Kansas up to North Dakota. Aster leafhoppers have a broad host range including grass and broadleaf plants. One concern in some crops, particularly vegetable crops, is that Aster leafhoppers are capable of transmitting the microorganism that causes Aster yellows disease.

Army cutworm moths

We had high populations of army cutworm moths in many areas of Nebraska in spring 2012 congregating around houses and other structures. There were many questions about what impact these moths would have on corn and other spring planted crops. In some cases, corn fields were treated at planting time because of concern about potential damage by army cutworms.

It is important to understand the life cycle of army cutworms. The moths have one generation per year. The eggs are laid in the fall, the caterpillars hatch and begin feeding, then overwinter as partly grown caterpillars. As temperatures increase in the spring, they become active again, feeding on small grains, alfalfa or pasture grasses until they complete development, and pupate. When the moths emerge, they feed on nectar from flowering trees and shrubs. After these flowers are no longer available they move west to the foothills of the Rocky Mountains, where they ‘hibernate’ during the summer. So the moths we see in the spring have no impact on corn or other spring planted crops. In some cases, there were more than one species present in the moths aggregating around houses, and some of these moths were species that lay eggs in the spring. Regardless, high numbers of moths around buildings does not predict damage to fields; moths use various factors to select egg-laying sites (type and stage of plants present, presence of crop residue, etc.). Don’t apply insecticides to control insects that are not present in your field.

False chinch bugs

False chinch bugs (*Nysius* sp.) (Hemiptera:Lygaeidae) were reported on several crops, including corn and alfalfa in southeastern Nebraska in early summer. False chinch bugs are similar in size and shape to chinch bugs, except they do not have the white X-shaped marking found on chinch bugs. The first generation of false chinch bugs usually develops on winter annual weeds in the mustard family (penny cress, wild mustard, etc.). As these plants mature or are killed by cultivation or herbicide use, the false chinch bugs migrate to nearby plants to feed. They have a rather large range of plants on which they will feed. Often large numbers of these bugs are found at field edges as they move into a field. High populations can damage or kill new growth on plants, and in some cases may kill plants. If needed, border treatments of foliar insecticides can be applied.

Japanese beetles in corn and soybeans

We continue to receive reports of Japanese beetles feeding in corn and soybeans in several areas of southeastern and south central Nebraska, including Hamilton, Saline and Saunders county. Infestations are known to occur in Lincoln and Omaha also, and agricultural areas close to these cities may also see Japanese beetles in the future. Japanese beetles typically cause damage to corn by feeding on silks and potentially interfering with pollination if abundant enough. Often damage is initially concentrated in field borders. This year adult emergence occurred early due to the warm spring, and Japanese beetle adults were found feeding on corn leaves before silks were available to feed on. Their feeding damage is similar to that caused by corn rootworm adults on pre-tassel corn; they scrape off the surface tissue of the leaf leaving a skeletonized appearance on the leaf. On soybeans, the adults produce a skeletonized appearance to the leaflets by feeding on the tissue between the veins, leaving a lacelike appearance to the leaves. Additionally the adults will feed on a variety of trees and shrubs, especially plants in the Rose family, including crab apples, roses, as well as trees such as linden.

Aphids in corn, sorghum and alfalfa

As we have seen in the past few years, corn leaf aphids and bird-cherry oat aphids built up in some corn fields in August across eastern Nebraska. There is very little data on the economic impact of this post-pollination stage feeding. Alfalfa aphids, including spotted alfalfa aphid and cowpea aphid were found in several fields. Both species are favored by hot, dry weather. If the crop growth stage is appropriate, early harvest is a cultural control tactic for aphid control.

Corn and soybean silage harvest restrictions

Due to drought, many growers chose to salvage their crop by cutting it for silage, or in some cases grazed their crop to livestock, rather than trying to harvest the grain. An issue to be aware of is that many insecticides, especially on soybeans, have restrictions that either prohibit harvest of soybeans for silage or feeding to animals or have lengthy pre-harvest intervals. If drought conditions continue into 2013 be sure to keep track of insecticides you apply on corn and soybeans and follow label restrictions concerning silage harvest for animal feed or grazing by animals.

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Management of spider mites on corn and soybeans

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Two species of spider mites, the Banks grass mite and twospotted spider mite, commonly feed on Nebraska corn. Banks grass mites (BGM) feed almost exclusively on grasses, including corn, small grains, and sorghum. Twospotted spider mites (TSM) not only feed on many species of grasses, but also on soybeans, fruit trees and a variety of vegetables and ornamental plants. Although these two species are somewhat similar in appearance, they differ in several biological characteristics and in their susceptibility to pesticides.

Banks grass mites usually appear earlier in the season, feed mostly on the lower leaves of the corn plant, and in Nebraska are moderately susceptible to many of the commonly used miticides. On the other hand, TSM tend to appear in mid to late season, increase rapidly, feed over the entire plant, and often are not consistently controlled by available pesticides.

Biology

Although mites may occasionally overwinter in crop residues, BGM primarily overwinter in the crowns of winter wheat and native grasses, and TSM primarily overwinter in alfalfa and other broadleaf plants bordering the fields. In the spring or summer, mites crawl or are carried by wind to corn or soybean fields where they deposit small, round, pearly-white eggs on the underside of the leaves. Early mite reproduction and damage often appear first on the south and west edges of fields due to the prevailing wind direction, but infestations also may arise in “hot” spots scattered throughout the field.

Mite eggs usually hatch in about three or four days. Young mites resemble the adults, and increase in size by periodically shedding their skins. It takes about five to 10 days after hatching (depending on the temperature) before mites are mature and begin to produce eggs. All stages of mites may be present at the same time, and there may be seven to 10 generations during the growing season.

Damage

Mites damage crops by piercing plant cells with their mouthparts and sucking the plant juices. The first evidence of mite feeding, which can usually be seen on the top of the leaf, is a *yellow or whitish spotting* of the leaf tissues in areas where the mites are feeding on the lower leaf surface. Because many other things can cause similar discoloration, it is important to check leaves closely to make sure mites are actually causing the damage. Leaf discoloration caused by mite feeding can be easily identified by checking the undersurface of leaves for the presence of mites, eggs and webbing. Both BGM and TSM produce webbing, and a fine network of silken webs likely will be associated with mite colonies. A magnifying glass or 10X hand lens is helpful in examining plants for the presence of mites.

As mite infestations develop, leaves may be severely damaged and the food manufacturing ability of the plants progressively reduced. If an infestation is severe, leaves may be killed. In corn, effects on yield are most severe when mites start damaging leaves at or above the ear level. Infestations may reduce corn grain yields due to poor seed fill and have been associated with accelerated plant dry down in the fall. The quality and yield of silage corn also may decline due to mite feeding.

Damage is similar on soybeans, and includes leaf spotting, leaf droppage, accelerated senescence and pod shattering, as well as yield loss. Early and severe mite injury left untreated can completely eliminate yields. More commonly, mite injury occurring during the late vegetative and early reproductive growth stages will reduce soybean yields between 40 percent and 60 percent. Spider mites can cause yield reductions as long as green pods are present.

Factors Contributing to Mite Infestations

Mites do not cause major economic damage every year in Nebraska. Several factors, which fluctuate from year to year, strongly influence spider mite numbers. Probably the most important of these factors are weather, natural enemies and pesticide use. Overwintering sites that are close to corn and soybean fields, especially grasses, wheat and perhaps alfalfa, also may increase the possibility of mite invasion.

Dry, hot weather favors mite reproduction and survival, especially if accompanied by drought stress in the crop. When the weather in June, July and August is especially hot and dry, mites can reach damaging numbers in most corn and soybean growing areas of Nebraska. Major mite infestations are more likely to occur in central and western counties that normally experience less rainfall. Sandy soil types also may contribute to spider mite problems in these areas because crops grown on these soils are more likely to experience drought stress even when irrigated.

Several species of insects and mites prey on spider mites. These predatory insects and mites play a major role in suppressing spider mites in most years. Many spider mite problems in corn and soybeans may be traced back to an earlier application of a broad spectrum insecticide that reduced populations of these natural controls. The most important of these include a predatory spider mite, the mite destroyer beetle, the six-spotted thrips and the minute pirate bug. In addition to these predators, a fungal disease also may be important in reducing spider mite populations.

The predatory mite, *Neoseiulus fallacis*, is the most important spider mite predator found in Nebraska. These mites are slightly larger than the pest mites, pear-shaped and uniformly pale brown or straw-colored. In addition, they do not have the dark pigmentation characteristic of the pest mite species. These predatory mites will eat an average of about 15 mites per day. When present, the predatory mite can quickly increase its numbers and significantly reduce pest mite numbers.

The mite destroyer beetle *Stethorus* is a small black ladybird beetle which can eat up to eight mites per hour. The adult beetle is about 1/16 of an inch in length and lays eggs in active mite colonies. The larvae, which feed on mite eggs, are gray and cylindrical, growing to about 1/16 inch in length before they complete their development.

The six-spotted thrips is a small (1/16 inch long), tan, cigar-shaped insect. Both adults and the immature stages feed within mite colonies. This predatory thrips has been observed to eat about 60 mite eggs each day of their 30-day life span.

Minute pirate bugs (*Orius* species) are small insects (1/16 inch long), and can be important predators of insect eggs and spider mites in both their immature and adult stages. The immature bugs are orange and wingless. The adults are black with white triangles at the tips of the wings.

In addition to predatory arthropods, a naturally occurring fungus can, under the proper conditions, control spider mite infestations. *Neozygites floridana* is a common pathogen of spider mites. Weather conditions that favor fungal growth are an average daily temperature below 85°F and relative humidity above 90 percent. If several cool, damp days occur together, the pathogen has an excellent opportunity to infect and kill spider mites. Infected mites have a shriveled, brown appearance and die quickly. If weather conditions favoring fungal infection occur, a re-evaluation of the mite population should be made before making a treatment decision.

These natural enemies may be important in keeping spider mite populations below damaging levels during many years. They are particularly effective during cool, moist periods in early and mid-summer when mite reproduction is slowed. For this reason, their presence and abundance should be noted and considered when evaluating spider mite populations.

Most pyrethroid and organophosphate insecticides used in corn and soybeans have severe, detrimental effects on spider mite predators. Additionally, pesticides differ a great deal in their effects on BGM and TSM. Some cause little mortality of either species, while others are somewhat toxic to BGM. Fewer are toxic to TSM. Thus, great care should be taken to evaluate the benefits of an insecticide application before any material is applied for insect control in a field that also has spider mites. Even small numbers of mites can rapidly increase to damaging levels when conditions are favorable. In many cases, it is an earlier treatment for European corn borers, western bean cutworms or corn rootworm beetles that leads to a later spider mite problem in corn.

If a decision is made to treat an insect pest in a field that also has spider mites, the choice of products becomes very important. Because TSM and BGM differ in their susceptibility to various pesticides, it is important to determine which species is present. Spider mites (particularly TSM) are noted for their ability to develop resistance to chemicals that were once toxic to them. For this reason, it is very likely that some products now toxic to spider mites will become less toxic in the future. Obtain the most current information before choosing an insecticide.

Field Identification of Spider Mites

Proper identification of the mite species present in a field is essential for making control recommendations and selecting an appropriate pesticide. This is because colonies of TSM generally are more difficult to control than BGM, and some insecticides used to control other pests are more likely to increase TSM numbers than others.

Accurate identification of spider mites is difficult and requires specialized microscopes and specimen handling procedures. Since BGM and TSM now are the only species known to damage corn in Nebraska, a simplified method has been developed to help differentiate between these two species in the field. Using this method and a 10X hand lens, it should be possible to determine the species composition of most mite infestations.

The characteristics used to identify the two species will apply to most specimens; however, there is considerable variation among individuals. Examine at least 20 adult female mites. In an established colony, adult female mites will be the largest individuals. The rear of their body is rounded whereas that of the much smaller male mite is more tapered.

The most useful characteristics for identification are the overall shape of the body and the pattern of pigmentation spots on the back. The dark green spots on both species are caused by food particles that accumulate in their gut. Because of differences in gut structure, these pigment spots accumulate in slightly different patterns. In BGM, the pigments accumulate along both edges of the body near the rear and along the sides of the body. In TSM, the pigments accumulate along the sides of the body in two distinct spots and do not extend back more than halfway on the body. The BGM is also slightly less robust than the TSM, and is slightly flatter from top to bottom.

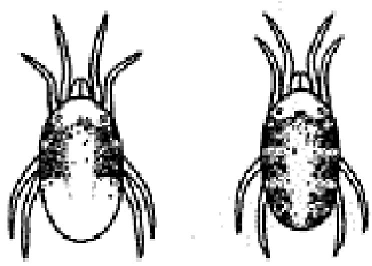

Fig. 1. **Drawing showing the appearance of adult twospotted spider mite (left) and Banks grass mite (right)**

In addition to the differences between individuals of the two species, there are some differences associated with colonies. There are exceptions, but TSM colonies tend to produce more webbing than BGM. BGM colonies often begin earlier in the season and remain longer on the lower leaves before moving up the plant. TSM usually appear later in the season and colonies can be found anywhere on the plant.

Treatment Thresholds

Researchers in Texas have developed economic injury levels for spider mites in field corn. Although these were originally developed based on data from TSM, additional research has shown that the BGM has the same damage potential as the TSM, so this information can be used for either species in corn. To use this procedure, the per acre control costs (miticide + application costs) and the expected value of the crop (yield [bu/acre] x corn grain value [$/bu]) must be estimated. A two-step sampling procedure is used.

Table 1. Economic injury level for the Banks grass mite or twospotted spider mite on corn based on percentage of infested leaves per plant and percentage of total leaf area damaged.

Control cost per acre	Market value per acre ($)								
	400	600	800	1000	1200	1400	1600	1800	2000
	% infested leaves per plant/% of total leaf area damaged								
$5	7/4	5/3	4/2	3/2	2/1	2/1	2/1	2/1	2/1
$10	15/8	10/5	8/4	6/3	5/3	4/2	4/2	3/2	3/2
$15	22/12	15/8	11/6	9/4	8/4	6/3	6/3	5/3	5/2
$20	29/16	20/10	15/8	12/6	10/5	9/4	8/4	7/4	6/3
$25	37/20	25/13	19/10	15/8	12/6	11/6	9/5	8/4	8/4

For other market values, use the following formulas to determine an economic injury level.

1. For percent infested leaves the formula is (cost of control x 600) ÷ (price per bushel x bushel yield).
2. For percent of leaf area damaged the formula is (cost of control x 312) ÷ (price per bushel x bushel yield).

First, check the field for the presence or absence of spider mites on individual green leaves on a corn plant. Record the number of infested green leaves (containing one or more live spider mites) and the total number of green leaves on each plant. Repeat this procedure on at least 10 plants from different portions of the field. Compare the percentage of infested green leaves to the first value in *Table I* associated with the appropriate control costs and crop value. If your sample equals or exceeds the value in the table, then estimate the percentage of leaf area on the corn plants that is damaged by spider mites, and compare that value with the second value in the table. Spider mite damage can be described as chlorotic spotting of the leaf surface caused by mites sucking out plant juices at a feeding site. At either step, if the sample value is less than the value in the table, control of spider mites is unlikely to be profitable.

For example, if your estimated control costs are $15 per acre and the crop value is $1600/acre (200 bu/acre x $8.00/bu), if 6 percent or more of the green leaves are infested, then you need to estimate the percentage of leaf area on the corn plant that is damaged by mites. If 3 percent or more of the total leaf area is damaged by mite feeding, it will likely pay to control spider mites in this example.

Research also has shown that corn is unlikely to benefit from treatment for either BGM or TSM after the **full dent** stage.

No research has been conducted that would allow calculation of an economic injury level for twospotted spider mites on soybeans. On soybeans, the following scale is suggested to assess damage by spider mites (Ostlie and Potter 2012):

0 – No spider mites or injury observed.
1 – Minor stippling on lower leaves, no premature yellowing observed.
2 – Stippling common on lower leaves, small areas or scattered plants with yellowing.
3 – Heavy stippling on lower leaves with some stippling progressing into middle canopy. Mites present in middle canopy with scattered colonies in upper canopy. Lower leaf yellowing common and some lower leaf loss. ***(Spray Threshold)***
4 – Lower leaf yellowing readily apparent. Leaf drop common. Stippling, webbing and mites common in middle canopy. Mites and minor stippling present in upper canopy. ***(Economic Loss)***
5 – Lower leaf loss common, yellowing or browning moving up plant into middle canopy, stippling and distortion of upper leaves common. Mites present in high levels in middle and lower canopy.

Damage from mites may be confused with that caused by drought and several foliar diseases, so be sure to base treatment decisions on the presence of mites, rather than just apparent injury symptoms. Fields may be spot treated if the infestation is localized, but check other areas for mites (especially downwind of infestation) and extend treatments into these areas if large numbers of mites are found. Although late-season infestations may accelerate soybean senescence and increase pod shattering, caution should be used in deciding to treat with pesticides because many of the pesticides used for mite control have 21-28 day preharvest intervals.

Control

Mite infestations occurring early in the season should be carefully scouted during the rest of the season. These populations may not need to be controlled because they frequently do not develop to damaging levels on pretassel stages of corn. Low numbers of spider mites may allow predators to build up and prevent the spider mites from reaching damaging levels.

For effective control, spider mites must come into contact with the miticide. Since mites are found primarily on the underside of the leaves, they are difficult to reach with low volume applications. Using three or more gallons of water per acre by air to carry miticides may increase effectiveness. Aerial applications are generally more effective if applied very early in the morning or in the late evening. Applications made at these times avoid the upward movement of sprays, away from the plants, on hot rising air.

Eggs are difficult to kill with many miticides, so reinfestation is likely to occur seven to 10 days after treatment as a result of egg hatching. The reinfestation is frequently heavy because natural enemies have been reduced or eliminated. A second application may be necessary to kill newly hatched mites before they mature and deposit more eggs.

In many cases, especially with TSM, slowing the rate of population increase is all that can be accomplished with a miticide application.

Failure to obtain adequate spider mite control may be attributed to:

1. Inappropriate choice of miticide.
2. Incorrect formulation.
3. Failure to obtain adequate plant coverage.
4. Application made during adverse climatic conditions.
5. Failure to repeat applications when infestations are heavy.
6. Mite resistance to the product.

To evaluate the effectiveness of a pesticide for control of spider mites, a field survey should be conducted before the pesticide is applied. Using a 10X hand lens or magnifying glass, closely examine 25 infested leaves and mark them so that the same leaves can be reexamined after treatment. Five to seven days after treatment, reexamine the same 25 leaves to determine if live mites are present. (NOTE: always observe the field reentry interval listed on the pesticide label.) If the treatment was effective, there should be no adult mites present. However, eggs present during treatment may not have been killed (most miticides do not kill the eggs) and may have begun to hatch, resulting in the presence of young mites. In some cases, retreatment may be necessary before immature mites can become adults and begin producing eggs.

Products available for control:

<u>Mode of action class 1B; organophosphate</u>

Dimethoate: labeled for use in soybean and corn. Multiple products; Dimethoate 4E, 4EC, 400, Dimate 4E, 4EC

Chlorpyrifos: labeled for spider mite control in soybeans. Multiple products; Lorsban 4E, Lorsban

Advanced, Chlorpyrifos 4E, Govern 4E, Hatchet 4E, NuFos 4E, Warhawk 4E, Yuma 4E

Mode of action class 3A; pyrethroid

Bifenthrin; labeled for use in soybean and corn. Multiple products; Bifenture 2E, Brigade 2E,Discipline 2E, Fanfare 2E, Sniper 2E, Tundra 2E

Mode of action class 10B

Zeal (etoxazole); labeled for spider mite control in corn; active against eggs and larvae

Mode of action class 12C

Comite (propargite); labeled for spider mite control in corn

Mode of action class 23; tetronic and tetramic acid derivatives

Oberon (spiromesifen); labeled for spider mite control in corn; most effective against egg and immature stages.

Onager (hexythiazox); labeled for spider mite control in corn **west of Highway 281 in Nebraska**. Does not control adult mites.

Combination products

Hero (zeta-cypermethrin and bifenthrin); labeled for spider mite control on corn and soybeans

Cobalt (chlorpyrifos and gamma-cyhalothrin); labeled for spider mite control on soybeans

Swagger (bifenthrin and imidacloprid); labeled for spider mite control on soybeans

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Corn rootworm management update 2013

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Several recent developments make it important that people carefully consider their management practices for corn rootworms in Nebraska. Higher corn prices have led to increased planting of corn after corn in many areas of Nebraska, which has encouraged higher populations of corn rootworms. The mild winter and dry spring of 2012 also encouraged survival of rootworms. Bt rootworm hybrids are being grown on more acres, particularly in corn after corn environments. Use of insecticides at planting time and against adult rootworms has increased over the last several years in response to higher rootworm populations.

Dr. Aaron Gassmann and colleagues at Iowa State University published research in 2011 which documented that some western corn rootworm populations in northeastern Iowa have reduced susceptibility to the toxin produced by some Bt corn hybrids. He collected rootworm beetles from fields where growers reported greater than expected injury to Bt corn, and tested larvae in the lab using a whole plant bioassay. He compared the results to populations from other parts of the state not having unexpected injury to Bt corn (Fig. 1). The problem fields identified all were all hybrids which express the Cry3Bb1 Bt toxin, which is found in YieldGard RW, YieldGard VT RW, YieldGard VT Triple and Genuity VT Triple Pro. The problem fields were all in corn after corn systems, where hybrids expressing Cry3Bb1 had been used repeatedly over several years (Fig. 3). Gassmann et al. (2011) reported no reduction in susceptibility to the Cry34/35Ab1 toxin which is present in Herculex RW, Herculex XTRA and SmartStax hybrids (Fig. 2).

Dr. Mike Gray, University of Illinois, recently reported fields in northwestern Illinois, just across the Mississippi River from the problem areas in Iowa, with heavy rootworm injury to roots, lodging, and high populations of western corn rootworm adults. He stated that many of the cropping practices in fields with heavy rootworm injury were similar to those described by Gassmann et al. (2011) in Iowa; corn after corn for several years, and repeated use of Bt corn hybrids with Cry3Bb1 as the rootworm active toxin. In September 2012 he reported the results of bioassays conducted by Dr. Gassmann that documented similar levels of reduced susceptibility to Cry 3Bb1 Bt toxin as previously reported in Iowa, with continued susceptibility to the Cry34/35Ab1 toxin.

We have received several reports of higher than expected injury by rootworms to Bt corn in several locations in Nebraska. We have not confirmed the presence of resistance in Nebraska, but studies are being conducted to evaluate potential shifts in rootworm susceptibility to Cry3Bb1 and other rootworm Bt proteins. One thing in common among all of these reports is that problem fields have been in continuous corn production, usually with

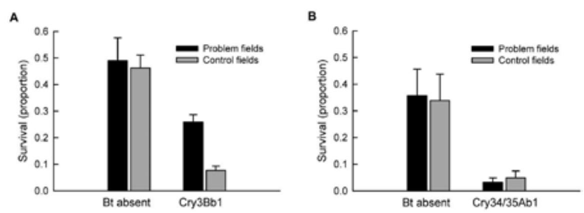

Figure 1. Survival of western corn rootworm on Bt and non-Bt maize. Data are shown for A) Cry3Bb1 maize and B) Cry34/35Ab1 maize. In both cases, survival also is shown for a non-Bt near isogenic hybrid. Bar heights are means and error bars are the standard error of the mean. Gassmann et al. (2011)

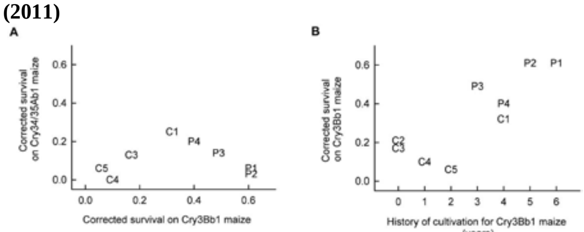

Fig. 2. Correlation analysis for corrected survival of western corn rootworm. Correlations are shown for A) survival on Cry3Bb1 maize and Cry34/35Ab1 maize and B) survival on Cry3Bb1 maize and number of years Cry3Bb1 maize was planted in a field. For (A), no significant correlation was present between survival on Cry3Bb1 maize and Cry34/35Ab1 maize (r = 0.068; df = 6; P = 0.87). For (B), a significant positive correlation was present between corrected survival on Cry3Bb1 maize and the number of years Cry3Bb1 maize had been grown in a field (r = 0.832; df = 7; P = 0.005). Gassmann et al. (2011).

hybrids producing the same Bt toxin used repeatedly over multiple years. Continuous corn production often leads to higher populations of corn rootworms. Heavy rootworm pressure may result in reduced efficacy of any insect control product, whether it is a Bt corn hybrid or an insecticide.

There are several steps to develop a sustainable approach to managing corn rootworms on your farm. The first is to assess your current management practices. There is a greater risk of injury from rootworms if the following occur:

- Corn is grown continuously for 3 or more years in a field without rotation
- Hybrids with the same Bt rootworm trait are used in a field for 3 or more years
- Lodging or goosenecking caused by rootworms was seen the previous year in a field
- High beetle populations (>2 adults per plant field avg) were seen in the field the previous year, and no controls were applied
- Previous year corn silked later than surrounding fields
- There is little rotation on your farm or neighboring fields

The following options are suggested if you have had high rootworm populations or higher than expected injury from corn rootworms in your Bt corn field in 2012:

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

2. If you must plant corn after corn:
   --Move 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 http://msuent.com/assets/pdf/28BtTraitTableApril2012.pdf for a listing of available Bt corns and the toxins they express.
   --If you plant a Bt corn hybrid, follow all refuge requirements for that hybrid.

3. It is important to use a diversity of control measures to manage rootworm populations, rather than rely only on Bt corn. Crop rotation, and use of different Bt corn hybrids over time expressing different or multiple Bt proteins are important strategies for rootworm resistance management. In addition, conventional insecticides may also 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

Be aware that insecticides applied for larval control are designed to protect the central root zone to minimize lodging of the plant. They do not necessarily control a high percentage of the larvae. Larvae can survive on roots outside the treated zone. It varies with product, rate, placement, timing, and the environment, but 25-50% reduction in adult emergence is commonly seen with insecticides applied against larvae.

Adult control is being used more commonly in Nebraska in fields of continuous corn, either to prevent silk clipping or to reduce egg-laying to minimize populations for next year. These are two different strategies. It is important to understand rootworm biology and behavior. Male rootworms emerge before females; after females emerge it takes them 7-10 to mate, feed and develop eggs. Often sprays targeted at reducing silk clipping occur when mostly males are present, and have little impact on egg-laying females. To make adult control work to reduce egg-laying, careful monitoring is needed. Timing of sprays will vary with weather; e.g. in 2012 there was early egg hatch, rapid larval development and early activity of adult beetles. Beetles may move from field-to-field if there are significant differences in timing of silking in nearby fields, and later silking fields may attract beetles from surrounding fields.

UNL Entomologists have conducted several studies evaluating seed-applied, liquid, and granular insecticides against corn rootworm larvae on conventional and Bt corn hybrids over the last several years. These reports are available at http://go.unl.edu/m8b

For more information see:

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Current status of wheat stem sawfly in Nebraska

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The wheat stem sawfly, *Cephus cinctus*, has long been a severe pest of spring wheat in Alberta, Canada, Montana and North Dakota. Historically, it was not a severe problem in winter wheat because the earlier maturing winter wheat was not attractive for egg laying, and larvae were not able to complete development before harvest. However, in recent years, winter wheat in the northern plains has seen increased damage from the sawfly. In the central High Plains, the wheat stem sawfly was not a pest of significance, presumably because of the predominance of winter wheat and lack of spring wheat. However, over the last three decades serious infestations have begun to occur and spread in southeastern Wyoming and in adjoining counties in Colorado and Nebraska. It is unclear why the sawfly is becoming more prevalent in winter wheat, but its increasing presence in this region is worth noting and watching. Serious infestations are most often associated with no-till wheat production.

Identification and life cycle

The adult wheat stem sawfly is a wasp-like insect about 3/4 inch in length (Figure 1). It has smoky colored wings and a shiny black body with three yellow bands across the abdomen. When present in the field, the adults are often seen resting upside down on the wheat stem. The sawflies will be active in the field when temperatures are above 50F (10C) and when conditions are calm. They are not strong fliers and usually only fly until they find wheat plants suitable for egg laying. Because of this, areas most impacted by the sawfly tend to be field margins closest to the adult emergence site. In western Nebraska, adults begin to emerge in May and can still be present in early June. The females begin to oviposit five days after they emerge. They will select the largest stems and insert a single egg just below the node. If populations are high, smaller stems will be selected and multiple eggs per stem will be laid. However, only one larva (Fig. 2) will survive in each stem.

Figure 1. Adult wheat stem sawflies (Photo: J. Kalisch, Department of Entomology)

Figure 2. Larva of a wheat stem sawfly in a wheat tiller.

Plant damage

Almost no spring wheat is grown in Nebraska; therefore, it hasn't been until the 1990's (once the change in this insect's biology was noticed) that this insect has posed a threat to wheat production in western Nebraska. Importantly, it isn't just the change in the insect's biology that has contributed to its damaging presence in winter wheat. Wheat management practices, such as, conservation tillage and continuous cropping of wheat have likely contributed to the spread of this insect. Finally, droughty weather can also encourage large populations of this insect. All of these factors add up to my concern regarding damage to wheat from this insect in Nebraska.

The damage is most distinct at the end of the growing season, once the larvae, feeding in the stem, cut the stem and cause the wheat to lodge. The larvae then overwinter and pupate in the remaining stubble. Although some hard-stemmed varieties of wheat are resistant to attack from this insect, these same varieties typically have less desirable agronomic traits.

Management

Cultural control

Tillage will reduce wheat stem sawfly larval survival through the winter and spring. The objective of summer and fall tillage is to bring the stubs containing the larvae to the surface, so they will be maximally exposed to the dry conditions in the late summer and the cold through the winter. Blading after harvest or before winter will accomplish this by lifting the crowns and loosening or removing the soil around them. This can result in about a 50 percent reduction in sawfly emergence the following year. In contrast, spring tillage should bury the stubble so that the adult sawflies will have a problem emerging from deeper soil levels.

The use of a trap crop (barley, oats, rye, or solid stem wheat) along the edge of winter wheat strips may be effective, especially when populations are low to moderate. These trap crops will be attractive to the sawflies for oviposition, but the larvae will not be able to complete development. However, if sawfly populations are heavy, trap crops may not be enough to satisfactorily reduce damage because significant numbers of sawfly adults will move past the trap crops to infest the wheat.

Another cultural practice that will reduce sawfly potential is the use of larger acreages in block plantings rather than planting in narrow strips. Strip planting maximizes the ability of the sawfly to move from the old stubble into the wheat crop. Reducing the amount of border in the fields reduces the potential for damage throughout the field. Soil erosion issues come into play when considering this option, but it may be feasible in a no-till cropping system.

Host Plant Resistance

Solid stem varieties of spring wheat have been successful at reducing the amount of damage from the wheat stem sawfly. However, the effectiveness of this resistance is influenced by environmental conditions. No winter wheat varieties adapted to the central High Plains region have solid stems; however, Montana has developed two winter wheat varieties (Rampart and Vanguard) that are solid-stemmed. Yield data indicates these varieties are almost competitive in yield with commonly used adapted varieties.

Biological Control

Several natural enemies of the wheat stem sawfly have been noted in the northern plains, but in most years none of these have been identified as a major factor in reducing the population. The presence and effectiveness of natural enemies in the central High Plains has not been determined.

C**hemical Control**

Insecticide control has proven to be an ineffective option because of the extended period that the adults are present and control is needed. Effective control efforts would require close monitoring to determine the timing of sawfly presence and repeated applications for most of the period adults are active.

2012 Wheat Stem Sawfly Status

With the cooperation of twenty-four growers, thirty-one fields were sampled by collaborating Extension Educators and crop consultants. Cooperating growers geographically included an area from eastern Wyoming and Colorado throughout the western half of Nebraska. Large tubes were distributed to each cooperator for the collection of wheat samples (postage included for their return), along with data and field information sheets and materials for subsequent post-harvest stem counts.

To survey for sawfly damage, fields were sampled along the east edge of wheat fields. Five, random 1-ft^2 counts of sawfly-cut tillers were taken. We also randomly collected 100 tillers from the emergence tubes and split them to make assessments for sawfly infestation

In the 2012 survey we found an average of 0 to 35% tiller loss due to wheat stem sawfly based on cut-tiller counts. However, based on tiller dissections the range of cut tillers (from the same fields) is from 0-68%. This indicates that careful examination of crowns may be a more accurate method for determining field infestation. Importantly, not all sawfly-infested tillers were cut. Many of the larvae were either dead or required more development. This finding indicates that some fields matured faster than the sawflies could develop, thus escaping sawfly cutting. Sawfly parasitoid numbers were also down from 2011, with 0-4 parasitoids collected from Banner, Scottsbluff, Morrill, and Box Butte counties.

Undergraduate degrees from UNL Entomology Department

The Department of Entomology is home to two undergraduate degrees – the **Insect Science** major, and the **Applied Science** major.

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- The Science Option, which is designed for students interested in careers focusing on the basic biology of insects and other arthropods. This option is suitable for students considering any career involving entomology (e.g., academia, research, medicine, forensics, environmental quality, conservation biology, or health-related fields), but is especially appropriate preparation for entry into professional programs such as veterinary and medical schools and many graduate school disciplines.
- The IPM and Pest Science Option is designed for students considering careers in agriculture, agribusiness, consulting (agricultural, environmental, public health, urban), extension, state and federal government agencies (e.g., APHIS, EPA, USDA, and state departments of agriculture), horticulture, the military, food processing, and pest control. Examples of areas of focus include urban pests or agronomic and horticultural pests. This option is also suitable as preparation for graduate studies leading to academic or research careers in applied entomology.

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For more information on either major, contact Lisa Silberman at lsilberman1@unl.edu or 402-472-3416

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(Revised February 2007)

Converting Center Pivot Sprinkler Packages: System Considerations

William L. Kranz, Suat Irmak, Derrel L. Martin, C. Dean Yonts, Extension Irrigation Specialists

This NebGuide points out some of the system-oriented factors that should be considered when changing sprinkler packages on a center pivot irrigation system.

Irrigators using existing center pivots may be interested in changing sprinkler packages to take advantage of new sprinkler technology, overcome a poor design on the original package, reduce energy requirements or simply to replace worn sprinklers on an older machine. Whatever the reason, there may be multiple benefits in changing the sprinkler package on an existing center pivot. If done properly, most systems will use less energy as a result of changing from a high operating pressure to medium or low pressure. Other systems may realize an increase in application efficiency by changing to a sprinkler package that has lower evaporation losses. Systems with insufficient capacity may actually show crop yield increases as a result of this increased application efficiency.

In any case, there are considerations that should be investigated before converting to a new sprinkler package. The new sprinkler package should be appropriate for the soil and topographical characteristics of the site. The information presented here deals with the irrigation system issues that should be addressed when changing a sprinkler package. The irrigation system includes the center pivot, the power unit and pump and their components. Since these components must work together efficiently, changing the operation of any component changes the way the other components operate.

Effect of Pressure Reductions on System Components

Reducing the operating pressure of a center pivot system may have many positive effects, but there are some trade-offs. When the overall system pressure is reduced, problems may arise that can be corrected by changing some equipment; however, in some cases it may not be economical to make these changes.

One potential problem associated with reducing the system pressure involves operation of the end gun. Systems with existing end guns may not have adequate pressure to operate the end gun after the pressure reduction. End-gun booster pumps can be installed to allow continued use of the original end gun. Some systems could require the addition of a booster pump and a smaller end gun. Others may require that the end gun no longer be used. An end-gun booster may have additional power and maintenance requirements. Removing the end gun will decrease the irrigated acreage. These costs should be considered when changing the operating pressure of a center pivot.

When converting to a low-pressure system, some irrigated acreage may be lost even if end guns are not used. The high pressure system may have additional throw from the outermost sprinkler in the range of 50 to 75 feet. Replacing this package with a low to medium pressure system with a wetted radius of 15 to 35 feet will result in loss of irrigated acreage. For example, if the wetted radius was reduced by 40 feet on a 1,320-foot center pivot, the irrigated acreage would be reduced by 7.5 acres.

Another consideration is the impact of reduced operating pressure on water application uniformity. Medium to low pressure sprinklers will be more sensitive to pressure variation due to field elevation changes than high pressure sprinklers. To overcome this sensitivity and ensure that the uniformity of application is not sacrificed, many systems will require pressure regulators on each sprinkler.

Changing Operating Pressure — Internal Combustion Units

Figure 1 illustrates how changing the operating pressure can affect pump performance. The relationship between pressure developed by each stage and gallons per minute of output is shown by the solid lines. For each of the three pump speeds shown, the pump will operate somewhere along the solid lines as long as the speed does not change. When the speed changes, the pump operates on a new performance curve. The dotted lines, which are roughly perpendicular to the solid performance curve lines, indicate the pump efficiency at that point. Pumps can operate below and/or to the left of the performance curve

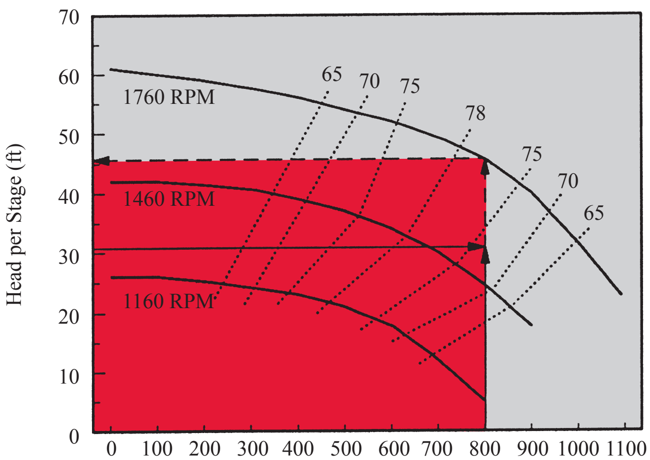

Figure 1. Pump curve showing the effect of decreasing the engine speed.

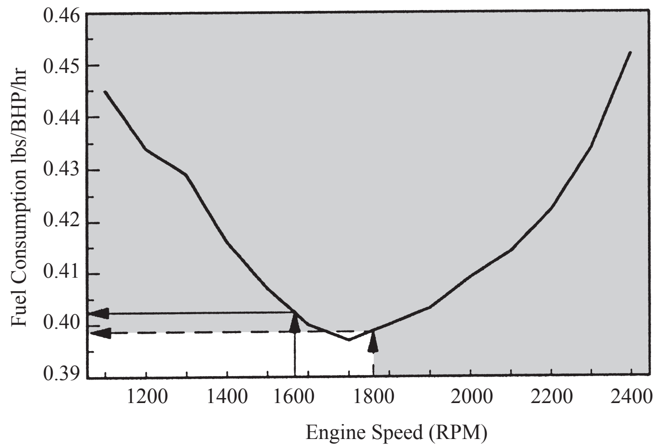

Figure 2. Engine performance curve, showing the effect of engine speed on efficiency.

if they are worn or out of adjustment. Keep in mind that the speed used on a pump curve (*Figure 1*) is pump speed, not engine speed. Pump and internal combustion engine speed will be equal only if 1:1 gears are used in the gear head, or if the driver and driven pulleys in a belt drive system are of equal diameter. The operating pressure of the pump may be reduced by reducing the engine speed. Reducing the engine speed will reduce both flow rate and operating pressure unless the center pivot has been altered to apply the same flow at the new lower pressure.

The application amount will remain the same with the lower pressure system if the flow rate and travel speed of the center pivot are not changed. The application rate (the rate at which water is added to any point on the soil surface) will probably increase because the lower pressure system will have a smaller wetting pattern. If the wetting pattern is smaller and the pump flow rate is unchanged, the application rate will increase.

One potentially negative effect of changing the engine speed is that the pump efficiency may decrease. This could mean that a lower percent of the energy delivered to the pump drive shaft is effectively converted to water movement. If this change in efficiency is large, reductions in energy use associated with reducing the pressure may be offset by the increase in energy use associated with the decrease in pump efficiency. As a result there may be no overall savings in energy costs. In fact, the energy costs may increase. A possible solution to this problem is to replace or modify the pump bowls and/or impellers. The pump curve should always be evaluated prior to any change to ensure that the new settings are satisfactory.

Another consideration when changing the engine speed is that the engine performance (fuel use) may change. Internal combustion engines are designed for maximum efficiency at a given speed. Deviation from that speed will decrease the engine efficiency, as shown in *Figure 2*. If the decrease in engine efficiency is significant, the pump gear head (or pulley diameters if belt drives are used) should be changed so that the engine runs at a speed near the minimum fuel consumption level.

Changing Operating Pressure — Electrical Units

Many electrically powered pumps are driven by vertical hollowshaft motors that are directly coupled to the pump lineshaft. There is no way to change the rotational speed of the pumps when using these motors.

Several options are available to reduce the operating pressure of center pivots that have electrically driven pumps. One option is to continue to use the original pump and design the sprinkler package to deliver more gallons per minute at a lower pressure. When looking at *Figure 1,* we would follow the pump curve downward to the right. The result is that pump efficiency will be reduced and the capacity of the well, peak application rate of the sprinkler, and other factors will limit how far this option can be taken. Another option is to pull the pump and remove one or more stages from the bowl assembly. This is a viable option only if the pump design is well matched to the volume to be pumped through the new sprinkler package. If the impellers or the bowl assembly are worn, this would be a good time to have the pump redesigned.

Another alternative would be to pull the pump and trim the impeller diameters to meet the new conditions. This has much the same effect on the head and capacity of the pump as operating the impeller at a lower rotational speed. Depending on the pump and operating conditions, it may be necessary to remove some bowls and trim others to meet the new conditions. In some cases it may be necessary to replace the pump with one that is designed to operate with the new conditions.

Using the old, higher horsepower electric motor to drive the pump would not be an operational problem since electric motors only draw the current required by the load. A potential problem with over-sized electric motors is that utility companies assess a demand charge based on the horsepower rating of the motor. An over-sized motor will therefore be assessed a high demand charge unless the utility company uses a demand meter instead of the nameplate horsepower.

An option with single phase motors is to change to one that operates at a lower speed. Again, the pump curve should be checked for potential pump efficiency problems associated with the new pump speed. This may be a more expensive option, but the lower operating speed may extend the life of the pump. The demand charge would not be a problem in this case, since the lower speed motor would have a lower horsepower rating, and thus a fair demand charge.

If a belt drive system is used, the pulley diameters could be changed to adjust for new pressure and flow rate conditions. In this case, the pump curve should be checked for the new pump efficiency, and the demand charge problem may occur.

Runoff Potential

It cannot be over-stressed that many low to medium pressure systems may generate a runoff problem that could overshadow the positive effects of the sprinkler package conversion to reduced pressure. Runoff is influenced by application rate, which is influenced by wetted diameter. The wetted diameter of low to medium pressure systems is often considerably less than that of high pressure systems. In some cases converting to lower pressures may generate unacceptable runoff amounts.

Cost Considerations

There are many cost-related factors that must be considered when making a change in sprinkler packages. *Table I* summarizes the potential costs and benefits associated with the change. For any system, the benefits should outweigh the costs before the conversion is made.

Other economic factors to consider are related to the projected life of the system and its components. There is more incentive to change sprinkler packages if the current sprinklers already need to be replaced due to wear. Also, any new sprinklers placed on an older center pivot may be salvaged and transferred to a new system if the center pivot itself is replaced.

Table I. Potential economic costs and benefits associated with changing sprinkler packages.

Potential Costs	*Potential Benefits*
Equipment	**Reduced Fuel Costs**
• sprinklers	• pump operates at lower pressure
• pressure regulators	• more efficient system (fewer pumping hours)
• drop tubes	• reduced demand charge
• end-gun booster pump	
• adding extra sprinkler fittings	**Application Efficiency**
	• higher if runoff is not a problem
Acreage Reductions	
• end gun inoperable	**Increased Yields**
• reduced wetted diameter of end sprinklers	• if pump capacity is too low
Pump Alterations	
• bowls and impellers	
• gear head or pulleys	
Motor Change	
Artificially High Demand Charge	

Procedure Summary

A general outline for the steps to take when deciding if a sprinkler change is warranted is given below.

1. Determine appropriate sprinklers for soil and slopes.
2. Determine operating pressure and flow rate needed for the chosen sprinkler package.
3. Determine if the pump and power plant should be redesigned for the new operating conditions.
4. Determine costs associated with any required system changes and the new sprinkler package.
5. Determine the investment that could be made and paid for with savings in operating costs or increased crop yield.

Example Calculations

An irrigator wishes to install a low pressure sprinkler package on an older high pressure center pivot. In doing so, he will need to change the system operating pressure. He has an internal combustion engine with the engine performance curve shown in *Figure 2*. The gear head on the well has a 1:1 gear ratio so the engine speed equals the pump speed. The engine drives a pump with the characteristics shown in the pump curve of *Figure 1*. Six stages are used, so all readings from the head per stage axis of *Figure 1* are multiplied by six. The initial (high pressure) settings are:

Flow Rate	800 gpm
Pressure at Pivot Point	70 psi (161.7 ft of head)
Pumping Lift and Friction Loss	114.3 ft of head
Engine Speed	1760 RPM

The new sprinkler package requires 30 psi (69.3 feet of head) at the pivot point. First, the irrigator needs to know the new engine speed required to pump 800 gpm at the new pressure. The elevation and friction losses in the column are the same, so the total head would now be 114.3 feet plus 69.3 feet, or 183.6 feet. This is 30.6 feet of head per stage. Following the solid arrows on *Figure 1* leads to a point that is approximately one-third of the distance from the 1,460 RPM curve to the 1,760 RPM curve, when measured perpendicularly. The new pump speed would be approximately 1,460 plus one-third times the difference between 1,760 and 1,460, or 1,560 RPM.

Having both the old (dashed arrows) and new (solid arrows) points on the pump curve (*Figure 1*), the difference in fuel consumption resulting in the change may now be calculated. The pump efficiencies are estimated in *Figure 1* based on position relative to the dotted lines.

The fuel consumption rate is read from *Figure 2*. The brake horsepower for either case is determined as:

$$BHP = \frac{\textit{total head (ft) x gpm}}{\textit{3960 x pump efficiency (decimal)}}$$

For the high pressure system, (pump efficiency from *Figure 1* = 76%) this is:

$$BHP = \frac{276\ x\ 800}{3960\ x\ 0.76} = 73.4\ hp$$

Fuel consumption for the high pressure system at 1,760 RPM is 0.398 lb/BHP/hr (dashed arrows, *Figure 2*). Thus the fuel consumption rate for the high pressure system was:

$$Fuel\ Consumption = \frac{0.398\ lb}{BHP \bullet hr}\ x\ 73.4\ BHP = 29.2\ lb/hr$$

For the low pressure system, the brake horsepower is (pump efficiency from *Figure 1* = 74%):

$$BHP = \frac{183.6\ x\ 800}{3960\ x\ 0.74} = 50.1\ hp$$

Fuel consumption for the low pressure system at 1,560 RPM is 0.402 lb/BHP/hr (solid arrows, *Figure 2*). Thus the fuel consumption rate for the low pressure system will be:

$$Fuel\ Consumption = \frac{0.402\ \mathrm{lb}}{BHP \bullet hr}\ x\ 50.1\ BHP = 20.1\ lb/hr$$

Thus the difference in fuel consumption due to the nozzle conversion will be (29.2 lb/hr - 20.1 lb/hr) or 9.1 lb/hr (about 1.3 gal/hr for diesel). This decrease in fuel consumption is the primary economic incentive for the conversion in this case and must offset the cost of the conversion when spread over the life of the new sprinkler components. In this case both the pump and engine efficiency decreased. The combined decreases were not sufficient to overwhelm the reduction in fuel consumption associated with the lower horsepower requirements. In some cases the reduction in efficiencies will cause an increase in fuel consumption, and equipment should be altered accordingly.

In this same example, another option would be to reduce the existing pump bowl assembly from six to four stages. Then the pump and engine could be run at the original speed and efficiency while consuming less fuel. The costs in this case would be associated with pulling the pump and modifying the bowl assembly.

Acknowledgments

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

Index: Irrigation Engineering
Irrigation Operations and Management
1992, Revised February 2007

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G1712

Application Uniformity of In-Canopy Sprinklers

C. Dean Yonts, Extension Irrigation Engineer; William L. Kranz, Extension Irrigation Specialist; and Derrel L. Martin, Irrigation and Water Resources Specialist

Use of in-canopy sprinklers can reduce application uniformity and increase runoff. Learn how to evaluate the efficiency of in-canopy sprinklers.

The goal, when using center pivot irrigation, is to uniformly distribute water on the soil surface. Uniform application of water combined with uniform infiltration of water into the soil gives plants equal access to water. As a method to reduce energy costs, many producers have converted their center pivot systems from high to medium or low pressure sprinkler packages. As a result, sprinkler manufacturers continue to develop new devices for use above and below the center pivot pipeline to uniformly apply water at lower pressures. On the positive side, lowering the operating pressure of a sprinkler system can reduce pumping costs. On the negative side, lower operating pressure reduces the sprinkler-wetted diameter.

Wetted diameter is defined as the distance across a water application pattern from dry soil in front of the system to dry soil behind the system. The wetted diameter defines a circular area that is wetted by a single sprinkler device and by a series of overlapping sprinkler devices. In addition to the sprinkler device selected, operating pressure of the irrigation system and height of operation are factors in determining wetted diameter. Wetted diameter decreases most significantly with lower operating pressure. As a result, the rate at which water is applied to the soil increases. This increase in water application rate can in turn cause runoff due to the soil's inability to take in the water fast enough.

When sprinkler devices are placed much below the truss rods, and corn is being grown, in-canopy sprinkler operation results. A sprinkler device operated within the crop canopy further reduces wetted diameter as a result of crop leaves interfering with the trajectory of water droplets. Our intuition would tell us that dropping the sprinkler device into the crop canopy will simultaneously reduce evaporation. Research, however, has shown the potential for reducing evaporation is small when changing from above-canopy to in-canopy operation. Consider the following questions before making changes:

- What happens to application uniformity when sprinklers are used in-canopy?
- What impact does application uniformity of in-canopy sprinklers have on water application efficiency?
- What is the cost of placing sprinkler devices in-canopy as opposed to above-canopy?
- What happens to the ability to chemigate and apply chemicals uniformly?

Application Uniformity Using In-canopy Sprinklers

Many low-pressure sprinkler devices have been designed to operate on drop tubes below the pipeline. However, few are designed specifically to operate within the crop canopy. As part of Low Energy Precision Application (LEPA) systems, drop tubes are used to place water at or near the soil surface. LEPA, a system that incorporates planting in a circle and placing drop tubes in every other row, compensates for high water application rates by constructing furrow storage reservoirs to prevent runoff and maintain infiltration uniformity.

In-Canopy Water Distribution

The coefficient of uniformity is a measure of how evenly water is distributed over the area where water is being applied. Results from a Kansas study, *(Figure 1)* shows the coefficient of uniformity of six nozzle spacings for spray heads located 12 inches above the ground in growing corn. As a reference,

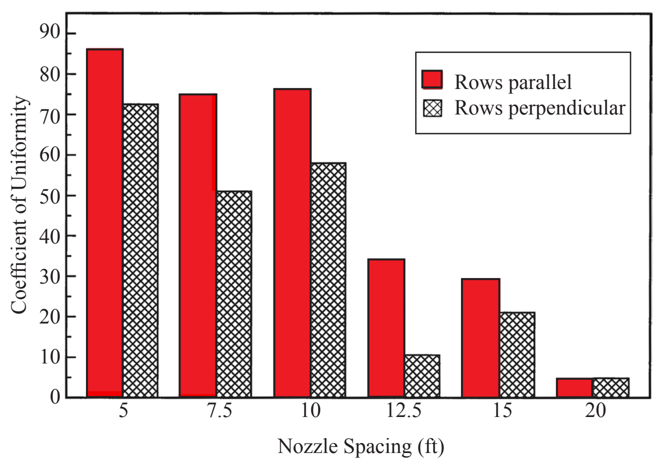

Figure 1. Uniformity coefficient for center pivot sprinkler using LDN 360° spray heads located 12 inches above base of the corn plant.

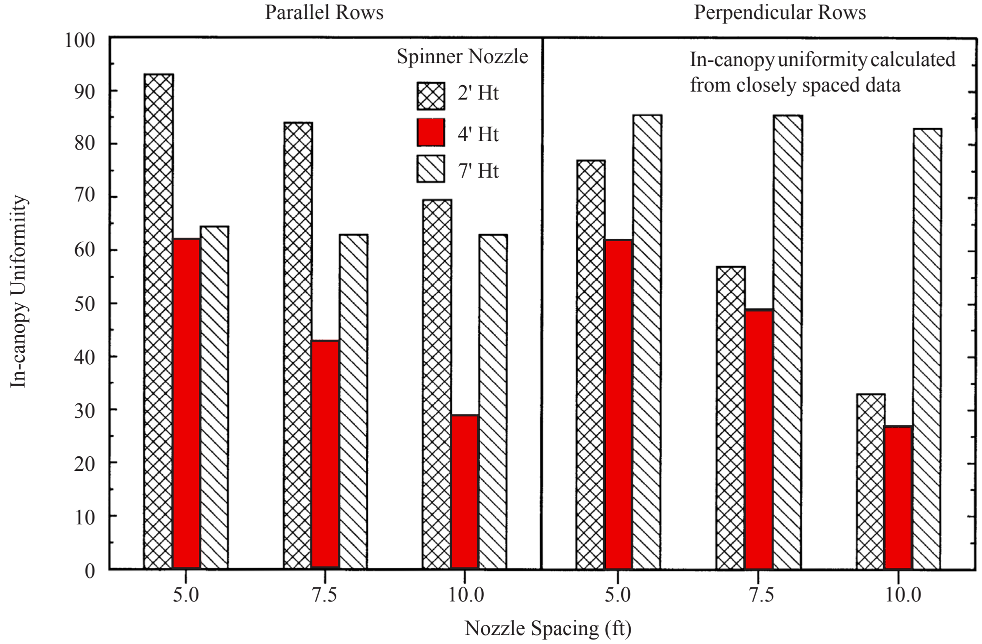

Figure 2. In-canopy uniformity as affected by nozzle spacing and row orientation for spinner nozzles at various heights in a fully developed corn canopy after tasseling.

a uniformity coefficient of 90 or greater is the normal level to which manufacturers expect sprinkler devices on center pivots to perform. A sprinkler device design that gives anything less would be considered substandard. In this study, corn was planted both parallel and perpendicular to the sprinkler line of travel, and as shown in the figure, none of the configurations meet the 90 or greater criteria for uniformity coefficient. As would be expected, when nozzle spacing increased, the coefficient of uniformity decreased.

The parallel row orientation, simulating corn planted in a circle, had uniformity coefficients of 70 or more for spacings up to 10 feet. When the sprinklers moved perpendicular to the rows, the coefficient of uniformity was reduced even further for all nozzle spacings. This row orientation would simulate the majority of a field when corn is planted in straight rows. Based on today's technology, five-foot spacing with parallel row orientation is only marginally acceptable and this design requires a large number of nozzles to be installed on a system.

In another Kansas study, Spinners were installed at three different heights and spacings in perpendicular and parallel rows, *Figure 2*. In-canopy uniformity was always worst at the 4-foot height where leaves are most abundant and ears are located. Spinners, at a height of 2 feet, were better in a parallel row orientation. The 7-foot height was better for the perpendicular orientation because of less distortion of the sprinkler pattern.

In a Nebraska study, soil water content was measured in mature corn to evaluate the uniformity of water distribution. Spinners were spaced 12.5 feet apart at a height of 42 inches in mature corn. Soil water content was measured in the top 12 inches of soil before and after irrigation. The system was moving parallel with the corn rows but Spinners were not necessarily between the corn rows. *Figure 3* shows the location of the sprinklers in the corn and the change in soil water content. Soil water content increased about 11 percent in the rows nearest the sprinkler device. In the rows centered between the sprinkler devices, the soils water content increased by an average of only 2 percent. The small change in soil water content indicates the rows between the sprinkler devices received little or no water during the irrigation event. The wetted radius in this case is assumed to be no better than about half the distance between the sprinkler devices. This is about 6 feet, or a little more than two 30-inch rows of corn. While this indicates a wetted diameter of 12 feet, the sprinkler device used here is capable of delivering a wetted diameter of about 40 feet.

These studies demonstrate the variability in water application as a result of in-canopy irrigation. Poor uniformity resulted regardless of nozzle height even if nozzles were closely spaced, 5 feet. Crop yields may or may not be influenced since soil has the ability to redistribute some of the water that is not uniformly applied. However, it would be difficult to uniformly redistribute all of the water in the soil given the water application pattern shown in *Figure 3* and the rapid use of water by a growing crop. The reduced uniformity of these studies is due to in-canopy interference and does not reflect performance of Spinners or other sprinkler devices.

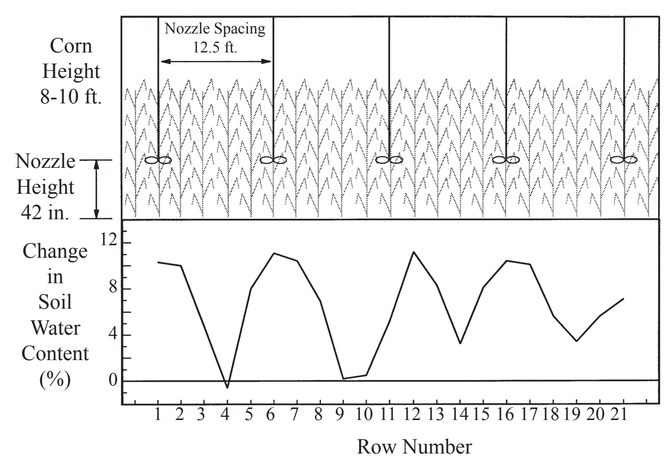

Figure 3. Percent change in soil moisture content after irrigation with Spinners at 42 inch height and 12.5 feet spacing.

Water Application Efficiency

As an irrigation system passes a given point in the field, the application rate gradually increases for the first half of the application and then decreases. If properly designed, the peak system application rate should be approximately equal to the soil infiltration rate. If the application rate of the irrigation system exceeds the infiltration rate of the soil, surface ponding will occur. If the application rate does not exceed the infiltration rate and surface storage capacity, water will pond until infiltration is completed. If application exceeds the infiltration rate and surface storage capacity of the soil, runoff will result.

In a second Nebraska study, runoff was measured from three different systems; a LEPA system with bubblers located at 18 inches, Spinners located 42 inches above the ground, and Spinners located above the corn canopy at the truss rods. A comparison also was made between normal cultivation and furrow diking. Field slope varied between 1 and 3 percent. The results of these studies are shown in *Figures 4* and *5*. The LEPA system resulted in 15 percent to 25 percent runoff from both irrigation events. The Spinners located at 42 inches had runoff of 12 percent to 16 percent. Even Spinners located above the canopy and using furrow diking had runoff of about 8 percent.

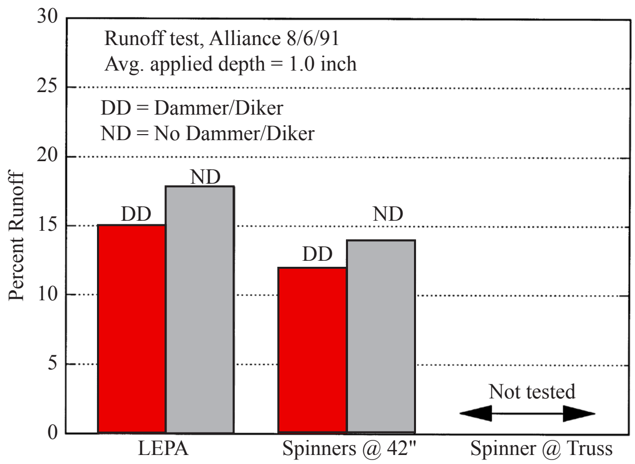

Figure 4. Percent runoff for LEPA system and Spinners at 42 inch height.

The amount of runoff when 0.7 inches of water was applied and the Dammer-Diker was used (*Figure 5*) decreased from 15 percent at 42 inches to 8 percent at truss rod height. Only 1 to 2 percent savings in evaporation losses can be expected when sprinkler devices are moved from immediately above to within the crop canopy. The result, is that water lost to runoff cannot be made up through evaporation savings.

Comparing the LEPA system with the above-canopy devices resulted in runoff being reduced from 20 percent to 8 percent. Based on Texas data, a 10 percent savings in water application can be achieved when using a LEPA system, compared to using above-canopy devices. In this soil type and slope, trying to save 10 percent of the water using LEPA reduced application efficiency by 12 percent due to runoff. In either case, the water runoff loss was unacceptable.

The LEPA system has been demonstrated in some areas as one method to uniformly apply water within the crop canopy and maintain high application efficiency. Based on the success

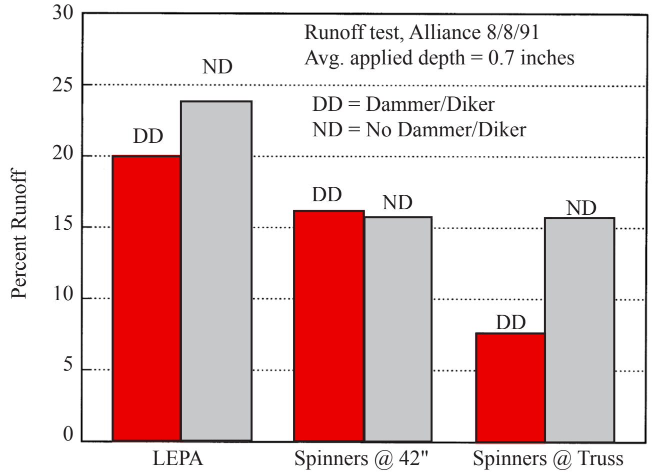

Figure 5. Percent runoff for LEPA system, Spinners at 42" height and Spinners at truss rod height.

of the LEPA system, variations of in-canopy application have been used to try to get the same results. When only a part of the LEPA system is used, the potential for saving water is not the same. Installation of the LEPA sprinkler package without using the associated cultural practices will lead to decreased application uniformity and water application efficiency.

Above-Canopy and In-Canopy Water Application Example

Assume a center pivot system irrigates 132 acres with an 800 g.p.m. well. One inch of water is applied with sprinkler devices located above the crop canopy. With no crop interference, the uniformity of application is as designed and the wetted diameter is about 40 feet (*Figure 6a*). The application pattern for the moving sprinkler also is shown at the bottom in *Figure 6a*. For a sprinkler located on the last span of the pivot, the peak application rate is 3.4 inches per hour. Also, shown in Figure 6a are intake curves for three different soil types, fine sandy loam (intake family 1.0), silt loam (intake family 0.5) and silty clay loam (intake family 0.3). The intake rate curves are initially high and gradually decrease to a near steady intake rate. Four to five minutes after irrigation starts, the water application rate exceeds the intake rate of the silt loam soil. The intake rate also was exceeded for the fine sandy loam (7 min) and silty clay loam (3 min) soils. Unless adequate surface storage is available to hold this water, runoff will begin.

In *Figure 6b*, the conditions remain the same except the height of the sprinkler devices is 42 inches. The wetted diameter is distorted and results in an estimated wetted diameter of about 12.5 feet. The application rate increases because the time water is applied is reduced from 22 minutes to 6 minutes. The peak application rate is increased to more than 11 inches per hour, exceeding the soil intake rate by approximately 7 inches per hour. This in turn increases the amount of potential runoff compared with above-canopy operation.

While infiltration rate varies with soil type, variation is small when compared to the change in application rate when sprinkler devices are operated in-canopy. Runoff potential can be reduced if infiltration rate or surface storage is increased.

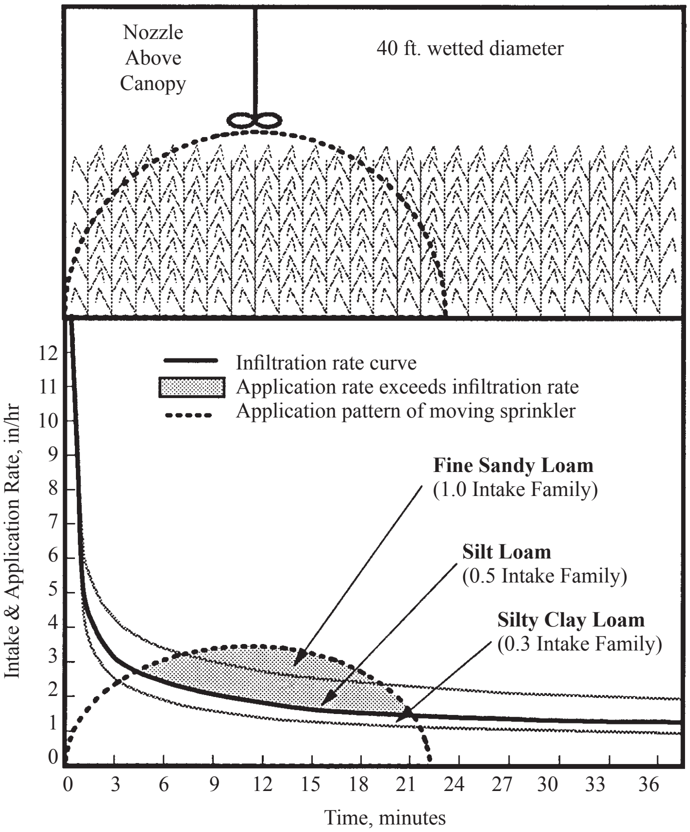

Figure 6a. Potential runoff for nozzle located above crop canopy.

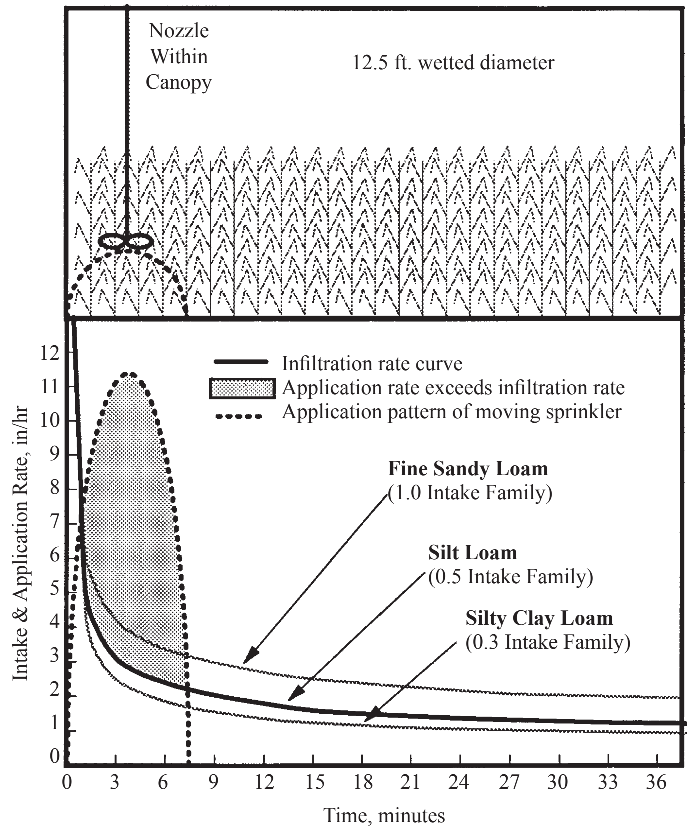

Figure 6b. Potential runoff for nozzle located within crop canopy.

Summary

Simply lowering spray heads from above the crop to within the crop canopy does not make a LEPA system and does not reduce energy costs unless time of operation is reduced. Operating sprinkler devices within the crop canopy distorts the sprinkler devices designed wetted diameter. This results in poor uniformity regardless of nozzle height, and even at a nozzle spacing of 5 feet. A smaller wetted diameter means higher application rates and the increased potential for field runoff. The gains made through improved sprinkler devices and reduced operating pressure can be quickly erased by runoff losses.

Unless specifically designed, low-pressure nozzles on drop tubes should be placed at or above the top of the crop canopy. As the use of low pressure and drop tubes expand, evaluate your system before making changes. If you notice runoff or can see the potential for runoff is close, reducing both pressure and the wetted diameter of the sprinkler device will only make things worse. Your current system may provide the most efficient application of water. Runoff, when not kept at a minimum, will result in increased pumping costs, crop water stress and/or deep percolation water losses.

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Water Loss from Above-Canopy and In-Canopy Sprinklers

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In-canopy and above-canopy sprinklers are compared to determine which irrigation method minimizes water loss and reduces installation and operation costs.

Center pivot systems are currently designed for low operating pressures as a way to reduce pumping costs. Many of the low-pressure sprinkler devices have been designed to operate on drop tubes below the center pivot pipeline. Operating low-pressure sprinkler devices closer to the crop canopy is considered more efficient than high pressure systems. The efficiency improvement is thought to result from reducing the amount of water lost through evaporation and wind drift. Because wind speeds are reduced at locations nearer to the soil surface or crop canopy, placing a sprinkler device just above the canopy reduces the amount of distortion in the sprinkler pattern and drift due to wind.

As low-pressure sprinkler devices became more common, producers began moving the devices from above the canopy to within the canopy in hopes of reducing water loss even more. In Nebraska, in-canopy operation occurs mainly in corn production. Before adopting in-canopy operation, however, a better understanding of how much water can be saved when converting from above-canopy to in-canopy operation is needed. More importantly, changes in water application that occur with in-canopy operation must be understood. This NebGuide discusses the water-saving and runoff potential sprinkler devices used within the crop canopy.

Where Water Loss Occurs

Water loss from sprinkler devices occurs in three main areas — through the air, from the canopy and from the ground. Water loss in the air can occur both as evaporation before water reaches the plant or as drift away from the application site. Once on the canopy, water loss occurs primarily through evaporation from plant leaves. When water reaches the soil surface, losses can occur from either runoff or evaporation. Water is considered to be runoff if it moves over the soil surface and off of the field or moves within the field into lowlands resulting in deep percolation. Water stored on the soil surface is not considered lost if it remains near the point of application and infiltrates into the soil over time.

Water Loss Measurements

To determine how much water loss occurs in the air above the canopy, within the plant canopy, and from the soil surface, researchers in Texas compared different sprinkler devices and heights of sprinkler devices with respect to the crop canopy. *Table I* gives the water loss during irrigation and the application efficiency for 1) six-degree low-angle impact sprinklers located on the sprinkler pipe, 2) spray heads located 5 feet above the ground and 3) Low Energy Precision Application (LEPA) system using bubblers located 1 foot above the ground. Both the water loss and application efficiencies given are based on a daytime irrigation of 1 inch applied to mature corn under no wind conditions. Evaporation from the soil during irrigation is assumed to be negligible for the low angle impact sprinkler and spray head, a result of evaporation demands being met by the water evaporating from plant leaves.

Table I. Sprinkler water losses and application efficiency for 1-inch water application.

Water Loss Component	*Low-Angle Impact Sprinkler Water loss*	*Spray Head Water Loss*	*LEPA Water Loss*
Air Evaporation and Drift	0.03 in.	0.01 in.	0.00 in.
Net Canopy Evaporation	0.08 in.	0.03 in.	0.00 in.
Plant Interception	0.04 in.	0.04 in.	0.00 in.
Evaporation From Soil	Negligible	Negligible	0.02 in.
Total Water Loss	0.15 in.	0.08 in.	0.02 in.
Application Efficiency	85%	92%	98%

The amount of water lost between the sprinkler nozzle and the top of the crop canopy, air evaporation and drift is 3 percent for low-angle impact sprinklers and 1 percent for spray heads. Low-angle impact sprinklers lost 8 percent from the canopy, while spray heads lost 3 percent. These differences primarily can be attributed to the length of application time. Low-angle impact sprinklers keep the plant canopy wet longer than spray heads, allowing more opportunity for evaporation. Application efficiency is improved by reducing the amount of evaporation from the crop canopy. Reducing water losses in the air results in less improvement in application efficiency.

Based on Schneider and Howell's results, and a review of other studies, converting from low-angle impact sprinklers to spray heads can improve application efficiency by up to 5 percent. Converting from low-angle impact sprinklers to a LEPA system can increase efficiency by 10 percent to 12 percent.

LEPA System

The LEPA system, with a 98 percent application efficiency, has no air or canopy water loss since water is applied near the ground, below the canopy. However, to realize the potential improvements in application efficiency using LEPA, a complete LEPA system, including the following, must be adopted:

1. The crop must be planted in a circular pattern on center pivots.
2. Drop tubes must be placed at a height of 12 to 18 inches between every other crop row.
3. Water must be discharged in the bubble mode or through socks to avoid wetting plant leaves.
4. Surface storage must be created to prevent any runoff and maintain infiltration uniformity.

LEPA systems apply water to the soil more rapidly than can be immediately infiltrated. Surface storage allows the water to pond temporarily until infiltration is complete. Evaporation from the soil is kept low by having drop tubes between every other crop row.

In the Texas study, the spray heads were operated at a constant height of 5 feet. Maintaining a constant height is more likely if drops are located between corn rows planted in a circle. Under pivots planted to straight rows, keeping the sprinkler device at a constant height within the canopy is difficult, especially at heights of 2 to 3 feet. As a pivot moves, drops catch on the corn plants. Sprinkler devices, rather than being held horizontally at the desired height, are held at an angle at a much greater height for a majority of the time. As a result, straight-row in-canopy operation applies water to a high percentage of the crop canopy, just as if the spray head were located above the canopy. In most cases the water savings by moving sprinkler devices from above-canopy to in-canopy is on the order of 1 percent to 2 percent. Even during days when wind drift is introduced, water savings is likely to be less than 5 percent.

Runoff Measurements

In a separate study, Schneider and Howell (1997) measured corn yield under both full and deficit irrigation, with no runoff, for LEPA, above-canopy and in-canopy irrigation systems. Within an irrigation level, they found no significant difference in yield between the irrigation methods tested. In other words, the small improvement in irrigation efficiency using the different systems was not enough to measure a difference in crop yield even under limited irrigation conditions.

On the other hand, in Texas' 1995 work, runoff was assumed to be negligible. This is correct as long as infiltration is increased to meet the increased application rate or tillage is used to provide surface storage. More recent research out of Texas (Schneider, 2000) has shown that runoff can be as high as 52 percent. This level of runoff occurred over a two-year period for a LEPA system operating in the bubble mode on a clay loam soil. Because the soils intake rate was less than the sprinkler application rate, runoff occurred. The loss of over half of the applied water through runoff, resulted in a 25 percent yield reduction in corn. From this information, it is clear that runoff reduces the water application efficiency.

Summary

The amount of water lost through evaporation and wind drift has been estimated and assumed for many years. The work described here separates and measures the different water loss components and determines the effect of these variables separately on yield. Converting from a high-pressure to a low-pressure sprinkler system is a method to reduce energy costs. Once the operating pressure is reduced, simply moving low-pressure sprinkler devices into the crop canopy does not save additional energy.

When compared to devices placed just above the mature crop canopy, moving low-pressure sprinkler devices from above to within the crop canopy provides little savings in water and has no impact on yield if runoff in the field is controlled. Left uncontrolled, low-pressure sprinkler devices operating in the crop canopy can result in significant runoff and subsequent yield loss. When sprinkler devices are operated within the crop canopy, changes occur with respect to the application pattern of water on the soil surface.

The University of Nebraska–Lincoln recommends locating sprinkler devices above the mature crop canopy. This location allows the operator to take advantage of low-pressure operation yet allows the sprinkler device to distribute water uniformly without interference from the crop canopy. This results in minimizing water loss, reducing runoff potential, and reducing installation and operation costs.

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University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
Know how. Know now.

G1851

Minimum Center Pivot Design Capacities in Nebraska

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Factors to consider in choosing an appropriate center pivot design are covered here.

Irrigators investing in a center pivot irrigation system need to consider this important question: *How much irrigation water is required to supplement rainfall?*

Irrigation system capacity needed to meet crop requirements is defined in units of gallons per minute (GPM) or gallons per minute per acre (GPM/AC). If the system capacity is too low, crop stress can occur during some portion of the growing season. If the capacity is too high, surface runoff may result, and capital investment for the pumping plant and center pivot will be greater than necessary.

Design capacities for center pivots may be determined by considering the crop type, peak crop water use rate, soil type, local climatic conditions, potential for electrical load control, and estimated system down time for repair or maintenance. This NebGuide discusses how these factors can be used to determine the appropriate system capacity.

Peak Crop Water Use

For any crop, water use expressed in inches per day depends on prevailing climatic conditions and the stage of crop development. Early and late in the growing season, daily crop water use or evapotranspiration (ET_c) is low (less than 0.15 inches per day). Near the beginning of the reproductive stage of crop development (flowering, tassel emergence, boot), the crop water use rate reaches its peak.

The crop water use rate during this period is referred to as the peak crop water use rate which varies from east to west across Nebraska. In Nebraska, the average peak crop water use rate over a period of three to five days varies from 0.36 inches per day in the west to 0.32 inches per day in the east.

Rainfall and crop water use rates vary daily and from year to year. When a system is designed to replace the peak crop water use, there is certainty that the system will prevent the crop from experiencing stress. However, a system designed to replace peak water use will not fully be used when rain occurs or when crop water use is less than the peak rate.

If the operator plans to accept some risk by using stored soil water, and not replace peak crop water use, the operator can reduce the system capacity.

System Capacity

On average, an irrigation system distributes less water to the crop or soil than is pumped from the water supply. The following definitions are used in the discussion that follows:

Net System Capacity is the amount of water that must be supplied to the crop root zone to replace crop water use. The amount of water supplied can be less than the peak water use rate.

Water Application Efficiency (WAE) is the fraction of the water pumped that reaches the crop root zone. Water application efficiency for a center pivot is assumed to be 0.85 (85 percent) in lieu of more accurate field estimates.

Gross System Capacity is the amount of water that must be pumped to ensure crop water use requirements are met. Gross system capacity is determined using the equation below:

$$\textbf{Gross Capacity} = \frac{\text{PET} \times 453}{\text{HRS} \times \text{WAE}}$$

where:

Gross Capacity = pumping rate required, gpm/acre
PET = peak water use rate, inches/day
HRS = hours of pumping per day, hours
WAE = water application efficiency, decimal
453 = conversion factor between gallons per minute and acre-inches per hour

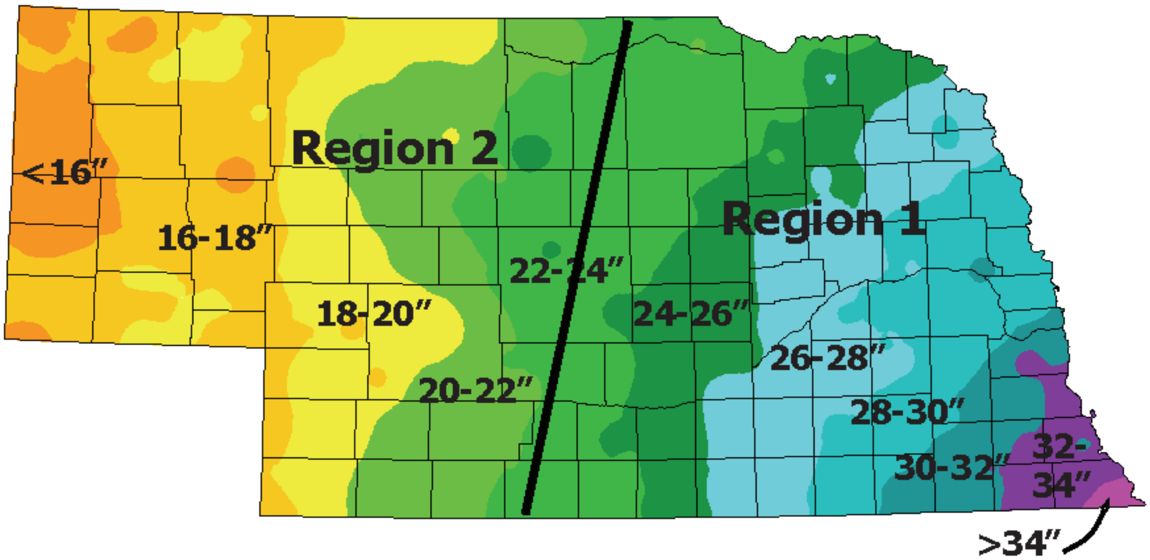

Figure 1. Long term average annual rainfall amounts and the climatic regions for irrigation system capacity determination.

For example, if the peak crop water use rate were 0.32 inches per day and the pump operates 22 hours per day, the gross system capacity would be (0.32 × 453)/(22 × 0.85) or 7.75 gallons per minute per acre irrigated.

Total pumping rate is determined by multiplying the system capacity by the number of acres irrigated. For this example a 130 acre center pivot requires a pump flow rate or gross system capacity of 1,008 gallons per minute.

Table I. Minimum net system capacities for the major soil texture classifications and regions of Nebraska.

Soil Texture	*Plant Available Water Capacity (inch/ft)*	*Net Capacity* 9 of 10 years* *Region 1 (gpm/ac)*	*Region 2 (gpm/ac)*
PEAK ET**		**5.65**	**6.60**
Loam, silt loam very fine sandy loam, w/silt loam subsoil	2.5	3.85	4.62
Sandy clay loam Loam, silt loam very fine sandy loam, w/silty clay subsoil	2.0	4.13	4.89
Silty clay loam Clay loam Fine sandy loam	2.0	4.24	5.07
Silty clay	1.6	4.36	5.13
Clay Sandy loam	1.4	4.48	5.19
Loamy sand	1.1	4.83	5.42
Fine sands	1.0	4.95	5.89

*Data taken from von Bernuth, R.D., D.L. Martin, J.R. Gilley and D.G. Watts. 1984. Irrigation System Capacities for Corn Production in Nebraska. *Transactions of ASAE* 27(2): 419-424, 428.
**Net system capacity required to replace average peak water use rate.

Soil Water Holding Capacity

Net system capacities to replace 100 percent of crop water use are presented in the top line of *Table I*. However, net system capacity can be reduced by assuming some crop water requirements are provided by stored soil water or rainfall during peak crop water use periods. Accounting for stored soil water and rainfall assumes that the irrigation system may fall short of supplying crop water needs during years when timely rainfall does not occur. If the net system capacity is reduced, it is uncertain whether the system can prevent crop stress from occurring.

Operators can assume some risk of crop stress to minimize the capital investment for the irrigation system (well, pump, motor, pivot). One reasonable scenario is when the net system capacity is adequate to ensure stress will not occur nine years out of 10. The net system capacities required to ensure that crop water needs are satisfied nine out of 10 years are presented in *Table I* for different soil textures by region. These capacities were developed from 20 years of rainfall and crop water use records.

The plant available water capacity of a soil is an important aspect of irrigation system design. Plant available water capacity is the maximum amount of water held in the soil that the crop can use. To ensure that plant stress is minimized, available water capacity should be maintained above the 50 percent available level.

A silty clay loam soil holds approximately 8 inches of plant available water in a 4-foot profile, while fine sand holds only 4 inches. The extra water stored in the silty clay loam soil increases the amount of water available to the plant during peak water use periods, allowing the net system capacity to be decreased. The primary soil textures found in Nebraska and their associated plant available water capacities are listed in *Table I*.

Environmental Factors

The location of the center pivot within the state also is important. Rainfall varies by as much as 18 inches from east to west across Nebraska (*Figure 1*). An irrigation system in western Nebraska must be capable of supplying more water during the growing season to account for the lower rainfall amounts.

Other environmental factors that impact irrigation requirements are relative humidity and average wind speed. The ability to evaporate water is usually less when air is humid than when air is dry, and the ability to evaporate water usually increases with increasing wind speeds.

Eastern Nebraska is more humid and less windy, meaning less water will be evaporated from the soil and plant surfaces than in western Nebraska. Thus, net system capacities can be reduced in high humidity areas (e.g., growing season average humidity >50 percent). Nebraska can be divided into two regions of differing environmental conditions, mainly rainfall, as shown in *Figure 1*.

Because precipitation and other weather variables change gradually as one moves across the state from east to west, it would be impossible to provide enough columns in *Table I* for each location. Thus, center pivot owners located near the division line should interpolate between the two regions to get a more accurate estimate of the minimum net system capacity. For example, a center pivot with a silt loam soil located in western Rock County should use a value of about 4.24 gpm/acre for the net system capacity [*(3.85+4.62)/2) = 4.24 gpm/acre*].

Repair and Maintenance

For irrigation systems to operate at a high efficiency, maintenance must be performed. Maintenance can be done only when the system is shut down, which also decreases total operating time per week.

Even the best-maintained center pivot or pumping plant eventually breaks down and requires repair of some part of the system. These shutdowns further decrease the total pumping time per week.

Electrical Load Control

Electrical load control occurs when the electrical power supplier regulates the peak power use rate for the distribution system by controlling power use by individuals during high use periods. Irrigators can agree to have their power interrupted in return for a reduction in power cost. The cost savings is determined by the frequency that the electric power supply can be interrupted.

The control period is generally from about 9:30 a.m. to 10 p.m., which allows power use between 10 p.m. and 9 a.m. regardless of the type of control the user selects. Four types of control are utilized by Nebraska Public Power Districts.

One day control is when the power cooperative is authorized to interrupt an irrigation system power supply for one 12-hour period per week, on a predetermined day of the week.

Two day control is similar, only with two 12-hour periods of potential power interruption weekly.

Anytime control authorizes power districts to interrupt power up to six 12-hour periods during a week, or about 40 percent of the time. Even though the power district may be authorized to interrupt power 72 hours per week, field data show that center pivots rarely are shut down more than 42 hours per week.

Hours per day control allows the power district to interrupt power for a specified number of hours per day. In this scenario, the power user agrees to let the power supply be interrupted for four, six, eight, 10 or 12 hours per day on Monday through Saturday.

Load control programs are aimed at reducing peak power use rates, but the impact to the irrigation system is to reduce water application time. If a system can be operated during only part of the day, the water supply rate must be increased to meet crop water needs. The multiplication factor for any number of downtime hours can be determined using the equation:

$$\textbf{Multiplier} = (168) \div (168 - DT)$$

Where: DT = hours of downtime

For example, if the system was on two-day control, the power could be interrupted for 24 hours so the multiplication factor would be 1.17 (168/(168-24)). The actual system capacity is determined by multiplying the system capacity with no downtime by the multiplication factor (in our example: 7.75 gpm/acre x 1.17 = 9.07 gpm/acre).

Finding the Minimum Center Pivot System Capacity Needed

The following example shows how to determine the gross system capacity needed for a center pivot irrigation system using *Table I* and *Figure 1*.

Example:

Determine the gross system capacity needed for a 130 acre center pivot irrigation system located in Antelope County in northeast Nebraska. The soils are primarily silty clay loams. The operator has decided that replacing peak crop water use rates nine years out of 10 is acceptable. The operator will enroll the system in the two-day electric load control program, and will need three hours per week for repair and maintenance.

Center Pivot System Capacity Worksheet

1. Select soil texture.
   (*Table I*) Soil texture *silty clay loam*.
2. Select the region of the state. (Antelope County).
   (*Figure 1*) Region number **1** (northeast)
3. Select the net system capacity opposite the soil texture in *Table I*.
   (*Table I*) Net System capacity **4.24** gpm/acre
4. Assume the load control per week is 24 hours.
5. Assume that repair and maintenance down time is three hours per week.
6. Add the load control and repair and maintenance times together to obtain the total estimated down time per week.

   24 hours + 3 hours = **27** hours of downtime

7. Calculate the multiplication factor for 27 hours (168) ÷ (168 - 27) = 1.19
8. Determine the total net system capacity by multiplying steps 3 and 7 together.

   step 3 *step 7*

   4.24 net gpm/acre × **1.19** = **5.05** net gpm/acre

9. Determine the number of acres to be irrigated.

   Area = 130 acres

10. Multiply the net system capacity (step 6) by the number acres (step 7) to determine the total net water supply rate needed for the system.

    step 8 × *step 9* = total system capacity

    5.05 net gpm/acre ×**130** acres = **656** gallon per minute

11. Divide the total net water supply rate (step 10) by the application efficiency (use 0.85 percent for high pressure impacts; 90 percent for low pressure impacts; 92 percent for low pressure spray heads on top of the pipeline; and up to 95 percent for spray heads on drop tubes at truss rod height).

    step 10 ÷ *Efficiency*

    656 gpm ÷ 0.85 = **772 gpm**

This example shows the minimum water supply rate for a center pivot equipped with high pressure impact sprinklers should be approximately 772 gallons per minute (656/0.85). The minimum system flow rate for a center pivot with low pressure spray nozzles at truss rod height would be 690 gpm (656/0.95).

Summary

Determining the appropriate system capacity for a center pivot is an important decision. Choosing a system capacity that is too low can result in crop stress. Choosing a system capacity that is too high results in an investment in a pump, motor and other distribution system components that is greater than necessary.

Using the water stored in the soil and rainfall that occurs and making adjustments for system down time due to repair and maintenance or load management modify the flow rate that must be supplied to the center pivot. Taking these factors into consideration assures the irrigation system has adequate capacity to carry out the operator's management scheme while minimizing system ownership costs.

This publication has been peer reviewed.

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Applying Pesticides Safely

Clyde L. Ogg, Pesticide Safety Educator and Pierce Hansen, 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 Program G1893*
- *Protecting Pesticide Sensitive Crops G2179*
- *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.

NO DRIFT ZONE

driftwatch

Pesticide Sensitive Crops and Habitats Registry

www.driftwatch.org

Sign Up!

Register or learn more:

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Pesticide Sensitive Crops and Habitats Registry

www.driftwatch.org

NEBRASKA DEPARTMENT OF AGRICULTURE

Driftwatch is an online registry that helps Nebraska pesticide applicators, specialty crop growers, and stewards of at-risk habitats communicate more effectively to protect pesticide-sensitive areas. It is maintained by the Purdue University Department of Agricultural and Biological Engineering. The Nebraska Department of Agriculture serves as data manager.

Driftwatch is not intended to be a registry for homeowners or sites less than half an acre.

For growers and stewards

Register your site so applicators know about your sensitive area and can plan to avoid it.

For applicators

Sign-up for automated email notification of grower locations in your area. Use the handy Google Maps™ interface to locate registered sensitive crops before you spray.

As the site grows, tools and training will be added to help stewards and applicators protect sensitive areas.

NebGuide

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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.

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). 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.

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 which address personal protection, protection of others and protection of sensitive sites, ground water and endangered species. Some pesticide labels direct an applicator to protect endangered species (plant or animal) as per an online county 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 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 licensing of persons wishing to purchase and use any restricted 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.

Nebraska's pesticide law and related regulations differ from that of FIFRA in several aspects. One difference is that a pesticide license is required for applicators AND mixer/loaders of all restricted use pesticides. The application of general use pesticides by a commercial applicator in the Ornamental and Turf and Structural categories requires a pesticide license. Under the Nebraska Pesticide Act, persons 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. Informally known as the chemical trespass regulation, pesticides can only be applied to property with the permission of the legal owner or tenant. No recommendation can be made that is contrary or inconsistent to the pesticide label.

Nebraska law also creates a noncommercial classification of applicators. This classification includes any person who applies restricted use pesticides "...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 pesticides (GUP or RUP) for vector control must obtain a license (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 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 before the license expires for private and commercial applicators. 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

Persons seeking initial certification (licensing) as commercial or noncommercial pesticide applicators in Nebraska can attend training provided through UNL Extension and/or complete self-study of training materials. In either case, the candidate must successfully pass both a general standards core exam and one or more specific category examinations. 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. A commercial/noncommercial applicator also may recertify by examination.

To become recertified as a private applicator, individuals can:

1. Complete an approved training program provided by UNL Extension
2. Complete a self-study workbook 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 — Plant or Ornamental and Turf Pest Control. 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. The management of vertebrate pests invading structures with pesticides is in the Structural/Health Pest Control category.

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. Unlicensed applicators applying GUPs in the Ornamental and Turf category, the Structural category and custom applicators in the Public Health category also may use this exemption for license. The 60-day exemption is allowed once in a lifetime for the applicator. In order to use pesticides as an unlicensed applicator, the individual or his or her employer shall apply to the department 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 which 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 of time

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 required pesticide commercial or noncommercial 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.

Records of commercial applications of any pesticide (GUP or RUP) made to an agricultural production site must be provided to the producer/grower. For the protection of the grower, his/her family and employees, application information, including the restricted entry interval (REI) and personal protective equipment (PPE) required of applicators must be provided to the grower prior to the application. Application records of RUPs custom applied for a grower must either 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 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 certified applicator who made or supervised the application

Spot treatments — Record Keeping

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. Authority to inspect private applicators is provided in the 1990 Food, Agriculture, Conservation and Trade Act. 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 persons 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 restricted use pesticides to hold a Nebraska pesticide dealer's license and to be registered with the NDA. Dealers who distributes restricted use pesticides must keep a record of each transaction involving an RUP for 3 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 restricted use pesticide was made available. (Note: No dealer may make an RUP available to an uncertified person unless he/she can document that the distribution is to a licensed dealer or the restricted use pesticide 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 restricted use pesticide, if different from Section 1 above
3. The number on the person's license or dealer license number, the state which 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 to whom the restricted use pesticide is made available
2. A photocopy or other facsimile of the applicator's license, a signed statement from the certified 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 which 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 gravity of the offense and 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" are 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.

References

University of Nebraska–Lincoln Pesticide Education Resources *http://PestEd.unl.edu*

Nebraska Department of Agriculture Pesticide Program *http://www.agr.state.ne.us/division/bpi/pes/pest1.htm*

Nebraska Pesticide Act and Pesticide Regulations, as amended (Title 25, Chapter 2) *http://www.agr.state.ne.us/regulate/bpi/pes/actbm.htm*

Federal Insecticide, Fungicide and Rodenticide Act, as amended *http://www4.law.cornell.edu/uscode/html/uscode07/usc_sup_01_7_10_6.html*

USDA Federal Pesticide Recordkeeping Program for private applicators *http://www.ams.usda.gov/science/sdpr.htm*

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

Index: Pesticides, General Regulations
1979, 2002, Revised August 2007

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

Know how. Know now.

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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.

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G2033

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 landfill, 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)*.

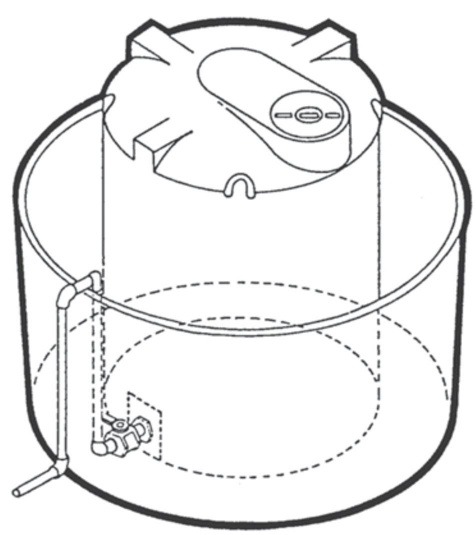

Figure 3. Secondary containment

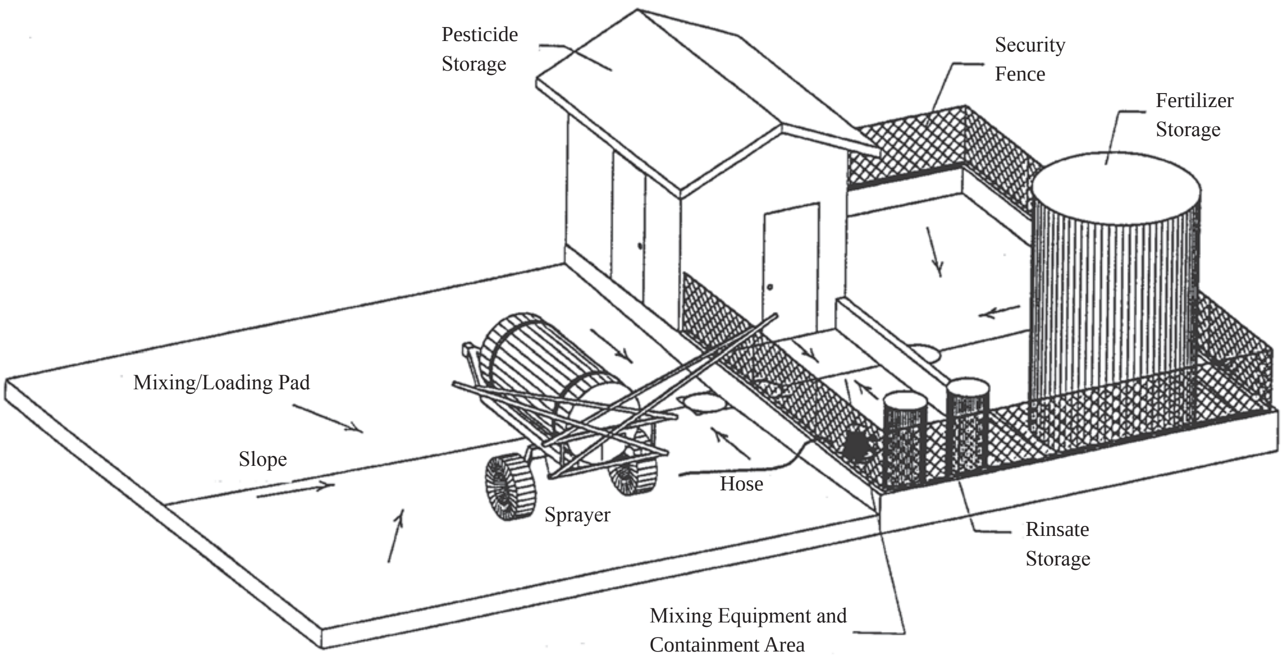

Figure 4. A load-out pad

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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G1955

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 a product. (For more information see NebGuide G479, *Pesticide Laws and Regulations*).

Not all labels are the same. 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. 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 furnish certain information on the label. The information includes:

- the brand name or trade name of the product;
- the ingredient statement;
- the percentage or amount of active ingredient(s) by weight;
- the net contents of the container; and
- the name and address of the manufacturer.

Other required parts of the label are:

- the registration and establishment numbers;
- statement of practical treatment;

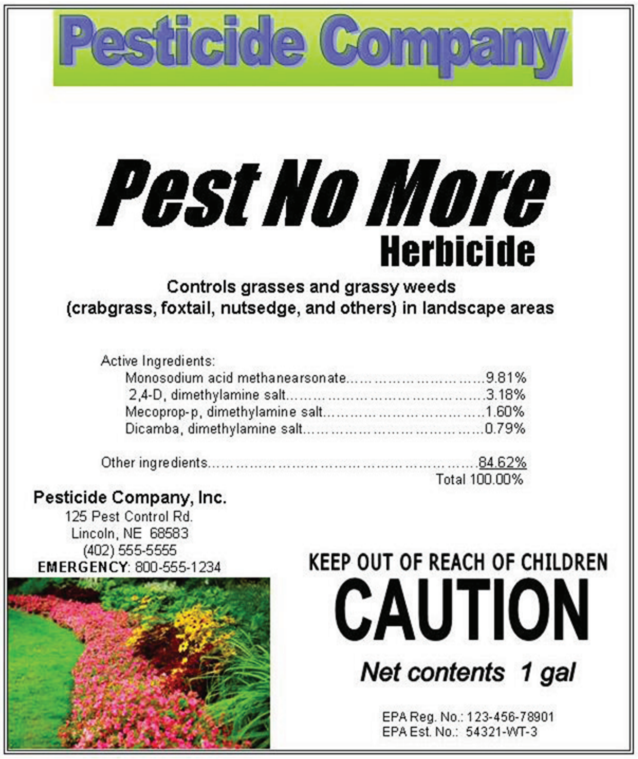

Figure 1. An example of what a pesticide label might look like.

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

The following information details the parts of the label and discusses the importance of each.

Brand, Trade, or Product Name

This is the name used to identify and market the product (e.g. Pest No More in *Figure 1*). Different companies will use different brand names to market their product 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 also show their 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). 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.

Table I. Signal-level words.

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.		

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 and Danger *(Table I)*.

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 *Protective Clothing and 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 *Protective Clothing and Equipment Statement* outlines the equipment requirements which protect the applicator from exposure to the pesticide. (See NebGuide G758, *Protective Clothing and Equipment for Applicators*) Even though it may not be required by the label, UNL Extension recommends applicants wear a long-sleeved shirt, long pants, chemical-resistant shoes plus socks, **and** chemical-resistant gloves in order to be adequately protected.

Statement of Practical Treatment

Also called *First Aid* on many consumer labels, the *Statement of Practical Treatment* tells what to do in case of product exposure. 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 "Get medical attention" are two examples of information found in the *Statement of Practical Treatment* section.

Environmental Hazards Statement

This 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

Descriptions of any possible fire, chemical, or explosion hazards specific to this product are listed in this section of the label. 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 the *Physical and Chemical Hazards* section of the label.

Agricultural Use Requirements

This section *(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 *(Figure 3)*.

Storage and Disposal Statement

Each pesticide label has general storage and disposal instructions. Proper storage of any pesticide is important. 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

These directions instruct the applicator how to properly apply the pesticide and achieve the best results. The *Directions for Use* provide information for things 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 that indicates how much time must pass between the application and harvest to avoid 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.

Everyone should read and follow all label directions for effective, safe, and legal use of pesticides. Reading the pesticide label before purchasing, transporting, mixing, applying, and before storing or disposing of excess pesticide or empty containers will help ensure proper and legal pesticide use.

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G1773

Spray Drift of Pesticides

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This NebGuide discusses conditions that cause particle drift, and methods private and commercial applicators may employ 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, 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 mainly on conditions that cause particle drift, and methods to reduce the drift potential of spraying pesticides.

Drift Dynamics

A solution sprayed through a nozzle divides into droplets that are spherical or nearly spherical in shape. A recognized measure for indicating the size of these droplets is micron size.

Droplets smaller than 100 microns, about the diameter of the human hair, are considered highly driftable and are so small they cannot be readily seen unless in high concentrations, such as fog. By comparison, a dime is about 1,270 microns thick. As a result of the small size, drift is more dependent on the irregular movement of turbulent air than on gravity.

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 size of the droplet. Small droplets fall through the air slowly, and are carried farther by air movement.

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 speed and movement of spray droplets.

Table I. Effect of droplet size on drift potential (Ross and Lembi, 1985)

Diameter, microns	*Time to fall 10 feet in still air*
1 (Fog)	28 hours
10 (Fog)	17 minutes
100 (Mist)	11 seconds
200 (Fine Spray)	4 seconds
400 (Coarse Spray)	2 seconds
1,000 (Coarse Spray)	1 second

Droplet speed is reduced by air resistance, which breaks up the droplets. After their initial speed slows, the droplets continue to fall under the gravitational pull.

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. Small droplets also evaporate quickly, leaving minute quantities of the pesticide in the air *(Figure 1)*. Larger droplets are more likely to be deposited on the intended target.

Ideally, most of the volume should be contained in larger droplets. When pressure is increased, a higher percentage of droplets are small droplets. With a greater proportion of the total spray volume in smaller droplets, the potential drift onto off-target sites increases.

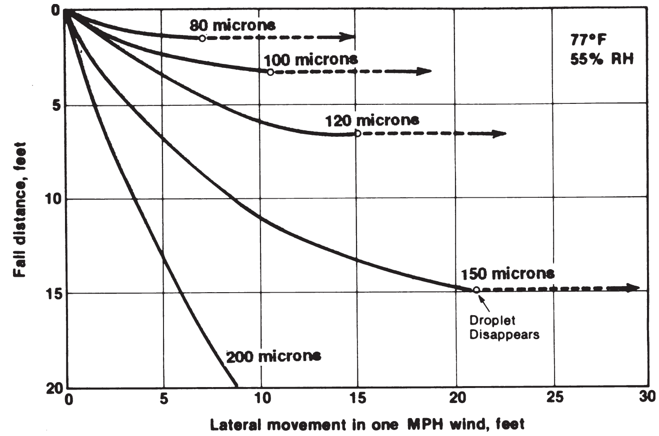


Figure 1. Lateral Movement of water droplets. (Hofman, et al., 1986)

Altering Droplet Size

Many components of a sprayer can be adjusted to alter droplet size. Of these, nozzle type selection is one of the most critical.

- ***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.
- 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.

Table II. Effect of nozzle type on droplet size at 40 PSI and 0.5 GPM (Spraying Systems Co., 2007)

Nozzle Type	*Volume Median Diameter, microns*
Hollow Cone	330
Drift Guard	440
Turbo TeeJet	500

Volume median diameter (VMD) is a term used to describe the droplet size produced from a nozzle tip. VMD is the droplet size at which one-half the spray volume consists of large droplets and one-half consists of smaller droplets. 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.

Droplet sizes are influenced by various nozzle types and different spray pressures. The Turbo TeeJet cone produces the largest droplets of the three, which results in lower 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.

Remember, nozzles produce a wide range of droplet sizes. A nozzle that can produce only one size droplet is not presently available. Therefore, the goal in the proper application of pesticides is to achieve a uniform spray distribution while retaining the spray droplets within the intended target area.

- ***Spray Pressure:*** Spray pressure influences the formation of the droplets. 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 the sheet breaks up into smaller droplets.

Large orifice nozzles with higher carrier volumes produce larger drops. Small droplets are carried farther downwind than larger drops formed at lower pressures *(Figure 1)*.

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 greatly contribute to the drift potential and is not an acceptable method to increase carrier volumes. If the carrier volume needs to be changed, select a different nozzle tip that meets the spraying requirements. Consult *NebGuide G955, Nozzles — Selection and Sizing,* for proper selection.

Table III shows the mean droplet size for nozzles when spraying at three pressures. Higher pressures decrease the droplet size.

- ***Nozzle Spray Angle:*** Nozzles that have wider spray angles produce a thinner sheet of spray solution and smaller droplets at the same pressure *(Table III)*. However, wide angle nozzles can be placed closer to the target, and the benefits of lower nozzle placement 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 III. Effect of spray angle and pressure on droplet size (Spraying Systems Co., 1990)

	Nozzle Pressure		
Nozzle Spray Angle	*15 PSI*	*40 PSI*	*60 PSI*
Degrees	***Volume Median Diameter, microns***		
40	900	810	780
65	600	550	530
80	540	470	450
110	410	380	360

- ***Spray Volume:*** The size or capacity of the nozzle also influences droplet size. The larger orifice increases the droplet size at a common pressure. It increases the number of refills, but the added carrier improves coverage and in some cases increases pesticide effectiveness. *Table IV* shows the influence of an increasing flow rate on droplet size at a constant pressure. With some pesticides, such as glyphosate, the carrier must be kept low.

Table IV. Effect of flow rate on droplet size at 40 PSI (Spraying Systems Co., 2007)

	Flow Rate		
Nozzle Type	*0.3 GPM*	*0.4 GPM*	*0.5 GPM*
	Volume Median Diameter, microns		
Extended Range			
Flat Fan	270	300	330
Drift Guard	400	425	450
Turbo TeeJet	450	480	510

Other Drift Factors

- ***Boom Height:*** Operating the boom as close to the sprayed surface as possible — staying within the manufacturer's recommendation — is a good way to reduce drift. A wider spray angle allows the boom to be placed closer to the target *(Table V)*. 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. Shielded booms reduce the drift from excessive air movement from travel speed and wind.

Table V. Suggested minimum spray heights. (NebGuide G955)

	Nozzle Spacing			
	20 inches		*30 inches*	
	Percent Overlap			
Spray Angle Degrees	*30%*	*100%*	*30%*	*100%*
	Spray Height, inches			
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:*** 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.

As a general guideline, do not exceed a 30-inch nozzle spacing because the spray pattern uniformity begins to degrade. A configuration of nozzle spacing, height and direction, which gives 100 percent overlap, is preferred.

• ***Wind Speed:*** The amount of pesticide lost from the target area and the distance it moves both increase as wind velocity increases *(Table VI)*. However, severe drift injury can occur with low wind velocities, especially under temperature inversion situations. Most recommendations are to stop spraying if wind speeds exceed 10 mph. Wind influences can be minimized by using shielded booms and lower boom height.

Table VI. Effect of wind speed on drift in a 10-foot fall (Ross and Lembi, 1985)

	Wind Speed	
Droplet Diameter, microns	*1 MPH*	*5 MPH*
	Drift, feet	
100 (Mist)	15.4	77
400 (Coarse Spray)	3.0	15

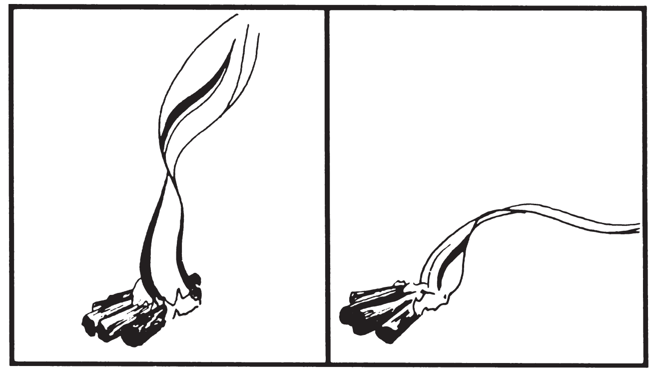
• ***Wind Direction:*** Pesticides should not be applied when the wind is blowing toward a nearby susceptible crop or a crop in a vulnerable stage of growth. Select a time when there is little wind or the wind blows gently away from susceptible crops. If these conditions do not exist, consider another method of control or time of application.

• ***Air Stability:*** Air movement largely determines the distribution of spray droplets. Wind generally is recognized as an important factor, but vertical air movement often 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.

Under inversion conditions, little vertical mixing of air occurs, 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.

Avoid applying pesticides near susceptible crops during temperature inversion conditions. Inversions can be identified by observing smoke from a smoke bomb or a fire *(Figure 2)*. Smoke moving horizontally close to the ground would indicate a temperature inversion.



Proper application condition — Temperature inversion — do not apply

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

• ***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 droplets become smaller.

The quantity of spray that evaporates is related to the quantity of the spray deposit. Evaporation is greater from the same deposit in small droplets than in larger drops because the small droplets have greater surface area relative to their volume. Less pesticide gets to the target *(Figure 1)*.

Evaporation increases the drift potential, so spray during lower temperature and higher humidity conditions. Pesticides differ in their evaporation rate. Use formulations and adjuvants that reduce evaporation.

As a rule of thumb, if the relative humidity is above 70 percent, the 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 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 Concerning 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. Surveys indicate approximately 65 percent of drift complaints involved application procedures in violation of the label. Apply a pesticide only if economic thresholds warrant an application.
3. Use spray additives within label guidelines. This will increase the droplet sizes and pesticide effectiveness.
4. Use larger orifice sizes. This will give larger droplets and increase the number of tank refills, but will improve coverage and effectiveness.
5. Avoid high pressure. High pressure creates finer droplets; 45 PSI should be considered maximum for conventional broadcast spraying.
6. Use drift-reduction nozzles. They will produce larger droplets when operated at low pressures.
7. Use wide-angle nozzles, low boom heights, and keep the boom stable.
8. Drift is minimal when wind velocity is under 10 mph. Do not spray when wind is greater or blowing towards sensitive crops, gardens, dwellings, livestock or water sources.
9. Use shielded booms. When banding, use shroud covers.

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Weight and Measure Conversions

Weight
16 ounces = 1 pound = 453.6 grams
1 gallon water = 8.34 pounds = 3.78 liters

Liquid measure
1 fluid ounce = 2 tablespoons = 29.57 milliliters
1 tablespoon = 3 teaspoons
16 fluid ounces = 1 pint = 2 cups
8 pints = 4 quarts = 1 gallon

Length
3 feet = 1 yard = 91.44 centimeters
16.5 feet = 1 rod
5,280 feet = 1 mile = 1.61 kilometers
320 rods = 1 mile

Area
9 square feet = 1 square yard
43,560 square feet = 1 acre = 160 square rods
1 acre = 0.405 hectare
640 acres = 1 square mile = 1 section

Speed
88 feet per minute = 1 mph
1 mph = 1.61 km/hour

Volume
27 cubic feet = 1 cubic yard
1 cubic foot = 1,728 cubic inches = 7.48 gallons
1 gallon = 231 cubic inches
1 cubic foot = 0.028 cubic meters

Common abbreviations and terms:
FPM = feet per minute
GPA = gallons per acre
GPH = gallons per hour
GPM = gallons per minute
MPH = miles per hour
PSI = pounds per square inch
RPM = revolutions per minute
VMD = volume median diameter

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Index: Pesticides, General Equipment

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G758
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Protective Clothing and Equipment for Pesticide Applicators

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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

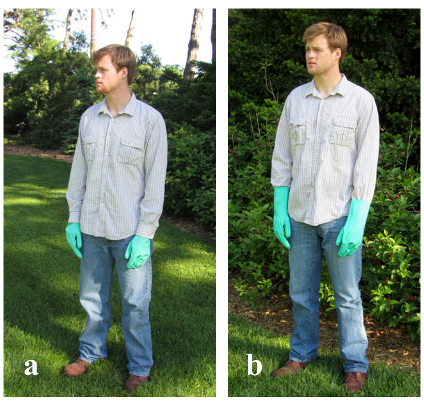

Figure 1. Wear a long-sleeved shirt, long pants, shoes plus socks, and chemical resistant gloves when applying pesticides. We recommend wearing gloves inside sleeves (1a), but wearing gloves outside sleeves may work equally well (1b).

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.

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.

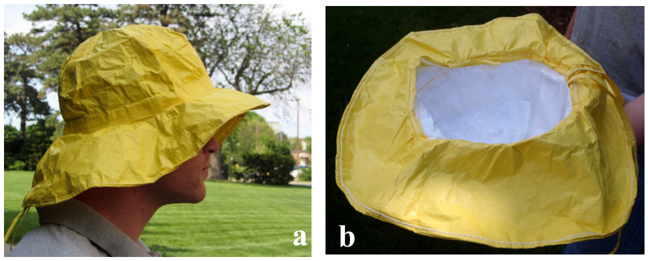

Figure 2. Example of protective hat that can be worn when applying pesticides.

Figure 3. Different types of safety goggles and glasses.

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:

- 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.

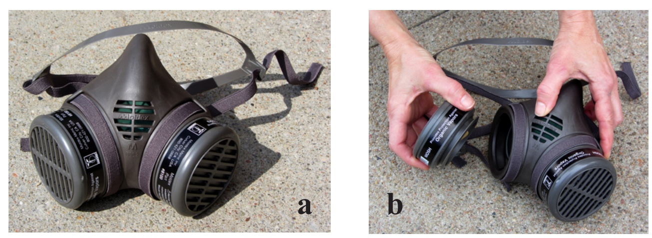

Figure 6. Half-face cartridge respirator with cartridges attached (6a) and cartridge detached (6b).

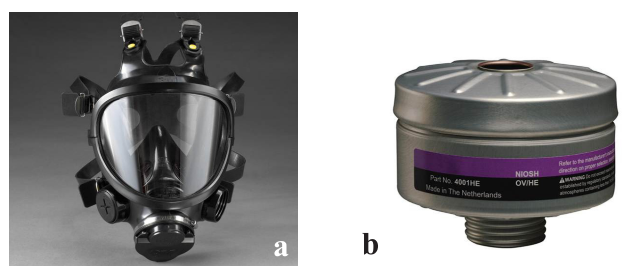

Figure 7a. Full-face canister respirator (no canister) (Photo courtesy of 3M); 7b. Close-up of canister. (Photo courtesy of North by Honeywell)

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*.

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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.

G1961

Pesticide Safety: Choosing the Right Gloves

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Leah L. Sandall, Extension Assistant

This NebGuide explains how to choose and properly use gloves when mixing, loading, and applying pesticides to help reduce exposure to chemicals and protect human health.

Properly protecting yourself when applying pesticides can decrease the potential risk of pesticides to your health and safety. Handling pesticides can include mixing, loading, and applying, all of which can potentially expose your hands to chemicals. The right gloves are 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 their use, chemical-resistant gloves should be worn when handling pesticides.

Types of Gloves

Glove selection depends on the type of pesticide and the application. In general, unlined, chemical-resistant gloves made of neoprene, butyl, or nitrile rubber are best. These materials provide good protection under most conditions, are durable, and are reasonably priced *(Figure 1)*. The most protective glove is a barrier laminate glove consisting of two or more materials laminated or blended together *(Figure 2)*.

Some gloves are waterproof, but do not provide adequate protection. Be sure you use gloves specified as "chemical resistant." Avoid latex gloves. They do not provide adequate skin protection, disintegrate rapidly, and are not recommended by the EPA for use with pesticides. Garden gloves, medical gloves, and household cleaning gloves are inadequate for pesticide applications.

Lightweight, single-use cotton liners may be worn inside chemical-resistant gloves. Liners improve the comfort and ease of putting on and taking off gloves. However, these

Figure 1. Examples of recommended gloves: nitrile (reusable and disposable), neoprene, and butyl rubber.

Figure 2. Example of EPA's highest rated protective glove material, barrier laminate.

Table I. Types and characteristics of personal protective material.
(for use when the personal protective equipment 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 10 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*

liners must be discarded after each use to avoid potential exposure to pesticides that may have been absorbed into the cotton material. You also 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 has developed a rating chart defining chemical resistance of various materials used in glove construction. These ratings vary 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 label. It is based on the solvents within pesticides rather than the pesticides themselves. The category refers to how long a glove of a certain material and thickness can be worn while handling a specific pesticide. This is also dependent upon the pesticide's formulation. For example, the amount of time you can wear a certain glove when using a dry formulation may differ from the same pesticide in a liquid formulation.

Table I, a reproduction of the EPA's ratings chart, contains a list of the types of personal protective material and their characteristics. It can be very helpful when determining the appropriate type of gloves for pesticide mixing, loading, and application. In addition, the solvents in pesticides assigned to each chemical resistance category are listed next to the corresponding category letter (A-H).

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 in mixing and loading, or a diluted pesticide, used during application. Glove lifespan is much longer when using a diluted pesticide than a concentrated one. Whether you are mixing, loading, or applying pesticides, the amount of contact time you have with pesticides also will be a factor. Depending on the amount of chemical resistance in the material, someone mixing and loading a concentrated pesticide all day will need to exchange gloves that are labeled as "Slight" or "Moderate" chemical resistance more often than someone who does mixing and loading for one hour or someone who spends half a day applying diluted pesticide. Always follow label instructions about proper glove wear.

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 other protective equipment, the number of times these gloves can be reused depends on the age and condition of the material and hours of use. Gloves have to be replaced after eight hours of continuous use, for example, but could be used several times if used in shorter intervals. After sufficient use or extended storage, glove material can become brittle and less impervious to chemicals. Also, any glove, regardless of thickness, should be discarded if it becomes torn or damaged. Do not use gloves more than one season.

Gloves with less than 14 mil thickness (often referred to as disposable) have a shorter lifespan than those indicated in the EPA chart. These disposable gloves also feature thickness (less than 14 mil), size, and cuff length choices.

Cost often varies with thickness; thicker gloves usually are more expensive. However, thicker gloves offer better protection.

In general, disposable gloves may be preferable to reusable because they can be discarded after one use and require much less maintenance. 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 more may be a better choice in some circumstances.

Reusable gloves must be washed and carefully removed after use to prevent contamination of your skin or areas such as a tractor cab interior. Reusable gloves must be stored properly and checked for leaks before using again, but disposable gloves can be thrown away — according to the label — after completing a 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 by measuring the circumference around the palm of your hand. For example, if the circumference is 8 inches, a medium probably would be the best choice.

Available glove sizes are found in the table below:

Glove size	*Circumference of palm (in inches)*
Extra small	6-7
Small	7-8
Medium	8-9
Large	9-10
Extra large	10-12
2XL	11-12
Jumbo	12-13

Proper glove fit is essential. Poorly fitting gloves can complicate your ability to apply pesticides correctly. Gloves that are too tight will be uncomfortable and may result in breakage, allowing pesticides to penetrate. Gloves that are too large can slide on the hands and potentially allow pesticide to run down into the gloves and onto your skin. Handling equipment also becomes more difficult when you can't sufficiently grip it, increasing the chance for mistakes. Always try on your gloves and ensure they fit properly before beginning a pesticide application.

Glove Thickness

The thickness of the material in chemical-resistant gloves can affect their lifespan, susceptibility to tears, abrasions, and general wear. Both disposable and reusable gloves are available in various thicknesses. Manufacturers sell gloves with thickness ranges falling between 4 and 22 mil. Other thicknesses also may be available. The breakthrough time generally increases with the material's thickness.

Concentrated pesticide will wear out gloves much faster and decrease their lifespan much more quickly than diluted pesticides. Keep this in mind when choosing a glove thickness.

Proper Use

Under normal circumstances, gloves should be worn over long sleeves to prevent pesticides from running under the gloves *(Figure 3)*. If working above your head, roll the glove tops into a cuff to prevent pesticides from running down the gloves and onto your forearms.

If applying fumigants, be especially cautious; read the label directions for gloves. Some fumigants can penetrate materials such as rubber and neoprene, and may result in 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 air flow so that fumigant gasses won't get trapped against and burn skin.

Figure 3. Wear gloves over long sleeves to protect yourself from pesticide exposure.

Proper Cleaning and Removal

After finishing a pesticide application, remove and discard disposable gloves. Wash your hands with soap and warm water, particularly before eating, smoking, or using the toilet. Reusable gloves should be washed with soap and warm water while still wearing them.

If a concentrated pesticide for mixing and loading gets on your gloves, rinse them immediately before continuing. Thorough washing and removal, as outlined below, can then be done after finishing the job. By implementing these guidelines, you can prolong the life of your gloves as well as protect yourself from exposure.

To properly remove disposable gloves:

1. Grasp the cuff of one glove with the other gloved hand; pull it inside out and off the hand. Deposit the glove into a plastic bag for later disposal. Do the same with the other glove by grasping the inside of the cuff and pulling the glove off with the uncontaminated side up. Don't let the contaminated glove touch your clothing or skin.
2. Dispose of the plastic bag containing the gloves according to label directions.

To properly remove reusable gloves:

1. Wash the outside of your gloves with soap and warm water. Then with a gloved hand, either grasp the fingers of the other glove and slowly pull both gloves off, or turn back the cuffs of each glove and proceed to remove the gloves inside out.
2. Hang the reusable gloves until dry. Do not put them in the washing machine!

After removal of either disposable or reusable gloves, always wash your hands with warm water and soap before resuming 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 potentially expose you, your family, or other people or animals to pesticides.

Storage and Disposal

1. Store unused disposable or reusable gloves in their original bag or other container with a lid, such as a plastic bucket. After disposable gloves have been used, they can be discarded according to label directions. Reusable gloves can be stored in a bucket or plastic bag once they are dry *(Figure 4)*. Never put contaminated gloves directly on the seat of your vehicle. Reusable gloves should be checked before each pesticide application for leaks and wear. Filling the gloves with water and looking for any holes or tears is recommended. Dispose of gloves according to the pesticide label if they are defective or have significant wear. Replace with new ones.

Figure 4. Properly store gloves in a plastic bag or bucket.

Gloves, as well as other PPE, should be stored separately from pesticides to prevent accidental contamination. Gloves should be stored in a clean environment away from direct sunlight or temperature extremes. Do not store used gloves where they could be accessed by children or pets.

By following the label and properly using chemical-resistant gloves when applying pesticides, you will be able to control pests safely and effectively while protecting yourself, your family, other people, animals, and the environment.

This publication has been peer reviewed.

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NebGuide

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

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Pierce J. Hansen, Extension Assistant; and Jan R. Hygnstrom, Project Coordinator

This NebGuide examines the proper way to fit test a cartridge respirator before beginning a pesticide application and how to maintain a respirator after use.

When working with any pesticide, you must follow all personal protective equipment (PPE) requirements listed on the label. This is for your safety, and also is a legal requirement for using pesticides. Some pesticides carry a risk of inhalation exposure and require the use of a respirator, such as a dust respirator, full or half face cartridge (air purifying) respirator, or self-contained breathing apparatus (SCBA). This NebGuide will focus on the half face cartridge respirator, which is one of the most common respirators used when applying pesticides.

Like other PPE, it is vital to properly maintain your respirator to ensure that it offers adequate protection when you apply pesticides. This includes testing the respirator before each use to make sure that it has a tight seal, as well as proper cleaning and storage of the respirator after each use.

Your New Respirator

Some pesticide labels clearly state specific types of respirators/cartridges/filters that are required. Be sure to follow these directions carefully; purchase and use the appropriate type for the product you will be applying.

When you buy a new respirator, it will come in a package with several components. These include an instruction manual, faceplate with straps, two cartridges, and extra accessories to attach for dust or particulate protection *(Figure 1)*. Check the labels on the cartridges to ensure they provide the protection you need, whether it is against organic vapors or other particulates.

It is important to read the instruction manual thoroughly before using the respirator. The manual explains how to properly assemble, fit, maintain, and store the respirator. The most important thing to remember when using a respirator is to get a good seal. Without a good seal, the respirator will not effectively protect you from pesticide inhalation exposure.

Fit Testing

Fit testing is mandatory under Occupational Safety and Health Administration (OSHA) regulations. Fit testing must be done to determine the size of the respirator for a particular user. Pesticide applicators need to meet certain health requirements before conducting a fit test or doing work that requires a respirator. OSHA requires that an employee who will be using a respirator have a medical evaluation prior to fit testing. The employee also needs to be properly trained in respirator use. For more information about OSHA's medical evaluation questionnaire, mandatory fit test procedures, and

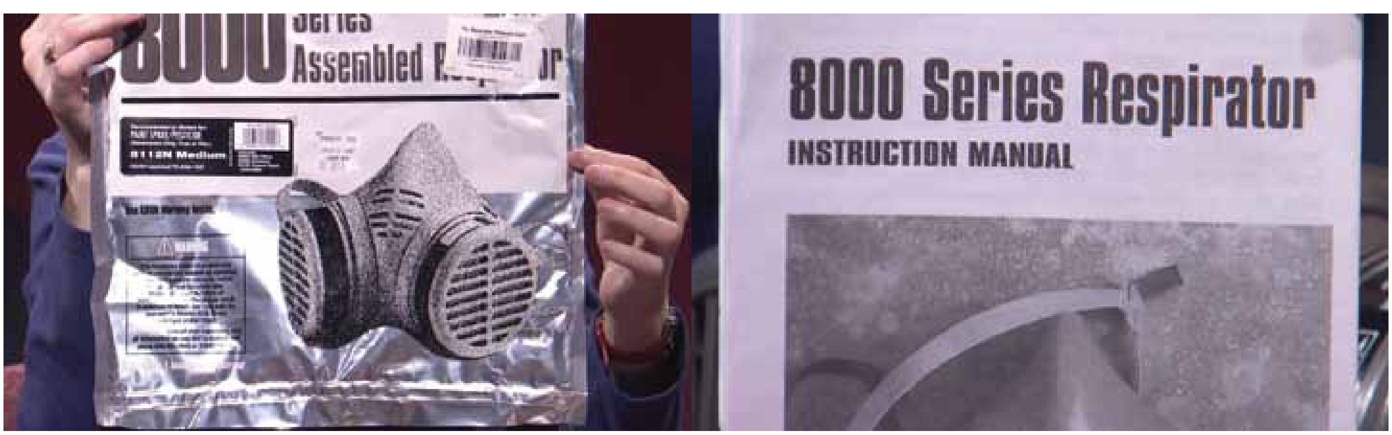

Figure 1. Examples of respirator packaging and instruction manual.

Figure 2. Adjusting a respirator step-by-step: 1. Place on face. 2. Adjust halo. 3. Adjust neck straps.

other respirator requirements, visit OSHA's website at *http://www.osha.gov* and search for regulation 1910.134.

OSHA lists minimum requirements for respirator fit testing and initial use. For example, a new fit test may be required if there is a change in size, make, or model of the respirator you are using, or a change in user characteristics such as dental work, body weight, etc. You should always follow these guidelines.

The most important part of a fit test is obtaining a good seal. It is good common practice to test the seal on your respirator **every time** you put it on. Between removal, cleaning, and storage, the respirator may not fit the same, so you'll have to readjust it before using it again. Prior to each use, check the face seal for cracks and abrasions. Check respirator assembly (components, valves, O-rings) to ensure they are intact, present, and appropriate.

To accomplish a seal check, the faceplate has to fit tightly against your face. Facial hair may prevent you from being able to get a tight seal, so you may need to shave before using a half face respirator, or choose an alternative pesticide that does not require a respirator.

There are three common ways to test the seal. Before testing, adjust the respirator so you think you have a good fit. To begin, place the respirator on your face, then pull the top (halo-shaped in some models) plastic strap and adjust it over and on top of your head. Next, connect the straps that go behind your neck, and pull the loose ends of the straps to adjust for comfort and fit. When you feel you have a tight seal, test to ensure your respirator is fitted 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

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

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Index: Pesticides, General Safety

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G1893

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. The registration of pesticides is required by the Environmental Protection Agency (EPA). Because some pesticides may harm certain threatened or endangered species, a review of potential impacts is required by the EPA.

The Endangered Species Protection Program (ESPP) described here is one of the ways that EPA is meeting the requirements of the ESA. EPA reviews information and data and determines whether a pesticide product may be registered for a particular use. The primary goal of this program 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 labeling of affected pesticide products, directing pesticide users to follow use limitations found in Endangered Species Protection Bulletins. When referenced on a pesticide label, bulletins are mandatory, enforceable pesticide use limitations.

Bulletins are available through EPA's "Bulletins Live" database program by state and county at *http://www.epa.gov/espp/bulletins.htm*. Click the "Bulletins Live" *(Figure 1)* link and select the state and county where pesticide applications will take place. You also may click "NE" on the map, and choose the county where applications will take place from the pull-down menu. Next, select the month of the pesticide application and follow the steps found in

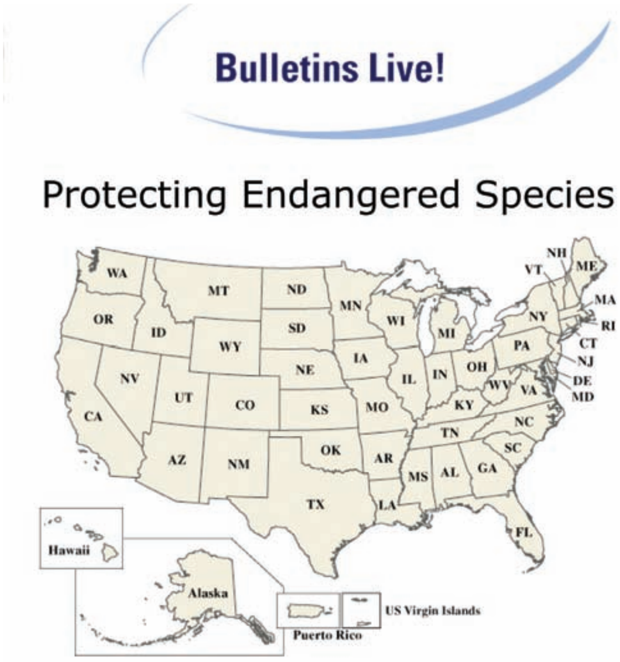

Figure 1. Bulletins Live! map on the EPA Web site.

the bulletin. Bulletins also are available by calling the toll-free endangered species hotline telephone number at 1-800-447-3813. Pesticide users can apply information from a bulletin accessed 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 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

Pesticides are included in the program if they pose a potential threat to a listed plant and/or animal species. The

Figure 2. Blowout penstemon (photo credit: James Stubbendieck, UNL).

Figure 3. Western prairie fringed orchid (photo credit: Nebraska Game and Parks).

Figure 4. Colorado butterfly plant (photo credit: Nebraska Game and Parks).

Figure 5. Interior least tern (photo credit: Nebraka Game and Parks).

EPA consults with the U.S. Fish and Wildlife Service to make this determination.

Discussed here are examples of threatened or endangered animal or plant species that may appear in bulletins for Nebraska. This is not an exhaustive list and it may be expanded in the future. For a complete listing of all Nebraska endangered and threatened species, see the Nebraska Department of Agriculture's Web site in the resources at the end of this publication.

The NDA Pesticide Program has focused its efforts on the protection of six endangered or threatened species in Nebraska by making contacts with landowners and raising the awareness of pesticide applicators. These include three plants: the blowout penstemon, the western prairie fringed orchid, and the Colorado butterfly plant; two birds: the piping plover and the interior least tern; and an insect: the American burying beetle.

Blowout penstemon (*Penstemon haydenii***).** The blowout penstemon (endangered) *(Figure 2)* is unique to the Sandhills region of Nebraska and Carbon County, Wyoming. About 20,000 plants exist today due to recovery efforts, primarily in Box Butte, Cherry, Garden, Hooker, and Thomas counties. It is a "pioneer" plant that begins growth in a sand blowout site before most other plant species, functioning to anchor the sandy soil and reduce wind erosion. Most of the known plants are on private land. However, they also are found in the Valentine Migratory Waterfowl Refuge (Cherry County), the Crescent Lake National Wildlife Refuge (Garden County), Bessey Ranger District, U.S. Forest Service (Thomas County), and McKelvie National Forest, U.S. Forest Service (Cherry County).

Western prairie fringed orchid *(Platanthera praeclara*). The western prairie fringed orchid (threatened)

Figure 6. Piping plover (photo credit: Nebraska Game and Parks).

Figure 7. American burying beetle (photo credit: Nebraska Game and Parks).

habitat *(Figure 3)* in Nebraska is in the eastern two-thirds of the state. It requires sites where near-surface groundwater maintains a relatively high and constant level of soil moisture. Known populations are in Cherry, Hall, Lancaster, and Seward counties. Contract agreements have been established with owners of private lands to protect the western prairie fringed orchid.

Colorado butterfly plant (*Gaura neomexicana* var. *coloradensis)***.** The Colorado butterfly plant (threatened) *(Figure 4)* 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 Kimball County. 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.

Interior least tern *(Sterna antillarum*). The interior least tern (endangered) *(Figure 5)* is small, measuring 8 to 9 inches long and having a 20-inch wingspread. Males and females appear identical with a black crown, white forehead, gray back, gray wings above with white below, orange legs, and a black-tipped yellow bill. Immature birds have darker feathers, a dark bill, and dark eye stripes on white heads.

The interior least tern resides from spring to fall on barren sand bars of four rivers in Nebraska: the Platte River (generally from North Platte to Omaha), the Loup River (St. Paul to Columbus), the lower Niobrara River (below Butte), and the unchannelized stretches of the Missouri River in Northeast Nebraska.

The nest is inconspicuous, unlined, and usually contains three brown spotted eggs. The interior least tern feeds on small fish and crustaceans taken by diving from the air into shallow water. During the breeding season, these birds usually feed within a few hundred meters of the nesting area.

Piping plover (*Charadrius melodus*). The piping plover (threatened) *(Figure 6)* is a sandy-gray, robin-sized shorebird with one dark breast band. It has a dark stripe across the crown during the breeding season. Other characteristics include a white wing stripe and a white rump that is visible in flight. A common relative, the killdeer, is larger, more darkly colored, and has two dark breast bands.

The piping plover is present in breeding areas from late March through August. Nesting occurs on sandbars and sand and gravel beaches with short, sparse vegetation along inland lakes, on natural and dredge islands in rivers, and in gravel pits along rivers.

Nests are shallow, occasionally lined with small pebbles, shells, or other material. A clutch of four eggs usually is laid in late May or early June. Piping plovers feed along the water's edge on small insects, crustaceans, and mollusks. The piping plover commonly is found in the same breeding areas as that of the interior least tern.

American burying beetle (*Nicrophorus americanus*). The American burying beetle (endangered) *(Figure 7)* is a carrion feeder that is now found only in six states, including Nebraska. This beetle is the largest North American carrion beetle and may reach 1½ inches. It is black with distinct orange band markings on its wing covers and on its face between the eyes. This species is nocturnal, seeking out and burying carrion to feed its young.

Carrion availability, rather than soil or vegetation type, appears to determine habitat of the American burying beetle. The species seems to occur in areas least disturbed by human influence, such as the Sandhills region of the state, where it has been found most recently. Locations include grassland prairie, forest edges, and scrubland.

There are perhaps fewer than 1,000 American burying beetles east of the Mississippi River. Populations in other areas, including Nebraska, are unknown but appear to be small. Factors that may be playing a role in the decline include potential habitat fragmentation that lower numbers of the size and species of preferred carrion, competition for carrion by other predators, artificial lighting that decreases nocturnal insect populations, changing sources of carrion, isolation of preferred habitats, and genetic characteristics within populations that reduce reproduction. Surveys currently are being done to further identify the location of American burying beetle populations and thus protect this species' habitat from further disruption.

Resources

The following individuals, offices, or Web sites may be contacted for additional information.

Craig Romary, Nebraska Department of Agriculture, Lincoln, NE (402) 471-2394

Dick Wiechman, Environmental Protection Agency, Lincoln, NE (402) 437-5080

Nebraska Game and Parks Commission, Lincoln, NE (402) 471-0641

EPA endangered species hotline number (800) 447-3813

U.S. Fish & Wildlife Service, Grand Island, NE (308) 382-6468

Nebraska Department of Agriculture List of Threatened and Endangered Species
http://www.agr.state.ne.us/division/bpi/pes/statelist.htm

Endangered Species Protection Program, Environmental Protection Agency
http://www.epa.gov/espp

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G1736

Rinsing Pesticide Containers

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Larry D. Schulze, Extension Pesticide Education Specialist

It is estimated that every year one 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 on pesticide use.

Proper rinsing of pesticide containers is easy to do, saves money and contributes to good environmental stewardship. Rinsing containers at the time of spray solution preparation prevents potential problems with unrinsed containers, storage of the rinse solution (rinsate), and the generation of 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, the need to store and later dispose of it is eliminated.
- Rinsing pesticide containers immediately upon 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 six ounces or more of pesticide product in a 2.5-gallon container. Six ounces is about two percent. If you do not rinse, you either apply two percent less product, which can affect performance of the pesticide, or incur two 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 and ground water. 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 only accept properly rinsed containers. Some landfill operations may not accept rinsed pesticide containers.

Types of Pesticide Containers

The most common agricultural pesticide containers are the minibulk containers from 85 to 300 gallons, plastic drums of 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 or other water-resistant containers. Pesticide products used on animals and in households are nearly all 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 it has been emptied. Two commonly used procedures are effective for rinsing of pesticide containers: triple-rinsing and pressure-rinsing.

Triple-Rinsing

Triple-rinsing means rinsing the container three times and can be used with all plastic containers.

Before emptying pesticide containers: With the cap on, shake the container to thoroughly mix the pesticide. If dilutents or solvents have separated from the pesticide product in the container, mixing will help in the complete removal of the product.

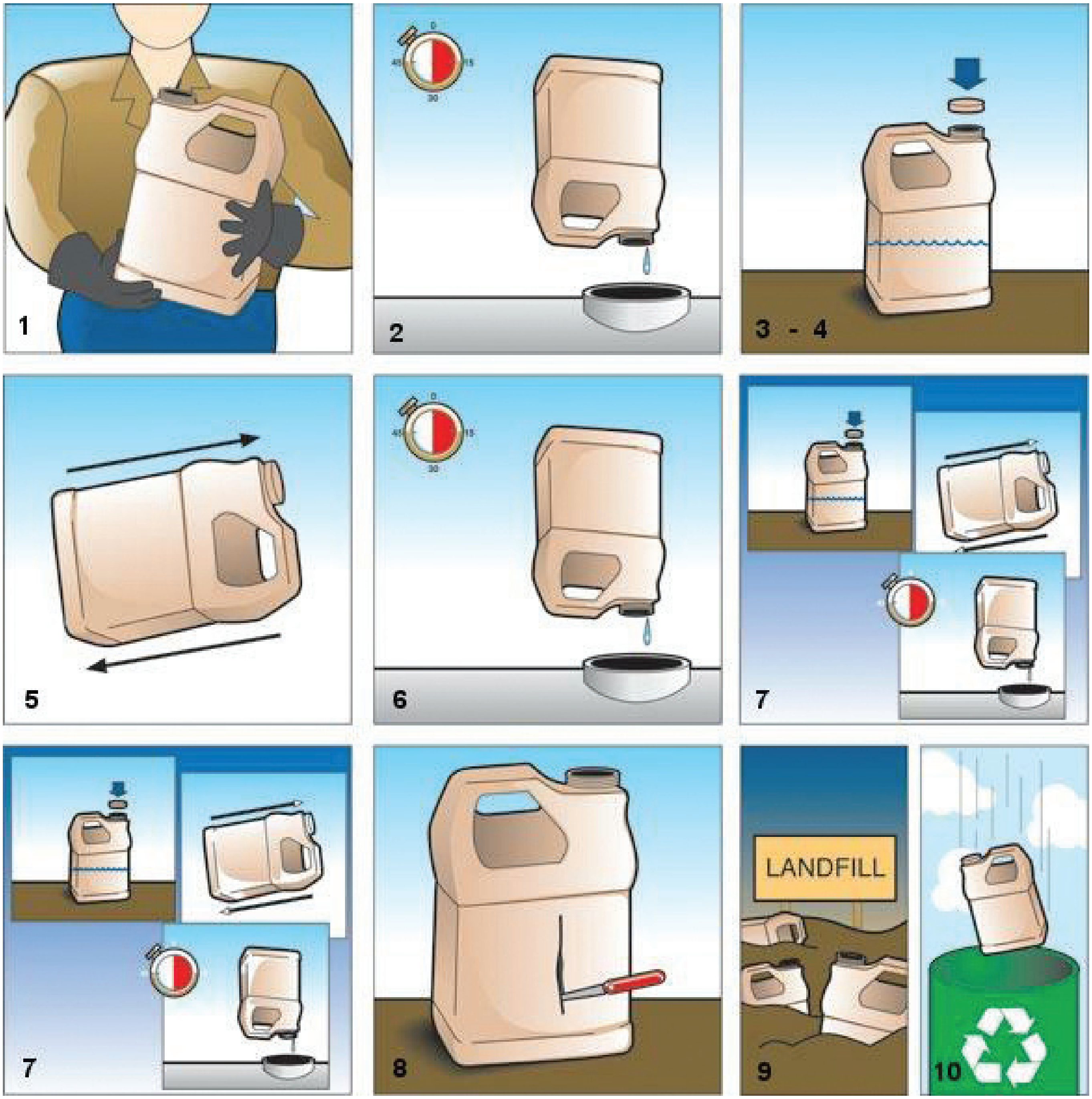

Figure 1. Triple-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.

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 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 not able 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 onto the container.
5. Swirl the liquid within the container to rinse all inside surfaces.
6. Remove cap from the container. Add the rinsate from the pesticide container to spray tank and allow to drain for 30 seconds or more.
7. Repeat steps 3 through 6 **two more times**.
8. Render container unusable by puncturing or crushing.

9. Replace 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 re-read 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 to the lowest possible level.
2. Fill the drum with water to 25 percent of capacity. Replace and tighten bungs.
3. Tip the drum onto its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds.
4. Stand the drum on its 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 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 wash the remaining pesticide from the container. A special nozzle with a spear-point, generally available from your pesticide supplier and other sources, and attached to the end of a water hose, supplies water under pressure to the interior of a pesticide container. Pressure-rinsing is faster and easier than triple-rinsing and can be used most effectively with plastic 2.5 gallon pesticide containers.

Before emptying pesticide containers. With the cap on, shake the container to thoroughly mix the pesticide. If dilutents or solvents have separated from the pesticide product in the container, mixing will help in the complete removal of the product.

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.

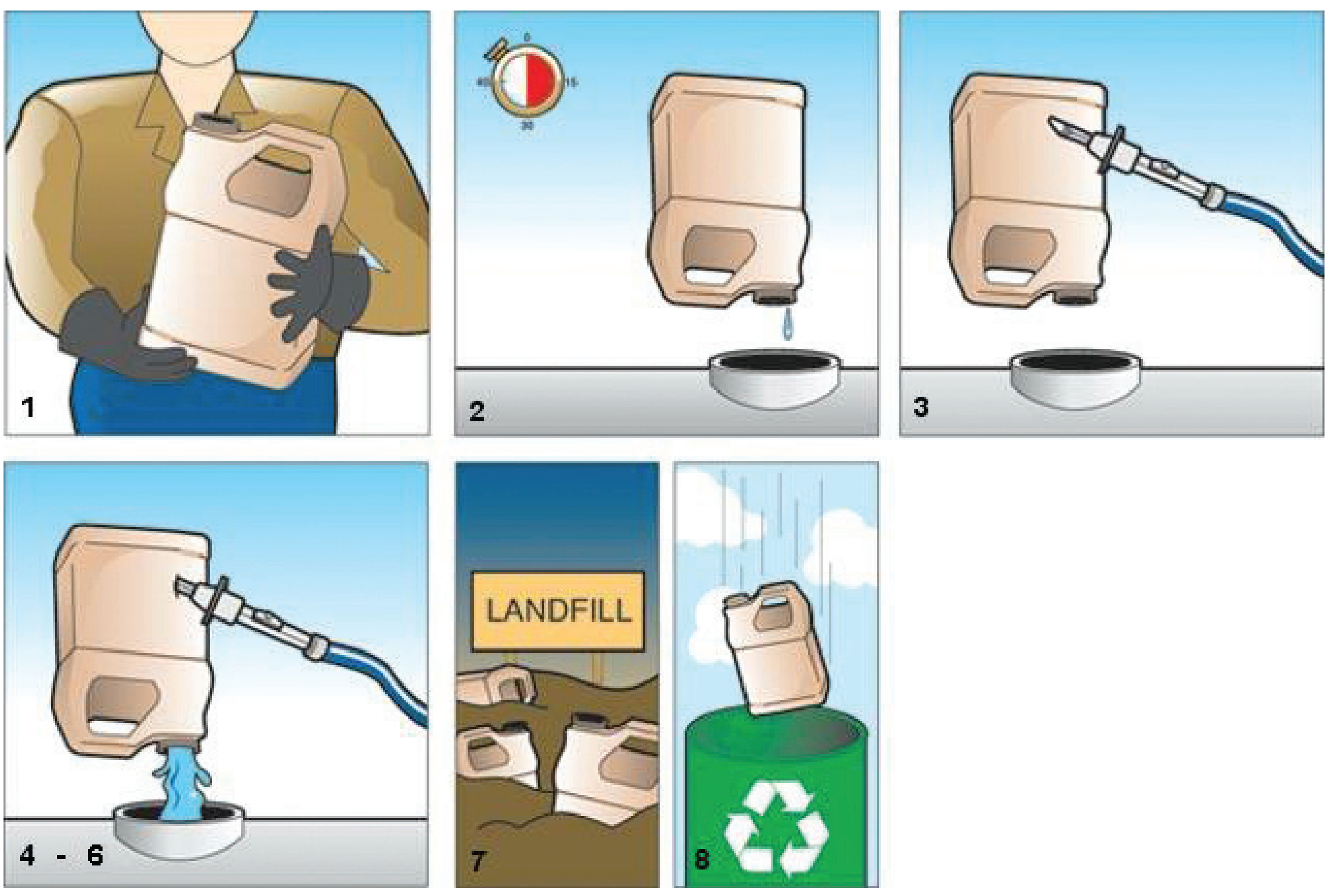

Figure 2. Pressure-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.

2. Remove cap from the pesticide container. Empty all pesticide into the spray tank. Turn the container so that any product in the handle may flow out. Allow the container 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 caps 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 (30 seconds or more). Rotate or rock the nozzle to rinse all inside surfaces.
6. Rinse caps separately in a bucket of water and pour this rinse water into the spray tank.
7. Replace 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

- Unrinsed empty pesticide containers should be stored in the same way you store containers with pesticide. Replace the cap and store unrinsed containers upright in a roofed or covered and secure (locked) area 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.

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.

Remove label booklets, plastic shrink-wrap labels and caps from containers before offering for recycling. Any pesticide container with pesticide residue that can be rubbed off with a neoprene- or nitrile-gloved hand is 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 Web site (*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 back-flow 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 set-backs from wells regardless if the well is active or not.

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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 do 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.

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 label 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 better 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

Figure 1. Cleaning a Sprayer (Photo credit: USDA).

When transitioning between crops, follow the specific cleanup procedures listed on the pesticide label.

Some cleanups require special cleaning agents. Sprayer-cleaning agents should be selected according to the pesticide and formulation to be removed (for herbicide-specific information see 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 also be 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, that 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 whomever 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, the washer should be run through one or more cycles with hot water and detergent but no clothing before doing normal laundry.

Equipment storage

When preparing to store your sprayer, add one to five gallons of lightweight oil like 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 Web site: *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.

Disclaimer

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

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NebGuide
University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
Know how. Know now.

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.

This publication has been peer reviewed.

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University of Nebraska Lincoln EXTENSION

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EC2505
(Revised October 2012)

Managing the Risk of Pesticide Poisoning and Understanding the Signs and Symptoms

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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.

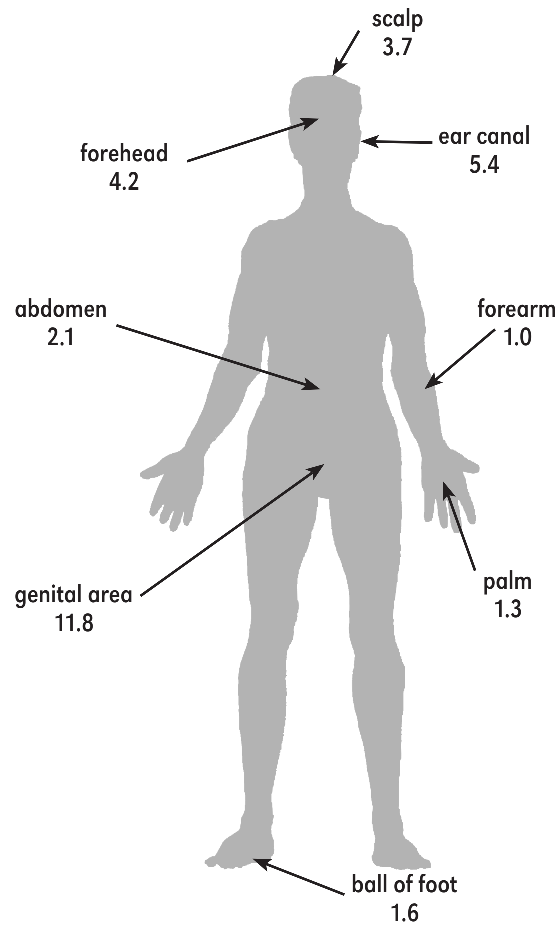

Figure 1. Absorption rates of the different parts of the body based on the absorption rate of the forearm.

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:

Risk = Toxicity *x* Exposure.

Understanding the toxicity of a product and the potential for personal exposure will help you to lower your risk. No matter how toxic a pesticide is, if the amount of exposure is kept low, risk can be held at an acceptably low level. The toxicity of a pesticide can't be changed, but an applicator can manage and reduce risk by selecting less toxic pesticides, carefully following the label instructions, and wearing the required PPE.

Recognizing Signs and Symptoms of Poisoning

Anyone who may be exposed to pesticides or is working with someone who may be exposed should be aware of the signs and symptoms of pesticide poisoning. *Signs* can be seen by others. Vomiting, sweating, and pinpoint pupils are signs of pesticide poisoning. *Symptoms* are any changes in normal condition that can be described by the victim of poisoning, including nausea, headache, weakness, dizziness, and others. Knowledge of these signs and symptoms will allow for prompt treatment and help prevent serious injury. People who are frequently involved with pesticides should become familiar with the following important steps.

1. Recognize the signs and symptoms of pesticide poisoning for those pesticides commonly used or to which people may be exposed. Often, pesticide poisoning resembles flu symptoms.
2. If you suspect poisoning due to a pesticide, get immediate help from a local hospital, physician, or the nearest Poison Control Center (800-222-1222).

3. Identify the pesticide to which the victim was exposed, giving the chemical name and the EPA registration number found on the label, if possible. Provide this information to medical authorities.
4. Have a copy of the pesticide label available when medical attention begins. The label provides information that will be useful to those assisting a victim of pesticide poisoning.
5. Know emergency measures you can undertake until help arrives or the victim can be taken to the hospital. Both first aid and medical treatment procedures are listed on the product label.

Recognizing Common Pesticide Poisonings

All pesticides in a given chemical group generally affect the human body in the same way. Severity of the effects, however, varies depending on the formulation, concentration, toxicity, and route of exposure of the pesticide. Therefore, it is important to know both the type of pesticide being used and the signs and symptoms associated with poisoning from it.

Pesticides that present the greatest potential health risks and those in which the mode of action is better understood are covered in the following sections. Categories of pesticides with similar signs and symptoms are covered together.

The listings of pesticides in *Tables III, IV, and V* are not necessarily complete, nor do they guarantee that the product is currently registered. They do, however, represent products that are or have been used in Nebraska. The Environmental Protection Agency (EPA) and Nebraska Department of Agriculture (NDA) maintain registrations for pesticide products. The EPA attempts to discontinue use of the most toxic products and replace them with less toxic products. Pesticides mentioned in this publication may not currently be registered for use in Nebraska, but still may be found on the shelves of applicators. Therefore, they still present risk, so signs and symptoms are included. Mention of a trade name does not constitute endorsement of a product, nor does omission constitute criticism.

Insecticides

Insecticides have many different modes of action. Some act on the nervous system of the insect. Others slow the production of energy that an insect needs to survive. Another type slows or stops the production of chitin, a major component of an insect exoskeleton, so the insect can't molt. Insect growth regulators, another type, also may prevent an insect from molting or keep it from maturing and reproducing. Some insecticides disrupt the water balance in an insect, causing rapid water loss and eventual death. The modes of action involving the nervous system and energy production may affect not only insects, but other animals as well. Insecticides such as the insect growth regulators typically are specific to insects. The following is a list of insecticides grouped by their chemical makeup.

Organophosphate and Carbamate Insecticides

Most cases of pesticide poisoning involve either organophosphate or carbamate insecticides. Both chemical groups affect humans by inhibiting acetyl cholinesterase, an enzyme essential for proper function of the nervous system. Without acetyl cholinesterase, nerve impulses continue and the victim has uncontrolled twitching. Examples of organophosphate and carbamate insecticides used in Nebraska are listed in *Table III*. Some are being phased out or are not used as much as other insecticides.

Table III. Organophosphate and carbamate insecticides that have been or currently are used in Nebraska. Examples of trade names are in parentheses.

Organophosphates			Carbamates
Acephate (Orthene®)	Dimethoate *(Cygon)* (DeFend)	Phorate (Thimet®)	**Aldicarb (Temik®)*
Azinphos-methyl (Guthion®)	Disulfoton (Di-Syston®)	Phosmet (Imidan®)	Carbaryl (Sevin®)
Chlorpyrifos (Lorsban®)	Ethoprop (Mocap®)	Pirimiphos-methyl (Actellic)	***Carbofuran (Furadan®)*
Coumaphos (Co-Ral®)	Malathion	Terbufos (Counter®)	Methomyl (Lannate®)
Diazinon	Methyl Parathion (Penncap-M®)	Trichlorfon (Dylox®)	Propoxur *(Baygon®)*
Dichlorvos (Vapona®, DDVP®)	Naled (Dibrom®, Trumpet®)		

*Registrations for italicized products have been discontinued or will be soon after this publication is printed. The product still may be in an applicator's storage, so names are listed in the tables.
**Registration of this product has been discontinued, and it must not be used after December 31, 2013.

The effects of these materials, particularly organophosphate insecticides, are rapid. Signs and symptoms begin shortly after exposure, and in cases of acute poisonings, during exposure. Exposure to either of these insecticide classes may pose special risks to people with reduced lung function, seizures, or other conditions. In some cases, consumption of alcoholic beverages may worsen the effects of the pesticide.

The onset of symptoms in milder exposures usually occurs within 4 hours, but can occur up to 12 hours after exposure. Diagnosis of a suspected poisoning must be rapid. Signs and symptoms associated with mild exposures to organophosphate and carbamate insecticides include headache; fatigue; dizziness; loss of appetite with nausea, stomach cramps, and diarrhea; blurred vision associated with excessive tearing; contracted pupils; excessive sweating and salivation; slowed heartbeat, often less than 50 beats per minute; and rippling of surface muscles just under the skin. Some of these symptoms may be mistaken for those of flu, heat stroke, heat exhaustion, or an upset stomach.

Moderately severe organophosphate and carbamate insecticide poisoning cases exhibit all the signs and symptoms found in mild poisonings listed above. In addition, a victim may be unable to walk, complain of chest discomfort and tightness, have marked pinpoint pupils, exhibit muscle twitching, and have involuntary urination and bowel movement. Signs of severe poisonings include incontinence, unconsciousness, and seizures.

The order in which these symptoms appear may vary, depending on how contact is made with the pesticide. If the product is swallowed, stomach and other abdominal manifestations commonly appear first; if it is absorbed through the skin, gastric and respiratory symptoms tend to appear at the same time.

Fortunately, good antidotes are available for victims of organophosphate or carbamate poisoning at emergency treatment centers, hospitals, and many physicians' offices. As with all pesticide poisonings, prompt assistance is critical. If a pesticide is swallowed, obtain prompt medical treatment. If dermal exposure has occurred, remove contaminated clothing, wash exposed skin, and seek medical care.

Organochlorine Insecticides

The U.S. EPA has sharply curtailed the availability of many organochlorines because they persist in the environment. Organochlorines are formed from carbon and chlorine; examples include DDT, chlordane, dieldrin, aldrin, and lindane. Although few are available for purchase or registered for use, some organochlorine insecticides still may be present in storage areas. In addition, organochlorines, such as pesticides, dioxins, and polychlorinated biphenyls (PCBs), are in the environment due to drift from application, spills, leaks, and improper disposal of industrial wastes. Because of the persistence of organochlorines, traces of them still can be found in sediment, water, and living organisms, even though most use was banned in the U.S. decades ago. Some areas have advisories limiting the consumption of fish and shellfish due to the presence of these materials in their tissue. When fish and shellfish such as crabs and mollusks eat, they accumulate pollutants such as organochlorines and heavy metals present in their food, in tainted sediment, or water they filter to get food. The process called bioaccumulation or bioconcentration describes how pollutants accumulate or concentrate in living tissue. The potential for bioaccumulation increases as you go up the food chain, from tiny fish with organochlorines, eaten by larger fish, eaten by larger fish, eaten by humans.

Organochlorines affect the nervous system as stimulants or convulsants. Nausea and vomiting commonly occur soon after ingesting organochlorines. Other early signs and symptoms include apprehension (feelings of suspicion or fear of the future), excitability, dizziness, headache, disorientation, weakness, a tingling or pricking sensation on the skin, and twitching muscles. Loss of coordination, convulsions similar to epileptic seizures, and unconsciousness often follow. When chemicals are absorbed through the skin, apprehension, twitching, tremors, confusion, and convulsions may be the first symptoms. Chronic exposure may lead to cancer, birth defects, and mutations of genes.

No specific antidotes are available for organochlorine poisoning. People assisting a victim should wear chemical-resistant gloves and be careful to avoid contamination by the pesticide. Remove contaminated clothing immediately and bathe and shampoo the person vigorously with soap and water to remove pesticide from the skin and hair. If the pesticide has been swallowed, empty the stomach as soon as possible by giving the conscious patient syrup of ipecac and water or by inserting a clean finger into the throat while the victim is turned to one side, facing the floor. Never induce vomiting when a victim is unconscious: inhaling vomit may cause suffocation.

Pyrethroid Insecticides

Pyrethroids are synthetically produced compounds that mimic the chemical structure of naturally occurring pyrethrins found in a specific type of chrysanthemum plant. As with organophosphates and carbamates, pyrethroids affect the insect's nervous system, but in a different way: They are not cholinesterase inhibitors. Some examples of pyrethroids are listed in *Table IV*.

Table IV. Pyrethroid insecticides, with trade names for some products in parentheses.

Allethrin (Sniper®)	Fenvalerate (Evercide®)
Baythroid (Baythroid®, Discus®)	Fluvalinate (Mavrik® Perimeter)
Cyfluthrin (Tempo®)	Permethrin (Pounce®, Ambush®)
Cypermethrin (Barricade®)	Resmethrin (Rid®, Mosquito Beater®)
Deltamethrin (Battalion®)	Tetramethrin (aero® Assault)
Esfenvalerate (Asana® XL)	Tralomethrin (Dead-Fast® Insecticide Chalk)

Risk of poisoning by pyrethroids through inhalation and dermal absorption is low. Very few poisonings of humans by pyrethroids have been documented. Dermal contact may result in skin irritation such as stinging, burning, itching, and tingling progressing to numbness. Some people experience a range of allergic reactions from pyrethroids. Repeated exposures may increase the intensity of the reaction.

Although some pyrethroids may be toxic by the oral route, ingestion of this type of insecticide usually presents relatively little risk. Occasionally, a large dose may cause loss of coordination, tremors, salivation, vomiting, diarrhea, and irritability to sound and touch. Most pyrethroids are promptly excreted by the kidneys.

Biological Insecticides

Insecticides produced from plant materials or bacteria are called biological insecticides.

Azadirachtin, derived from the Neem tree, is an insect growth regulator that interferes with the insect molting process. For humans, exposure to azadirachtin causes slight skin and gastrointestinal irritation. Stimulation and depression of the central nervous system also have been reported.

Eugenol is derived from clove oil and used both as an insect attractant and insecticide. In humans, large doses can cause skin burns. Extremely large doses may result in liver problems and coma.

Pyrethrum and pyrethrins. Pyrethrum is found in the flowers of *Chrysanthemum cinerariaefolium*. Crude pyrethrum is a dermal and respiratory allergen for people. Skin irritation and asthma have occurred following exposures. Refined pyrethrins are less allergenic, but appear to retain some irritant and/or sensitizing properties.

In cases of human exposure to commercial pyrethrum products, realize that other toxicants may be present and will be listed on the label. Synergists may be added to insecticide products to enhance the killing power of the active ingredient. Synergists such as piperonyl butoxide, discussed later, have low toxic potential in humans, but organophosphates or carbamates included in the product may have significant toxicity. Pyrethrins themselves do not inhibit the cholinesterase enzyme.

Rotenone is a naturally occurring substance found in several tropical plants. Until 2011, it was formulated as dusts, powders, and sprays for use in gardens and on food crops. The Agriculture Health Study, involving 90,000 applicators and spouses from Iowa and North Carolina, showed a relationship between exposure to rotenone and the incidence of Parkinson's disease. More research is needed to reach any conclusions on the specifics of that relationship. Manufacturers of rotenone have voluntarily stopped producing the pesticide for all uses except the management of undesirable fish species. Rotenone is now a restricted use pesticide.

Antibiotics include abamectin, ivermectin, *Bacillus thuringiensis* (Bt), spinosad, and streptomycin. These compounds are practically nontoxic to humans. In studies involving deliberate ingestion by human subjects, slight inflammation of the gut occurred. Antibiotic insecticides in the form of emulsifiable concentrates may cause slight to moderate eye irritation and mild skin irritation due to the solvent carriers. Antibiotic pesticides are different from antibiotics taken by people to cure bacterial infections.

Inorganic Insecticides

Boric acid and borates. Boric acid, derived from borax and usually combined with an anti-caking agent, is commonly used to kill cockroaches. It can be harmful to humans if accidentally ingested. Avoid inhaling the dust during application. Inhaled borax dust causes irritation of the respiratory tract and shortness of breath. Borax dust is moderately irritating to skin. Infants have developed a red skin rash that most often affects the palms, soles of the feet, buttocks, and scrotum in severe poisonings. The skin developed a "boiled lobster appearance" followed by extensive skin peeling.

Diatomaceous earth (DE) is mined from the fossilized silica shell remains of diatoms, which are microscopic sea animals. Labels may refer to this ingredient as silicon dioxide, or "silicon dioxide from diatomaceous earth." DE is used commercially to control crawling insects, such as cockroaches, ants, and insects that infest grain. It is virtually nontoxic to humans. Avoid inhaling diatomaceous earth, however, as it can irritate the eyes and lungs.

Silica gel is a nonabrasive, chemically inert substance used as a dehydrating agent because the small particles absorb moisture and oils. Avoid inhaling the dust. Some grades of diatomaceous earth contain small amounts of crystalline silica, which is known to cause a respiratory disease called silicosis and cancer. The risk of cancer depends on the duration and level of exposure. Pesticide-quality diatomaceous earth and silica gel are amorphous (non-crystalline), and do ***not*** cause silicosis or cancer.

Sulfur is moderately irritating to skin and has been associated with skin inflammation. Dust is irritating to the eyes and respiratory tract. If swallowed, it acts like a strong laxative.

Other Insecticides

Fluorines. Sulfluramid (Spectracide terminate® and Firstline®) is formulated as an ant, roach, or termite bait and is slightly irritating to the skin. Sulfluramid has low toxicity in lab tests. However, with repeated exposure, it has caused developmental abnormalities in young laboratory animals and affected the reproductive systems of male laboratory animals.

Nicotinoids, sometimes called **neonicotinoids,** were introduced in the 1990s. They are chemically similar to nicotine. They have a lower toxicity to humans than organophosphates and carbamates. Imidacloprid and thiamethoxam are used to control termites, turf insects, and some crop insects.

Farm workers reported skin or eye irritation, dizziness, breathlessness, confusion, or vomiting after they were exposed to pesticides containing imidacloprid. Similar symptoms, along with increased heart and breathing rates, also were noted after a victim ingested a product containing imidacloprid; the victim suffered severe cardiac toxicity and death 12 hours after oral exposure.

Pyrazoles. Fipronil is a moderately toxic pyrazole that may cause mild irritation to the eyes and skin. It is used to control termites (Termidor®, Taurus™), cockroaches (Combat®, Maxforce®), certain insect pests of corn, and fleas and ticks of cats and dogs (Frontline®, Effipro®, PetArmor™). Lab animals exhibited reduced feeding, reduced urination, increased excitability, and seizures following a toxic oral dose. After ingesting fipronil, humans have reported sweating, nausea, vomiting, headaches, abdominal pain, dizziness, agitation, and weakness. Direct, short-term contact with skin can result in slight skin irritation. Inhalation or dermal contact while spraying fipronil for five hours may have caused a person to have a headache, nausea, dizziness, and weakness. Symptoms developed two hours after spraying and then disappeared. According to the National Pesticide Information Center, signs and symptoms from a brief exposure to fipronil generally improve and clear up without treatment (*http://npic.orst.edu/factsheets/fipronil.pdf*).

Pyrroles. Chlorfenapyr (Phantom®, Pylon®) is the only product in this group. It is formulated to control ants, cockroaches, termites, and some insect and mite pests on fruits and vegetables. It is slightly toxic if swallowed or if it contacts the skin, and can be moderately irritating to eyes and skin.

Tetronic acids. Spiromesifen is the sole insecticide in this group. It is used to control mites and whiteflies on some vegetable crops (Oberon®) and ornamental trees (Forbid™, Judo™, Oberon®). No indication of eye irritation has been reported.

Tetramic acids. Spirotetramat (Kontos®, Movento®) is a systemic insecticide that controls a number of major sucking insects and mites that are pests of trees, vegetables, potatoes, and other plants. Some products with tetramic acids may cause moderate eye irritation. Prolonged or repeated skin contact may cause allergic reactions in some individuals.

Insect Growth Regulators

Insect growth regulators (IGR) act on insects in different ways. Those that mimic juvenile hormones keep insects in immature stages and prevent insect reproduction. Chitin synthesis inhibitors prevent insects from molting and growing into adults. In general, IGRs are very low in toxicity and cause mild skin irritation with limited exposure. No human poisonings or adverse reactions in exposed workers have been reported. Some examples of insect growth regulators are listed in *Table V*.

Table V. Common insect growth regulators. Examples of trade names are in parenthesis.

Diflubenzuron (Adept®, Clarifly®)	Methoprene (Bio Spot®)
Hexaflumuron (Shatter™)	Noviflumuron (Recruit®)
Hydroprene (Gentrol®)	Pyriproxyfen (First Shield™)

Mosquito Repellents

Diethyltoluamide (DEET) was developed by the U.S. Army in 1946 as an insect repellent and has been available to the general public since 1957. Products containing DEET (Detamide®, OFF!®) have been effective and generally well tolerated when applied to human skin. If left on skin for an extended period, some people have experienced irritation, redness, a rash, and swelling. Tingling and mild irritation have occurred following repeated application. In some cases, DEET has caused skin irritation and worsened preexisting skin disease. It is very irritating to the eyes but not corrosive. When swallowed, it has caused nausea and vomiting.

Serious adverse effects have occurred when DEET was used under hot, humid conditions and not washed off before going to sleep. The skin became red and tender, then blistered and formed ulcers, leaving painful weeping bare areas that were slow to heal. Permanent scarring resulted from most of these severe reactions. Very rarely, seizures in people have been associated with exposure to DEET. Most have occurred after drinking products with DEET or using the products in ways that do not follow label directions.

Exercise great caution when using DEET on children: only use products containing lower concentrations. The American Academy of Pediatrics (AAP) recommends against using any repellent on infants 2 months of age or younger. The AAP cautions parents not to use DEET on the hands of a child and to avoid applying it to areas around a child's eyes and mouth. Consider applying DEET only to clothing, using as little repellent as possible. If a child experiences a headache or any kind of emotional or behavioral change, discontinue the use of DEET immediately. Limited information is available on childhood responses to DEET from research or Poison Control Center reports. Most adverse responses were the result of improper use or accidents.

Picaridin, a synthetic compound first made in the 1980s, resembles a natural compound found in the group of plants used to produce black pepper. Although widely used as an insect repellent in Europe and Australia, picaridin has been available in the United States only since 2005. Although uncommon, some people have experienced skin irritation. Picaridin also may cause irritation if it gets into a person's eyes. Rats lost weight and their kidneys were affected when fed large doses of picaridin. The material is considered practically nontoxic if inhaled. While children may be especially sensitive to pesticides compared to adults, no data suggest that children have increased sensitivity specifically to picaridin.

Oil of Citronella has been used for over 50 years as an insect and animal repellent. It is found in many familiar insect repellent products, including candles, lotions, gels, sprays, and towelette wipes. These products vary in effectiveness and may repel various insects, such as mosquitoes, biting flies, and fleas. When used according to the label, citronella products are not expected to harm humans, pets, or the environment. The only concern in studies involving laboratory animals is skin irritation. The EPA requires precautionary labeling because some citronella products are applied to human skin. Citronella is not expected to pose health risks to people, including children and other sensitive populations, if used according to label instructions.

Fumigants

Fumigants deliver the active ingredient to the target site in the form of a gas. Fumigants can completely fill a space, and many have tremendous penetrating power. They can be used to treat objects such as furniture, structures, grain, and soil for insect pests and other vermin. Fumigants are among the most hazardous pesticide products to use due to danger of inhalation.

Various fumigants produce differing physiological effects. Headache, dizziness, nausea, and vomiting are common early signs and symptoms of excessive exposure.

Prompt medical treatment is critical with fumigant poisoning. Immediately move a victim of fumigant inhalation to fresh air. Keep the individual quiet in a semi-reclining position even if initial signs and symptoms are mild. If breathing has stopped, give mouth-to-mouth or mouth-to-nose resuscitation. If the victim has no pulse, immediately give cardiopulmonary resuscitation (CPR) using chest compression. Some fumigant products, along with signs and symptoms of poisoning, are listed below.

Chloropicrin causes severe irritation of the upper respiratory tract, eyes, and mucous membranes. Symptoms of exposure to chloropicrin include burning eyes, tearing, coughing, difficulty breathing, headaches, nausea, and vomiting. Chloropicrin may be a stand-alone fumigant or may be combined with other fumigants to increase their potency. When present in low percentages, it serves as a warning agent.

Sulfuryl fluoride (Vikane®) poisoning symptoms include depression, slowed walking pattern, slurred speech, nausea, vomiting, stomach pain, stupor, itching, numbness, twitching, and seizures. Inhalation of high concentrations may irritate the respiratory tract and may be fatal due to respiratory failure. Sulfuryl fluoride almost always is applied with chloropicrin, so the first signs of poisoning are often associated with severe irritation of the eyes and mucous membranes. Skin contact with gaseous sulfuryl fluoride normally poses no hazard, but contact with liquid sulfuryl fluoride can cause pain and frostbite due to cold temperatures from rapid evaporation.

Phosphine fumigants, such as aluminum and magnesium phosphide (Phostoxin®, PhosFume®, Fumitoxin®, and Fumi-Cel®) affect cell function in the liver and lungs. Mild exposure is signaled by a sensation of cold, chest pains, diarrhea, and vomiting. Exposures that are somewhat more serious will be evidenced by cough, tightness in the chest, difficulty in breathing, weakness, thirst, and anxiety. Signs and symptoms of severe exposure include stomach pain, loss of coordination, blue skin color, pain in limbs, enlarged pupils, choking, fluid in the lungs, and stupor. Severe poisonings can lead to seizures, coma, and death.

Methyl bromide (Metabron, Meth-O-Gas®) affects the central nervous system, lungs, heart, and liver. People poisoned by methyl bromide experience the common signs and symptoms of fumigant poisoning along with abdominal pain, weakness, slurred speech, mental confusion, muscle twitching, and convulsions similar to epileptic seizures. Some liquid fumigants cause skin injuries indicated by areas of redness or blisters that rupture, leaving raw skin or deep ulcers. There are few registered uses of methyl bromide: those remaining are on a conditional year-by-year basis.

Acrolein (Magnacide H®) is an extremely irritating gas used as an aquatic herbicide. Inhalation of the vapor causes irritation in the upper respiratory tract, which may lead to a buildup of fluids in and narrowing of the air passages. If ingested, it attacks the stomach lining, resulting in open sores and cell death. Contact with skin may cause blistering.

Dazomet (Basamid® G) is a granular soil fumigant. It is used to sterilize soil to eliminate weeds, nematodes, and soilborne diseases. Dazomet is highly toxic if swallowed and can be fatal. Frequent or prolonged exposure to skin can result in irritation or more serious skin problems for some individuals. Inhalation can cause a variety of acute and chronic lung conditions, including local irritation, inflammation, fluid buildup, and lung disease.

Metam sodium (Vapam®) is a soil fumigant used to kill fungi, bacteria, weed seeds, nematodes, and insects. When combined with water, it produces a gas that is very irritating to respiratory mucous membranes, eyes, and lungs. Inhalation can cause severe respiratory distress, including coughing of blood and frothy sputum. It can only be used outdoors, and precautions must be taken to avoid inhaling the gas.

Dichloropropene (Telone®) is very irritating to skin, eyes, and the respiratory tract. Inhalation may cause spasms of the bronchi, where air passes into the lungs. Although limited data for humans exist, animals have experienced liver, kidney, and cardiac toxicity. Most dichloropropene products contain chloropicrin; severe irritation of the eyes and mucous membranes is an early sign of exposure. Apparently, risk for oral toxicity is low for humans unless large quantities of dichloropropene are ingested.

Rodenticides

Pesticides designed to kill rodents pose particular risks to humans. Since they are designed to kill mammals, their mode of action is toxic to humans as well. In addition, rodents often live near humans and other mammals, so accidental exposure to baits is a risk. In the effort to make more effective rodenticides, more toxic materials have been developed, increasing the risk to humans. Symptoms from ingestion of rodenticides can be delayed for days — up to four days for bromethalin, and up to seven days for anticoagulants.

Benzenamines. Bromethalin (Tomcat®), the only chemical in this class of rodenticide, is not an anticoagulant (substance that slows clotting of blood). Instead, it acts on the central nervous system. Possible signs and symptoms of exposure to this compound include skin and eye irritation, headache, confusion, muscle twitching, convulsive seizures, and difficulty breathing. Bromethalin poisoning in dogs usually results in paralysis or convulsions and sometimes swelling or bloating of the abdomen.

Coumarins are anticoagulants: they slow the ability of blood to clot and disrupt capillary and liver function. Examples include brodifacoum (Jaguar®, Talon®, WeatherBlok®, now d-CON®), bromadiolone (Contrac®, Maki®), and warfarin (Kaput®, formerly d-CON®). The main signs and symptoms are nosebleeds, bleeding gums, blood in the urine, tar-colored feces, and large irregular blue-black to greenish-brown spots on the skin. Vitamin K is an antidote.

Indandiones also are anticoagulants. Examples are chlorophacinone (Rozol®) and diphacinone (Ditrac®, Ramik®). Main signs and symptoms are similar to coumarin compounds, but some indandiones cause nerve, heart, and blood system damage in laboratory rats, leading to death before hemorrhage occurs. None of these signs and symptoms have been reported in poisonings of humans. Vitamin K is an antidote.

Strychnine is not easily absorbed through the skin nor does it accumulate in the human body. When ingested, however, it acts on the central nervous system within 10 to 30 minutes. Convulsions — violent seizures with involuntary jerky movements that cause the victim to stop breathing — also can occur. Treatment of strychnine poisoning is geared toward eliminating outside stimuli. If strychnine poisoning occurs, place the victim in a warm, dark room to reduce outside stimuli that trigger convulsions. Consequently, in the case of strychnine poisoning, bring medical help to the victim rather than transporting the victim to a medical center, because movement will trigger the convulsions.

Zinc phosphide causes severe irritation if ingested. It reacts with water and stomach juices to release phosphine gas, which enters the blood stream and affects the lungs, liver, kidneys, heart, and central nervous system. Zinc phosphide can be absorbed through the skin and inhaled from fumes. With repeated exposure, it accumulates in the body to dangerous levels. Signs and symptoms of mild zinc phosphide poisoning include diarrhea and stomach pains. In more severe cases, nausea, vomiting, chest tightness, excitement, coldness, loss of consciousness, coma, and death can occur from fluid buildup in the lungs and liver damage. No antidote for zinc phosphide poisoning exists. It is a slow-acting material, which allows time to get the victim medical assistance.

Wood Preservatives

Pesticides registered as wood preservatives extend the life of wood by reducing or preventing the establishment of populations of organisms such as fungi that cause rot or insects that degrade the wood. Some preservatives can leach slowly into the surrounding soil or water. Sometimes, touching treated wood can leave residue on exposed skin.

Creosote (coal tar) typically is found on railroad ties that sometimes are used for landscaping. Exposure can cause skin irritation and prolonged exposure may lead to inflamed skin. Vapors and fumes of creosote are irritating to the eyes and respiratory tract. Ingested creosote may result in severe liver damage. Creosote is considered a probable human carcinogen. Creosote-treated wood cannot be used in residential settings; it may only be used in commercial applications.

Pentachlorophenol (PCP, Penchlorol, Penta, Dura-treat®), typically used on utility poles or fence posts, is irritating to the eyes, skin, and respiratory tract. It can cause a stuffy nose, scratchy throat, and tearing eyes. Prolonged exposure sometimes leads to an acne-like skin condition. Ingestion of PCP solutions, excessive skin contact, or inhalation of concentrated vapors may cause fever, headache, weakness, dizziness, nausea, and profuse sweating. Extreme cases of exposure can lead to a loss of coordination and seizures, high fever, muscle spasms and muscle twitching, difficulty breathing, a sense of tightness in the chest, abdominal pain and vomiting, restlessness, excitement, and mental confusion. Intense thirst also is a characteristic. Pentachlorophenol poisoning can be fatal.

Arsenical wood preservatives such as chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) were used extensively in the past to treat construction lumber for decks, play sets, and fence posts. CCA is not well absorbed through the skin, but hand-to-mouth contact can result in exposures. If swallowed, arsenicals can cause nausea, headache, diarrhea, and abdominal pain. Extreme signs and symptoms can progress to dizziness, muscle spasms, violent mental agitation, and seizures. Prolonged exposure to arsenical wood preservatives can result in persistent headaches, abdominal distress, salivation, low-grade fever, and upper respiratory irritation.

Herbicides

Herbicides kill weeds by affecting metabolic processes in plants. Therefore, risk to humans and other mammals is relatively low. Some herbicides, however, can pose a risk of poisoning if not handled according to label directions. Regardless of their chemical structure, the vast majority of herbicides often affect the human body in a similar way. In general, they can irritate the skin, eyes, and respiratory tract. Always read and follow label recommendations carefully to avoid any of these health risks. Herbicides that present the greatest potential health risks are covered in the next four sections.

Bipyridyl Herbicides

Diquat and **paraquat** are the most common bipyridyl herbicides. Paraquat is more toxic than diquat and produces chronic abnormal cell growth in the lungs, cornea and lens of the eyes, nasal mucous membranes, skin, and fingernails. Diquat affects the eye lens and intestinal tract lining but usually does not produce the frequently fatal lung changes characteristic of paraquat.

Ingesting diquat or paraquat causes severe irritation to the mucous membranes of the mouth, esophagus, and stomach. Repeated vomiting generally follows. Large doses of diquat also produce restlessness and reduced sensitivity to stimulation. Large doses, and sometimes even small doses, of paraquat initially can affect the kidneys, liver, adrenal glands, and lungs: potentially fatal fluid accumulation in the lungs can occur in 24 to 72 hours.

Lesser amounts of paraquat will cause decreased urine output because of kidney failure. Yellowing of the skin due to liver damage is sometimes observed. This initial phase is followed by an inactive period lasting up to two weeks, during which the victim appears to improve. The victim, however, may have permanent and gradually advancing lung damage caused by rapid growth of connective tissue. This prevents proper lung function and eventually leads to death through respiratory failure. Paraquat selectively concentrates in cells in the lungs.

Skin exposure to paraquat and diquat concentrates may cause severe skin irritation and burning. Contact with dilute liquids and diquat dusts may cause slight to moderate irritation. Skin absorption of paraquat apparently is slight. Diquat, however, is absorbed and after repeated contact will produce symptoms similar to those following ingestion.

Exposure to paraquat and diquat spray mist may produce skin irritation, nasal bleeding, irritation and inflammation of the mouth and upper respiratory tract, coughing, and chest pain. Exposure to paraquat concentrates may cause nails to blacken and grow abnormally.

No specific antidotes are available to counteract the effects of paraquat, diquat, and other bipyridyl herbicides once significant exposure and absorption has occurred. Seek medical attention promptly. If ingested, and the victim is conscious, induce vomiting immediately unless a physician advises not to. Flush affected eyes with water, and wash skin with soap and water.

Chlorophenoxy Herbicides

2,4-D and MCPA are examples of chlorophenoxy herbicides. These compounds are moderately irritating to skin and mucous membranes. Inhalation may cause a burning sensation in the nose, sinuses, and chest, which may result in coughing. Prolonged inhalation sometimes causes dizziness.

Stomach irritation usually leads to vomiting soon after ingestion. Victims may experience chest and abdominal pain and diarrhea. Headache, mental confusion, and bizarre behavior are early signs and symptoms of severe poisoning, which may progress to unconsciousness.

Arsenical Herbicides

Ansar®, Montar®, MSMA, and **cacodylic acid** are some examples of arsenical herbicides. Acute arsenic poisoning usually appears within one hour of ingestion. Garlic odor of the breath and feces may help to identify the responsible toxicant in severe cases. Effects on the digestive tract include inflammation of the mouth and esophagus, burning abdominal pain, thirst, vomiting, and bloody diarrhea.

Arsenic may affect the central nervous system as well. Effects include headache, dizziness, muscle weakness and spasms, low body temperature, sluggishness, delirium, seizures, and coma. Liver damage may lead to yellowness of the skin. Injury to tissues that form blood may cause a reduction in red and white blood cells and blood platelets. Death usually occurs one to three days after the onset of symptoms and is usually the result of circulatory failure.

Chronic arsenic poisoning through skin exposure usually is more of a problem than acute poisoning, characterized by effects in the intestinal tract. Chronic arsenic poisoning may result in cancer. Symptoms of chronic exposure include overgrowth of the eye's cornea; scaling off of dead skin; excessive fluids under the skin of the face, eyelids, and ankles; white streaks across the nails; loss of nails or hair; and brick red coloration of visible mucus membranes.

Other Herbicides

Endothall (Aquathol®) is commonly used as an aquatic herbicide or algaecide. It is irritating to skin, eyes, and mucous membranes. In one case, a man died after ingesting endothall. In this case, bleeding and swelling were noted in the gut and the lungs.

Sodium chlorate (Drexel®, Defol®) is used as a defoliant, nonselective herbicide, and soil sterilant. It is irritating to skin, eyes, and stomach. Even though sodium chlorate is poorly absorbed in the digestive tract, ingestion of a large dose will cause severe poisoning. Irritation to the gut causes nausea, vomiting, and abdominal pain. Bluish skin sometimes is the only visible sign of poisoning. Dark brown staining of the blood and urine can indicate sodium chlorate poisoning.

Fungicides

Fungicides are used extensively in industry, agriculture, and the home and garden. Fungicides vary in their potential for causing adverse effects in humans. According to the EPA manual, *Recognition and Management of Pesticide Poisoning* (Morgan, 1999), "… most fungicides currently in use are unlikely to cause frequent or severe systemic poisonings for several reasons. First, many have low inherent toxicity in mammals and are inefficiently absorbed. Second, many fungicides are formulated as suspensions of wettable powders or granules, from which rapid, efficient absorption is unlikely. And third, methods of application are such that relatively few individuals are intensively exposed." Fungicides probably have caused a large number of irritant injuries to skin and mucous membranes, as well as some skin sensitization. As with any pesticide, always read and follow label recommendations carefully to avoid any health risks that a specific fungicide may pose.

Other Pesticides and Synergists

The three chemicals listed in this section are among the many pesticides and synergists that have not been discussed. These are listed because they have a relatively high potential for harming humans and nontarget animals.

4-aminopyridine (Avitrol®) is a highly toxic powder used as a bird repellent, often mixed with whole or cracked corn. It is toxic to all vertebrates. No human poisonings have occurred when used according to label directions. However, intentional ingestion has resulted in immediate abdominal discomfort, nausea and vomiting, weakness, dizziness, profuse sweating, and, sometimes, death.

Metaldehyde (Deadline®) has been used to control slugs and snails for many years. Poisoning of animals (particularly dogs) and children occurs occasionally when metaldehyde is swallowed. Ingestion of a toxic dose often is followed by nausea and vomiting, then fever, seizures, and changes in mental status, sometimes leading to coma. Other signs and symptoms that can occur are excessive salivation, facial flushing, dizziness, rapid breathing, and high acidity in the blood. While most poisonings are dramatic, they are rarely fatal. Deaths of dogs are common, however, when they eat enough of the product.

Piperonyl butoxide (PBO) is not a pesticide but one of the most common synergists in use. Synergists typically are added to insecticide products to enhance the effectiveness of the active ingredient. For example, PBO slows the ability of an insect to break down a pesticide. If PBO was not added to a particular insecticide, the insect could break down the pesticide before it could have an effect. As a synergist, PBO reduces the amount of a pesticide that is needed to be effective. Toxicity of PBO in mammals is low, although based on limited evidence of cancer in laboratory animals, it was considered a possible human carcinogen. PBO may trigger allergic responses in some people. Another common synergist that works the same way is known by either MGK 264 or n-octyl bicycloheptene dicarboximide.

What if a Pesticide Poisoning Occurs?

The key to surviving and recovering from a pesticide poisoning is ***rapid*** treatment. **Take emergency action immediately when you suspect a pesticide poisoning has occurred.** As time elapses after exposure, the toxic effects are heightened, and the victim may need more time to recover.

Immediately dial **911** whenever you suspect a pesticide poisoning. An advanced life support team will be dispatched to provide assistance. In addition, you may wish to contact the following:

1. **The Poison Control Center (800-222-1222)** will provide specific directions on procedures to follow until a life support team arrives.
2. The nearest hospital or a physician. These can benefit by having preliminary information before the patient arrives.
3. Another source of medical and consumer information related to pesticides during non-emergencies is the National Pesticide Information Center (**800-858-7378** or online at *http://npic.orst.edu*).

What a victim might think is a cold or the flu could be a fatal pesticide poisoning. Whenever possible, get answers to the following questions.

1. Has the victim been exposed to a pesticide?
2. If so, which one and how did the exposure occur?
3. What emergency actions are given on the pesticide label?

Many pesticide labels direct that vomiting be induced. You can do this by giving the patient syrup of ipecac and water or by inserting a clean finger into the throat of the victim. **Do not induce vomiting when:**

- the label says not to,
- the victim is having or has had seizures accompanied by involuntary jerking movements,
- the victim is unconscious, or
- the pesticide contains petroleum products such as xylene.

Caution: Inhaling vomit can be life-threatening. Timely emergency treatment is vital to survival.

After exposure to a pesticide, always wash the victim's exposed skin with soap or detergent and plenty of water, then obtain medical treatment. Skin irritation can result from continuous exposure if not treated. If the victim's clothing has been contaminated by a pesticide that is readily absorbed by the skin, remove the clothing and wash or rinse the victim's skin.

Remember to protect yourself as you help the victim. Wear chemical-resistant gloves. If a pesticide spill is involved, move the victim away from the spill. Assist the victim first; take action to clean up the spill after all first aid has been completed.

Even though most people are careful when working with pesticides, accidents can happen. Be prepared. Keep the telephone number for the Poison Control Center readily available either in your telephone directory or near your telephone. Do not hesitate to contact medical authorities if any symptoms of pesticide poisoning occur. It is better to be safe than sorry.

Most pesticides used by Nebraska farmers, ranchers, and people with lawns and gardens have lower toxicity levels than many of the pesticides discussed in this publication. When applied properly, with the required protective clothing and equipment, they are unlikely to cause problems for the user. However, ***any*** pesticide ***can*** cause problems due to exposure or overexposure. **Use all pesticides safely. Federal and state laws require that you read the pesticide label completely and comply with all directions. Failure to do so may subject you to federal and/or state sanctions or penalties.**

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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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EC2507

SAFE Transport, Storage and Disposal of Pesticides

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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.

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 product 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 or harm the environment.

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 feed or minerals. Also, transport pesticides separately from seed, grain or consumer goods.

Keep a hazardous materials spill kit in your vehicle at all times. A spill kit commonly contains chemical-resistant gloves, coverall and goggles; sorbent pads, and absorbent material (such as kitty litter); and a plastic temporary storage container.

In case of a pesticide spill follow the three "Cs": control, contain, and cleanup. **Control** the spill immediately to prevent further spillage. **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 is available by calling CHEMTREC, the pesticide emergency network, at 800-424-9300.

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 fork lifts. 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 an emergency 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 vehicle), the papers must be within your reach and readily recognizable by emergency personnel or placed in a door pouch. 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 on-line (*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 on-line (*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, 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 at *http://www.access.gpo.gov/nara/cfr/cfr-table-search.html.*

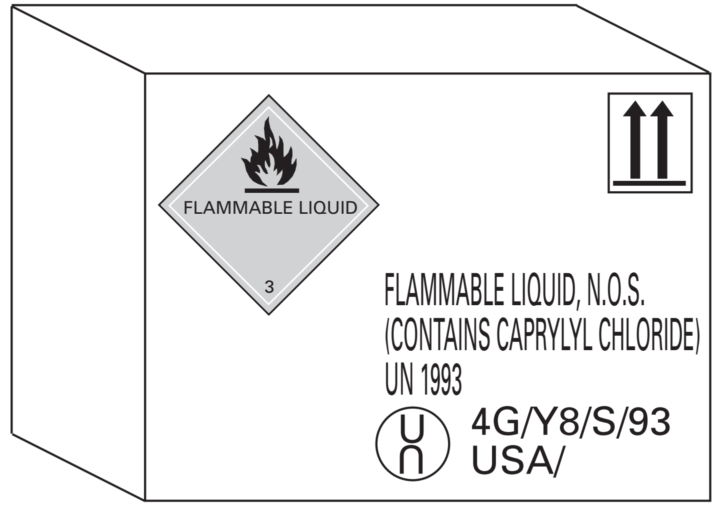
The print version can be ordered by writing to:

U.S. Government Printing Office
Superintendent of Documents
Mail Stop: SSOP
Washington, DC 20402-9828

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 Drivers 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 drivers 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 a private motor carrier 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 which have 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 which have been declared to be "hazardous waste."

Except for someone 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 other persons not trained to use pesticides. Always keep personal protective equipment (PPE) and a hazardous materials spill kit (chemical-resistant gloves, coverall and goggles; sorbent pads and absorbent material such as kitty litter; and a plastic temporary storage 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 become repellent to the pest.

Always store pesticides in the original container with the label intact. Once a container is opened, the shelf life is considerably reduced. Never store pesticides, 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 glasses are a common cause of accidental poisonings. Store pesticides away from food, pet food, 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 Pesticides. If necessary, contact either the pesticide manufacturer or CHEMTREC (800-424-9300) 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 can be reduced in effectiveness if they are frozen or overheated. Expansion of pesticides caused by freezing or heating can cause containers to crack or break, resulting in potentially dangerous leaks or spills. Heat expansion of a liquid pesticide also may result in contents that are under pressure. When the container is opened, the pressure may cause an overflow and/or contamination of the user or storage site. Excessively high temperatures (120^{o} F or higher) can also 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 their storage and disposal, the guidelines do not answer every question. If you have questions on 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*** (similar to the hazardous pesticide spill kit described earlier). 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 persons 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. Sufficient absorbing materials should be used to completely soak up the liquid. The material then should be swept or shoveled into a leakproof drum. Dispose of this material as you would the pesticide involved.

Always refer to the product label and, if necessary, contact either CHEMTREC (800-424-9300) or 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), they must submit specific information 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.

Pesticide Storage Site Selection

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 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.

Weatherproof signs, stating "Danger - Pesticides - Keep Out!" or a similar warning, should be posted 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 only be used 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 need to be disposed of properly. Empty containers which 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. Other containers are refillable and 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 are also 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 are often 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 are commonly referred to as "refillables". Refillable containers must not have the seal broken or the container opened. They should never be rinsed.

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:

- Unless the container is rinsed immediately, the remaining residue may dry and become difficult to remove. An unrinsed pesticide container is typically considered hazardous waste, but once rinsed, the same container is usually 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

Pressure-rinsing is usually 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 wash 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 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 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 container to supplier or pesticide container recycling site or dispose of the pesticide container according to label directions. Plastic caps and containers are usually 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 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% 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. Add the rinsate from the pesticide container to spray tank and allow to drain for 30 seconds or more.
6. Repeat steps 2 through 5 **two more times.**
7. Return container to supplier or pesticide container recycling site or dispose of the pesticide container according to label directions. Plastic caps and containers are usually made from different materials and usually are recycled separately. For more information on pesticide container recycling sites, contact your local Extension office.

When Rinsing is Not Possible

It is not possible in certain situations 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 bag contents into spray tank.
2. Shake the bag to remove as much product as possible.
3. Cut the sides and folds of the bag to allow it to fully open; add 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.

Excess Pesticide Waste Disposal

The best way to dispose of small amounts of pesticide is to apply it to a label-permitted site (specific plant, animal, 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:
Poison Center 800-222-1222
For aid in human poisonings
CHEMTRAC 800-424-9300
For help involving spills, leaks and fires
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
_____Keep 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
_____Hazardous materials spill kit

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 and 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_______________________________

Inspected by_______________________________

Date _______________________________

Notes_______________________________
____
____

Adopted 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						

Adopted from Pesticides and Commercial Vehicle Maintenance, *Purdue University.*

Impacts of Drought on Disease Development and Management

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Tamra Jackson-Ziems, Extension Plant Pathologist
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Kevin Korus, Extension Educator

Drought conditions such as those that occurred in Nebraska in 2012 can impact the development of plant diseases. In general drought slows down or prevents the development of plant diseases caused by pathogens that thrive under moist conditions. However, some diseases are favored by drought. This is because when plants are stressed due to lack of moisture or excessive heat, they become more susceptible to these diseases. This article presents examples of diseases of agronomic crops favored by drought and how to manage them. Data are provided on the effect of dry or wet conditions on the profitability of applying fungicides to control foliar fungal diseases of wheat.

Charcoal Rot Diseases of Field Crops

Charcoal rot, also known as dry-weather wilt in soybean, is caused by the fungus *Macrophomina phaseolina* and can affect corn, sorghum, soybean, sunflowers, and dry beans (for which it is has been named ashy stem blight). The fungus has a widespread distribution and wide host range. Microsclerotia (hardened fungal survival bodies) are formed inside infected crop tissue. These microsclerotia are how the fungus overwinters in infested crop debris and soil. Survival of microsclerotia is several years in dry soil but only a few weeks in wet, saturated soils. As most rotations include hosts for this fungus every year, the potential for the pathogen to be present in many fields is high and will be favored by dry conditions.

*Favorable Environmental Condition*s. Charcoal rot thrives in the hottest, driest part of the growing season. This is why it was more common in the 2012 production season. Charcoal rot develops when there is a high level of the pathogen in the soil and when plants are under stress from hot dry weather. Infection of soybean typically occurs early in the season at the emergence and early seedling growth stages. These seedling infections remain latent until environmental stresses (drought and high ambient temperatures) occur during the R1 (flowering) -R7 (mature pod) growth stages. In corn, high soil temperatures (98°F) and low soil moisture during grain fill are known to be related to higher levels of charcoal rot.

Symptoms of Charcoal Rot. Seedling damage has been found in soybean when infected seed is planted, but this has not been observed in Nebraska. Typically, symptoms occur after midseason during the reproductive stages of crop development. Infected plants produce slightly smaller leaflets than healthy plants and have reduced vigor. As the disease advances, leaflets yellow, then wilt and turn brown. The brown leaves remain attached to the petioles (leaf stems). A light gray of silver discoloration will be visible in the taproot and lower stem when plants are split open. Black specs (microsclerotia) will be visible in this tissue of the stem and tap root. Outer tissues will have black, dusty microsclerotia. Plants in the driest parts of the field will typically show symptoms first. Upper pods may have poor fill and general low plant vigor. In some cases, the upper one-third of the plant may have only flat pods without seed.

In corn and sorghum, internal shredding of the lower nodes will occur with dark black sclerotia being very visible when the stalks are split. Like the name of this disease, the plant will look like charcoal inside the stem and the microslerotia will be attached to the vascular tissue strands in the stalk.

Management of Charcoal Rot

- Seed treatments have not been demonstrated to be effective even though early season infections are common and symptoms develop at grain fill.
- Reducing plant density will reduce drought stress and reduce charcoal rot.
- Tillage does not affect this disease, as the microsclerotia will survive several years.
- Use of resistant varieties and hybrids.
- Crop rotation to non-hosts such as wheat can help reduce microsclerotia numbers.

Aspergillus Ear Rot and Aflatoxin Contamination

Aspergillus ear rot of corn is another important disease in drought-damaged and non-irrigated fields. This disease receives attention because the fungal species that cause it (usually *Aspergillus flavus* and *A. parasiticus*), can also produce aflatoxin, which can be toxic to animal and human consumers of contaminated grain. You can find more details on this disease and the mycotoxin, as well as how to manage stored grain to minimize contamination in grain in other articles in the CPC Proceedings:

- *Corn Disease Update*
- *Grain Storage To Minimize Mold And Mycotoxins*

Fusarium Diseases

Fusarium pathogens are microbes which exist in soil and on crop residues for a long time. Many factors can lead to diseases caused by *Fusarium*. Plant stress, such as drought, is one of the factors that increase the incidence and severity of these diseases. *Fusarium* species have been associated with many important diseases of corn, wheat and soybean, causing significant yield losses. Drought can significantly impact these diseases. Fusarium stalk rot, ear rot, and kernel rot of corn caused by *Fusarium verticillioides* can cause significant yield losses and mycotoxin contamination under drought conditions. Wheat root diseases, such as common root rot caused by *Bipolaris sorokiniana*, and Fusarium crown rot caused by *Fusarium* spp., are also more severe under drought conditions. Early root infections by these pathogens can cause severe yield reduction in dry soils. However, drought will reduce the potential for sudden death syndrome (SDS) in soybean but can favor other Fusarium infections causing Fusarium wilt.

Management of Fusarium Diseases

- Minimize stress and injury by herbicides, foliar diseases, hail damage or drought
- Optimize the soil fertility level
- Minimize soil compaction
- Use fungicide-treated seed
- Crop rotation with non-host crops can reduce pathogen inoculum
- Plant resistant/tolerant cultivars

Additional information on Fusarium diseases can be found in the NebGuide “Major Fusarium Diseases on Corn, Wheat and Soybeans in Nebraska”.

Phoma Black Stem of Sunflower

Phoma black stem is a stalk rot disease caused by the fungal pathogen *Phoma macdonaldii*. It is characterized by large, black shiny lesions that may reach several inches in length. Infection generally starts on leaves from airborne or rain-splashed conidia. The pathogen makes its way down the petiole to the point of attachment on the stem before causing the black lesions on stems.

Although moist weather shortly before and after flowering is beneficial to the pathogen, periods of stress prior to this such as drought, predisposes the plants, making the potential damage from the infection greater. The pathogen may also girdle the stems at the soil line, causing premature maturation, reduction in head size and poor seed fill in heads. Stem infections also become more prone to lodging.

The pathogen is residue-borne, so rotation and some type of tillage will help reduce inoculum in the soil. Insect control can also limit spread since their feeding can also provide openings for the pathogen to initially infect plants.

Root and Crown Rot Diseases of Wheat

Root and crown rot diseases in wheat are often overlooked because of the absence of obvious above-ground symptoms. These diseases are caused by several different fungi. The diseases caused by fungi in the genera *Bipolaris* and *Fusarium* are favored by dry soil conditions. Therefore, there is an increased risk for the occurrence of these diseases in the 2012 fall-sown winter wheat crop due to the drought of 2012. When seedlings are attacked by these fungi, winter survival is reduced due to seedling blights. Later in the growing season, root and crown rots develop. The fungus *Bipolaris sorokiniana* causes common root rot. The disease is characterized dark-brown to black necrotic lesions on roots, subcrown internodes, and stem bases. Discoloration of the subcrown internode is diagnostic of the disease. Several *Fusarium* species cause Fusarium foot rot and dryland foot rot. The most common symptom of Fusarium foot rot is a dark-brown lesion around the node of mature plants. Long and thin dark-brown vertical streaks are also commonly seen on the lower stem. In dryer areas, dryland foot rot may develop. It is characterized by a dark-brown lesion that girdles the entire stem base. Affected tissue becomes soft and white, and a pink fungal growth bearing orange spore masses may develop.

Management of Root and Crown Rot Diseases of Wheat

- When possible, irrigate fields to reduce stress due to inadequate moisture.
- Avoid excessive nitrogen fertilization. Under dry conditions, excessive nitrogen promotes vegetative growth (especially tiller formation) to levels that cannot be sustained through heading and grain-fill. The excessive growth prematurely depletes available soil water. This increases water stress which predisposes plants to severe root and crown rot diseases.
- Severely affected fields in the current cropping cycle (2012-2013) should be rotated to a non-cereal crop in future cropping cycles to reduce fungal inoculum for root and crown rot diseases.
- Damage from these diseases can further be reduced by planting pathogen-free, fungicide-treated seed.
- Planting drought-tolerant varieties can also help to reduce loss due to root and crown rot diseases.

Management of Foliar Diseases of Wheat with Fungicides in a Dry versus a Wet Growing Season

Foliar fungal diseases of wheat are favored by moisture. They include the rusts (leaf, stripe, and stem rust) and the leaf spots such as tan spot, spot blotch, and Septoria leaf blotch. Field experiments were conducted in Nebraska in 2006 (dry year) and 2007 (wet year) to demonstrate the effects of applying foliar fungicides on disease severity, yield, yield increase, and economic returns under these two environmental conditions. In both years, the experiments were conducted at Mead, Clay Center, North Platte, and Sidney. The fungicides applied were Quilt, Headline, Tilt, Quadris, and Stratego. They were applied to winter wheat cv. Millennium at the stem elongation or the flag leaf growth stage. Table I shows average total rainfall in the months of May, June, and July and averages of disease severity, yield, yield increase, and net return across fungicides and locations in each year.

The data show that net returns from fungicide application to control foliar fungal diseases of wheat were almost negligible in the dry year, but were substantial in the wet year. Therefore, when foliar fungal disease development is limited due to dry conditions during the wheat growing season, fungicide application may not be profitable and may actually result in a net loss.

Table I. Summary data from experiments conducted to determine the effects of fungicides on foliar fungal disease severity, yield, yield increase, and net return in winter wheat cv. Millennium in Nebraska in 2006 and 2007.

	2006 (dry)	**2007 (wet)**
Avg total rain (in): May-July	6	12
Avg temp (^{o}F): May-July	70	69
Avg disease severity (%)		
Sprayed plots	2	22
Unsprayed plots	4	59
Avg yield (bu/A)		
Sprayed plots	44	69
Unsprayed plots	38	49
Avg yield increase (bu/A)	6	20
Average net return ($/A)[a]	5	76
Probability of a profit	0.63	1.00

[a]Net return was calculated based on a wheat price of $3.87/A in 2006 and $4.83/A in 2007.

What's New in Plant Pathology

Loren Giesler, Extension Plant Pathologist
Tamra A. Jackson-Ziems, Extension Plant Pathologist
Casey Schleicher, Extension Technologist
Kevin Korus, Extension Educator

Extension Plant Pathology Team Update

There have been several changes in our team over the last year. Below is a listing of Extension Plant Pathology Team members and their responsibilities.

- Loren Giesler, Extension Specialist – UNL Lincoln Campus. Diseases of soybean and turf and extension team leader.

- Robert Harveson, Extension Specialist – UNL Panhandle Research and Extension Center (Scottsbluff, NE). Diseases of specialty crops, including chickpeas, dry beans, sugar beet, sunflower, etc. (all crops outside of corn, forages, small grains, sorghum and soybean)

- Tamra Jackson-Ziems, Extension Specialist – UNL Lincoln Campus. Diseases of corn and sorghum.

- Kevin Korus, Extension Educator-Plant Pathology - UNL Lincoln Campus. Coordinator of the Plant & Pest Diagnostic Clinic and diseases of trees and backyard fruits and vegetables.

- Bo Liu, Extension Specialist – West Central Research and Extension Center (North Platte, NE). Cropping systems soil microbial communities with an emphasis on Fusarium and Rhizoctonia Diseases.

- Stephen Wegulo, Extension Specialist – UNL Lincoln Campus. Diseases of small grains, forages, and ornamentals.

Plant and Pest Diagnostic Clinic Update

The Plant and Pest Diagnostic Clinic provides plant disease diagnostics as well as insect pest and weed identification. Chemical injury and nutrient deficiencies are assessed by visual identification only. The clinic is not set up to perform tissue analysis for chemical injury or nutrient deficiency. A sample fee restructure will be implemented to accommodate the rising cost of processing samples and to ensure accurate and timely diagnoses. Although the final price adjustment is not set, prices will remain competitive and economical.

Tips for Submitting a Sample

- Be sure to send samples for disease diagnostics and pest identification in a sealable plastic bag.
- Never add water to the bag.
- If the plant is excessively wet, add a dry paper towel.
- Collect fresh samples that are symptomatic.
- Ship samples early in the week (Monday – Wednesday) in a sturdy container.
- Be sure to thoroughly fill out the sample submission form and include it in the shipping container with the sample. The sample submission form can be found at and printed from the following address: http://pdc.unl.edu/diagnosticclinics/plantandpest.

Disease Management Products

During the past year, several new products have become available for disease management and some changes have been made to the labels of existing products. The label changes and new products are summarized in Tables 1 and 2, respectively, as well as included in the 2013 Guide for Weed Management in Nebraska with Insecticide and Fungicide Information. In addition, fungicide information has now been included for sugar beet and dry bean.

Table 1. Foliar Fungicide Label Updates

Foliar Fungicide	Crop	Update Description
Domark	Corn	Aerial application changed from 5 gpa to 2 gpa minimum
Domark	Soybean	Chemigation changed from 'Not Allowed' to 'Allowed'
Headline AMP	Corn	Ground application changed from 10 gpa minimum to 15 gpa minimum
Proline	Corn	Supplemental label recently added for new crops, including corn
PropiMax	Corn	Pre-harvest interval (PHI) changed from 36 days to 30 days
Stratego YLD	Wheat	Supplemental label recently added for new crops, including wheat

Table 2. New Products

Foliar Fungicides	Active Ingredient	Fungicide Class	Labeled Crops
Priaxor	fluxapyroxad + pyraclostrobin	carboximide + strobilurin	Barley, Dry Bean, Corn, Oats, Potato, Rye, Soybean, Sugar Beet, Sunflower, Triticale, Wheat and others
Topguard	flutriafol	triazole	Corn, Soybean, Sugar Beet and others
Vertisan	penthiopyrad	carboxamide	Barley, Dry Bean, Corn, Oats, Potato, Rye, Sorghum, Soybean, Sugar Beet, Sunflower, Triticale, Wheat and others.

Seed Treatment Fungicides	Active Ingredient	Fungicide Class	Labeled Crops
CruiserMaxx Advanced	fludioxonil + mefenoxam + thiamethoxam	phenylpyrrole + acylalanine + neonicotinoid	Soybean
CruiserMaxx EZ	fludioxonil + mefenoxam + thiamethoxam	phenylpyrrole + acylalanine + neonicotinoid	Soybean
CruiserMaxx Vibrance Cereals	sedaxane + difenoconazole + mefenoxam + thiamethoxam	carboxamide + triazole + acylalanine + neoniocotinoid	Barley, Oats, Rye, Triticale, and Wheat
Evergol Energy	prothioconazole + penflufen + metalaxyl	triazole + carboxamide + acylalanine	Alfalfa, Barley, Dry Bean, Soybean, Triticale, Wheat and others
NipsIt SUITE Cereals OF	clothianidin + metalaxyl + metconazole	neonicotinoid + acylalanine + triazole	Barley, Oats, and Wheat
Vibrance	sedaxane	carboximide	Barley, Oats, Rye, Soybean, Triticale, Wheat and others
Vibrance Extreme	sedaxane + difenoconazole + mefenoxam	carboxamide + triazole + acylalanine	Barley, Oats, Rye, Triticale, and Wheat

Corn Disease Update

Tamra A. Jackson-Ziems, Extension Plant Pathologist
Craig B. Langemeier, Graduate Research Assistant
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Goss's Bacterial Wilt and Blight

Goss's Bacterial Wilt and Leaf Blight, or more commonly referred to as Goss's wilt, was prevalent early in the 2012 growing season, but disease progression slowed, presumably due to the extreme heat and drought through most of the state. Goss's wilt was prevalent in the 1970s and 1980s, but only developed sporadically from the late 1980s until 2006. Around 2006, the disease reemerged in western Nebraska, northeast Colorado, and southeast Wyoming. From there, the disease appeared to quickly progress eastward and in 2008 it was first reported in Indiana (Ruhl et al., 2008). The disease has also been documented as far south as the northern panhandle of Texas, and as far north as North Dakota (Korus et al., 2011) in the U.S. and two provinces of Canada, Ontario and Manitoba.

Symptoms

As the name implies, there are two phases of the disease. The wilt phase usually occurs following early season wounding (e.g. sandblasting, hail, high winds, or heavy rainfall). The wilt phase is usually most severe when plants are injured when nodes are stacked beneath the soil line during the early vegetative stages V3-V5 (Suparyono and Pataky 1989). Stand reductions around V4 have been reported to be as high as 30% when the systemic wilt phase was severe. The wilt phase is caused by a buildup of bacteria in the vascular bundles, which reduces the plant's ability to transfer water, thus causing the plant to wilt and die. The wilt phase can also occur when plants are larger, but disease occurrence is usually not as severe (Suparyono and Pataky 1989). The wilt phase was confirmed in June 2012 in York County, which was especially early further east than normal during recent years in Nebraska.

The second and more common phase of the disease is leaf blight. Leaf blighting caused by this disease is also most commonly seen in association with the wounding events as previously described. Leaf blighting often is accompanied by water soaked lesions with discontinuous water soaked spots, often called freckles, along the lesion margin. The lesions run parallel to the veins, but are not confined between veins. Shiny bacterial exudate or "ooze" may also be observed on mature lesions giving it a glossy or wet appearance.

2011 Survey results

In 2011, a survey was initiated to begin to understand which agronomic factors and environmental conditions had the most impact on disease development. More than 500 surveys were returned from eight states and were accompanied by 486 leaf samples. The two statistical analyses used identified several factors that could have a significant impact on the development and severity of Goss's wilt in the Corn Belt.

The top five factors associated with the development of Goss's wilt are:

1. planting population density
2. Goss's wilt rating for the hybrid (assigned by the seed company)
3. crop rotation sequence
4. planting date
5. percentage of residue cover

This study confirmed that the best way to avoid Goss's wilt in a field is to plant a resistant hybrid. It also showed that crop rotation and percent residue cover affected the ability of the pathogen to infect in subsequent years. Since the pathogen is residue-borne, planting continuous corn, or leaving large amount of infected corn residue on the soil surface increased the likelihood that the sample tested positive for Goss's wilt. The other two factors associated with Goss's wilt development were planting population and planting date. Future research efforts will need to be made on these two topics before any recommendations can be made to better understand their impact on disease development and to better manage for Goss's wilt.

New alternate hosts identified

In greenhouse trials, 3 previously unconfirmed hosts of Goss's wilt were confirmed during the spring of 2012. Green foxtail was the only foxtail species previously identified as a host to the Goss's wilt bacteria (Schuster, 1975). Research conducted in the greenhouse showed that yellow foxtail, bristly foxtail, and giant foxtail are also hosts, in addition to green foxtail, and could be providing a reservoir of bacterial inoculum. Symptoms on these foxtail species were similar to those observed for the leaf blight phase of the disease on susceptible corn hybrids.

Other known hosts include eastern gama grass, barnyard grass, sudangrass, grain sorghum, teosinte, and volunteer corn.

Goss's Wilt Management Strategies

- Plant resistant hybrids
- Rotate with nonhost crops, such as wheat or soybean
- When practical, reduce the amount of residue, if planting into infected corn residue
- Control alternate hosts, such as volunteer corn, foxtail species, and other known alternate hosts

More Resources

Additional information on these and other diseases and their management can be found at the website Plant Disease Central at http://pdc.unl.edu/ or in the following UNL Extension publications:

<u>Goss's Bacterial Wilt and Leaf Blight of Corn</u>
http://www.ianrpubs.unl.edu/sendIt/g1675.pdf

Literature Cited

1. Korus, K. A., Timmerman, A. D., French-Monar, R. D., and Jackson, T. A. 2011. First report of Goss's bacterial wilt and leaf blight *(Clavibacter michiganense* subsp. *nebraskensis)* of corn in Texas. Plant Disease 95:73.

2. Ruhl, G., Wise, K., Creswell, A., Leonberger, A. and Speers, C. 2009. First report of Goss's wilt and leaf blight on corn caused by *Clavibacter michiganense* subsp. *nebraskensis* in Indiana. Plant Disease 93:841.

3. Schuster, M.L. 1975. Leaf freckles and wilt of corn incited by *Corynebacterium nebraskense* Schuster, Hoff, Mandel, Lazar 1972. Agricultural Experiment Station. IANR University Nebraska Lincoln Research Bulletin 270. 40pp.

4. Suparyono and Pataky, J. K. 1989. Influence of host resistance and growth stage at the time of inoculation on Stewart's wilt and Goss's wilt development and sweet corn yield. Plant Disease 73:339-345.

Aspergillus Ear Rot and
Aflatoxin Contaminated Grain

The drought conditions of 2012 had severe impacts on Nebraska corn. In addition to reductions in test weight and overall yield, secondary problems developed in some corn fields as a result of these conditions. Drought and high temperatures promote development of the disease Aspergillus ear rot. The fungi that cause this disease (most commonly caused by *Aspergillus flavus*) can produce aflatoxin. Aflatoxin is one of many in a group of chemicals, known as mycotoxins, that are produced by fungi (molds). Mycotoxins, such as aflatoxin, can be toxic to animal and human consumers and at certain concentrations can lead to dockage or rejection of grain at elevators.

Mycotoxins are common and can be safely consumed at low concentrations. The concentration of aflatoxin that is considered safe for consumption depends upon the age and species of the animal consumer. An abbreviated summary listing the Action Levels identified by the FDA for aflatoxin is listed in Table 1.

Table 1. FDA Action Levels for Aflatoxin in Feed and Food

Consumer	Action Level in parts per billion (ppb)
Finishing (feedlot) beef cattle	300
Finishing swine of 100 pounds or greater	200
Breeding beef cattle, breeding swine, or mature poultry	100
Immature animals and dairy cattle	20
For animal species or uses not otherwise specified, or when the intended use is not known	20
Humans	20

Action Levels were established by the U. S. Food and Drug Association (FDA) for Aflatoxin are available at: http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/ChemicalContaminantsandPesticides/ucm077969.htm#afla

Testing for Aflatoxin

Corn harvested from fields where there was Aspergillus ear rot should be tested for aflatoxin prior to use, sale, or storage. Corn is at higher risk for Aspergillus ear rot if it was grown under drought-stressed conditions or if injury occurred to the kernels. The concentration of aflatoxin in a sample can be determined by laboratory testing. The U.S. Grain Inspection, Packers and Stockyards Administration (GIPSA) certifies some laboratories for aflatoxin testing. A list of laboratories certified for aflatoxin testing in the Nebraska region is below.

Accurate lab test results for aflatoxin depend greatly on the quality of the sample that is collected and methods used by laboratories conducting tests. The test results are only applicable to the sample that is submitted, so it is very important to collect an adequate and representative sample for the best results. Refer to the publication, **Sampling and Analyzing Feed for Fungal (Mold) Toxins (Mycotoxins)** (link below) for recommendations on how to collect and submit a high quality sample for the most accurate mycotoxin analysis. In addition, you should contact and submit samples to a laboratory that is certified by the Federal Grain Inspection Service (FGIS) and Grain Inspection, Packers & Stockyards Administration (GIPSA) for mycotoxin analysis. A list of GIPSA-certified laboratories in and near Nebraska is below:

- Fremont Grain Inspection. 603 East Dodge St., Fremont, 402-721-1270; email fgid@neb.rr.com
- Hastings Grain Inspection, 306 E. Park St., Hastings, 402-462-4254; email Hastings at hgihast@hastingsgrain.com; email Grand Island office at hginsp@hastingsgrain.com
- Kansas Grain Inspection Service, 517 13th Ave., Sidney, Nebr., 308-254-3975
- Lincoln Inspection Service, 505 Garfield St., Lincoln, 402-435-4386; email lismf@neb.rr.com
- Omaha Grain Inspection Service, 2525 South 13th St., 402-341-6739; omahagrain@gmail.com
- Sioux CIty Inspection and Weighing Service, 840 Clark St., Sioux City, Iowa, 712-255-8073; email tomd@scigrain.com

The complete list of laboratories certified by GIPSA for aflatoxin testing can be found at: http://www.gipsa.usda.gov/fgis/svc_provid/providers.html

Black (ultraviolet) lights have been used by some grain elevators and individuals in an effort to detect fluorescence as a method for rapid screening of grain samples. This practice is NOT recommended when making decisions about aflatoxin contamination in loads of grain. The component that produces fluorescence under black light is called kojic acid. Although kojic acid is produced by the same fungus that produces aflatoxin, its presence is not an indicator of aflatoxin and might lead to false positive results and unnecessary rejection of grain.

High risk factors for aflatoxin contamination in corn:

- Drought-damaged fields, including rainfed (dryland) fields and non-irrigated pivot corners
- Fields or areas with higher incidence of corn ear feeding insects, such as the corn ear worm
- Grain damaged before or during harvest or after harvest while in storage

Scouting for Aspergillus Ear Rot

Ear rot diseases and aflatoxin are not evenly distributed across fields or in the grain, so scouting and/or sampling should include a substantial portion, at least several acres. And, the presence of visible fungus in kernels does not always correlate well with the presence of aflatoxin, nor does the absence of visible fungal growth necessarily indicate the absence of aflatoxin.

- Open husks to view a large number of ears
- Look for the presence of dusty yellow-green to olive-green spores, especially on the surface of damaged kernels or ear tips
- Pay special attention to corn in higher risk areas

Harvest and Storage

If fields have documented Aspergillus ear rot and/or risk of aflatoxin contamination, it is recommended that you harvest and keep grain separate from other grain at less risk, such as irrigated fields. Storage of affected grain is not recommended because ear rot diseases and mycotoxins can continue to accumulate during storage. If storage is necessary, cooling and drying grain to less than 15% moisture within 48 hours of harvest will help to slow fungal growth and aflatoxin production. Grain intended to be stored for longer periods of time should be dried to less than 13% moisture.

Based on aflatoxin test results from the Lincoln Inspection Service, only about half of the samples submitted had detectable concentrations of aflatoxin. And, only a low percentage of samples had aflatoxin concentrations of more than 20 ppb.

For more information, refer to the list of publications below or to the article in these Proceedings entitled, "Grain Storage Management to Minimize Mold and Mycotoxins."

More Resources

Plant Disease Profiles #3: Ear Rot Diseases and Grain Molds
http://www.ianrpubs.unl.edu/sendIt/ec1901.pdf

Sampling and Analyzing Feed for Fungal (Mold) Toxins (Mycotoxins)
http://www.ianrpubs.unl.edu/sendIt/g1515.pdf

Understanding Fungal (Mold) Toxins (Mycotoxins)
http://www.ianrpubs.unl.edu/sendIt/g1513.pdf

Use of Feed Contaminated with Fungal (Mold) Toxins (Mycotoxins)
http://www.ianrpubs.unl.edu/sendIt/g1514.pdf

Stalk Rot Diseases

The crop stress created by the harsh growing conditions in 2012 led to the development of stalk rot diseases and lodging that slowed harvest progress in some areas.

Weakened stalks became evident in some of the corn still waiting to be harvested across the state late this past fall. The high winds in October 2012 led to lodging in corn where some stalks were weakened by stalk rot diseases and other problems. Crop stress during the 2012 growing season contributed to the development of some stalk rot diseases.

Scouting for Stalk Rot Diseases

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 point in the stalk from the crown at/below the soil line all the way to the tassel. Rotting that occurs at an upper node and kills only the upper plant parts is referred to as "top rot" and does not necessarily cause lodging of the whole plant. However, degradation of the stalk below the ear can lead to plant lodging and losses during harvest.

Scouting for Stalk Rot Diseases

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 fail to snap back to vertical, then the stalk has 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 other fields that are 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 that can cause stalk rot diseases. Some of the most common stalk rot diseases this year are listed below:

- **Charcoal rot** is one of the few diseases that are more common during drought conditions, and so, is more likely to affect non-irrigated crops. 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 (hence the name). 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.

- **Fusarium stalk rot** is especially common during damp conditions, but may occur anywhere, including in irrigated fields this year. The pathogen, *Fusarium verticillioides*, can sometimes be visible as white 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 rots in corn. In more advanced stages the disease can cause the development of black lesions visible on the outside of the stalk and is caused by the fungus *Colletotrichum graminicola.*

Management

Usually, there is nothing to be done to stop stalk rot development once it is identified in the field. In most cases, 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 those fields that are heavily impacted by stalk rots first to minimize losses after lodging.

More Resources

For more information on stalk rot diseases of corn, see the UNL Extension publications:

Corn Disease Profiles II: Stalk Rot Diseases
http://www.ianrpubs.unl.edu/sendIt/ec1868.pdf

Common Stalk Rot Diseases of Corn
http://www.ianrpubs.unl.edu/sendIt/ec1898.pdf

Crop Watch
http://cropwatch.unl.edu/

If you are in doubt about the identity of a disease or cause of another plant problem, you may submit a sample to the UNL Plant and Pest Diagnostic Clinic (P&PDC) for diagnosis. For more information about these and other plant diseases or for submission forms for the P&PDC and submission instructions, visit the **Plant Disease Central** website at:
http://pdc.unl.edu/

Wheat Disease Update

Stephen Wegulo, Extension Plant Pathologist
Emmanuel Byamukama, Postdoctoral Research Associate
Kevin Korus, Extension Educator

In 2012, above normal spring temperatures following a mild winter led to early maturation of the wheat crop. Wheat was harvested three to four weeks earlier than normal. Intermittent rainfall and cool temperatures earlier in the spring favored the development of stripe rust, which was widespread in southeast and south central Nebraska by mid-April. Leaf rust was first detected on May 1 in Lancaster County, about two weeks earlier than when it is usually first seen in Nebraska wheat fields. Other fungal diseases observed during the 2012 growing season included loose smut, tan spot, Septoria leaf blotch, powdery mildew, and trace levels of Fusarium head blight (scab).

Wheat streak mosaic virus (WSMV) and Triticum mosaic virus (TriMV) were consistently detected in samples submitted to the Plant and Pest Diagnostic Clinic. Field surveys showed varying degrees of incidence and severity of these two diseases, with some fields severely affected. Barley yellow dwarf virus (BYDV) was observed at low levels in most fields surveyed and at moderate to severe levels in localized areas in some fields.

Management of Wheat Diseases

In general, wheat diseases can be managed by planting resistant, adapted cultivars and good cultural practices such as balanced fertilization, crop rotation, irrigation management, and weed control. Management strategies can vary depending on the specific disease and prevailing environmental conditions.

Little can be done during the growing season to control virus diseases. The wheat curl mite which transmits WSMV and TriMV survives best on wheat, but can also survive on grassy weeds. Therefore, for next year's growing season, it is best to control volunteer wheat and grassy weeds in the field before planting in the fall. All volunteer wheat should be completely dead at least two weeks before planting. Planting resistant/tolerant cultivars, avoiding early planting, and controlling weeds and aphids (the vectors of BYDV) can reduce damage caused by WSMV, TriMV, and BYDV.

Seedborne fungal diseases such as loose smut, common bunt, and Fusarium seedling blights can be managed by planting certified, pathogen free seed. These diseases, as well as soilborne fungal diseases that cause seedling blights and root and crown rots, can also be managed by planting fungicide-treated seed. Foliar fungal diseases can be managed by applying a fungicide timed to protect the flag leaf. For Fusarium head blight, fungicide application should be timed at early flowering.

Stripe Rust Fungicide Trial

In 2012, stripe rust was the predominant disease at our experimental site at Mead in southeast Nebraska where we had planted the susceptible cultivar '2137'. Therefore, we conducted a fungicide trial on stripe rust. A total of 12 treatments including the check were included in the trial. Treatments were arranged in a randomized complete block design and were replicated four times in plots measuring 5 ft x 15 ft. Fungicides were applied at flag leaf (Feekes 9) with a CO_2-powered backpack sprayer set at 38 psi and equipped with a 4-ft wide boom with four Teejet #8001VS nozzles set 1 ft apart. Percent disease severity (whole-plot rating) was visually estimated on May 16 and May 23. Results showed a wide range of fungicide efficacy and yield among treatments (Table I).

Table I. Fungicides, rates, foliar disease severity, and yield in a stripe rust fungicide trial conducted at Mead, Nebraska in 2012.

Fungicide	Rate/A (fl oz)	Foliar disease severity[a] (%) May 16	Foliar disease severity (%) May 23	Yield bu/A
Check	…	68.8 a	92.5 a	64.3 ef
EcoGuard	0.375%	61.3 b	88.8 ab	66.4 ef
EcoGuard	0.75%	70.0 a	86.8 ab	59.5 f
Regalia Maxx	8.0	60.0 b	83.8 ab	67.9 c-e
Regalia Maxx	4.0	57.5 b	79.5 b	66.7 d-f
Aproach	9.0	4.5 c	22.5 c	74.5 a-c
Aproach	6.0	3.4 c	21.3 cd	74.0 b-d
Headline	9.0	1.5 c	11.8 ef	81.5 a
Headline	6.0	2.0 c	11.3 ef	76.0 ab
Headline + Regalia Maxx	6.0 4.0	2.5 c	5.5 e-g	76.8 ab
Prosaro	5.0	0.3 c	1.8 fg	71.0 ab
Prosaro	6.5	0.3 c	1.0 g	77.0 ab
LSD(0.05)[b]		5.8	9.8	7.4

[a]Means followed by the same letter within a column are not significantly different at $P = 0.05$
[b]Least significant difference at $P = 0.05$.

Soybean Disease Update

Loren J. Giesler, Extension Plant Pathologist

While 2012 was a tough year, soybeans still yielded well in many areas. The hot and dry weather resulted in less disease activity overall, yet there are still some diseases that showed up. Excessive early season moisture after many fields were planted resulted in Phytophtora Stem and Root Rot developing before the drought. In dry years Soybean Cyst Nematode will result in more yield loss and continues to be identified in new areas. Other diseases associated with later reproductive stages such as Charcoal Rot, Brown Stem Rot and SDS also showed up in 2012. This article will help to identify, differentiate and manage these diseases that occurred in 2012. Additional information on disease identification can be found at the UNL Plant Disease Central Web Site (http://pdc.unl.edu).

Phytophthora Root and Stem Rot (*Phytophthora sojae*)

Phytophthora root and stem rot of soybean, is caused by, a soilborne fungus that is present in many Nebraska soybean fields. The pathogen survives primarily as “resting” spores in the soil or in association with infested crop debris. Disease development is favored at soil temperatures of 60^{o}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 stresses 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 *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.

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^{o}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)*

This disease was first confirmed in Nebraska in 2004 and we have found more since that time. The sudden death syndrome (SDS) pathogen is spread with soil; thus, the methods used to prevent soybean cyst nematode spread are also applicable to preventing spread of SDS. For symptoms to develop there needs to be high soil moisture available at flowering. As this is a soilborne disease, it will not spread rapidly across the field from individual spots that show up. Infected areas in a field can also have an oblong distribution in the direction of tillage or equipment traffic.

Symptoms

The first signs of SDS appear as scattered yellow or white spots on the leaves in the upper portion of the canopy. In the intermediate stage, these spots eventually coalesce to form brown streaks between the veins (interveinal necrosis). On these leaves only the midvein and major lateral veins remain green. As the disease reaches the more advanced stages, premature defoliation occurs with petioles (leaf stems) remaining on the plant. The progression from early 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. Seed treatment has **not** been shown to affect disease levels.

Charcoal Rot (Macrophomina phaseolina)

Charcoal rot is also known as dry-weather wilt. The fungus has a widespread distribution and large host range and also affects corn and sorghum. Microsclerotia (hardened fungal survival bodies) are formed inside infected tissue. These microsclerotia are how the fungus overwinters in infested crop debris and free in soil. Survival of microsclerotia is several years in dry soil but only a few weeks in wet, saturated soils. Infection of soybean typically occurs early in season at emergence and early seedling growth stages. These seedling infections remain latent until environmental stresses (drought and high ambient temperatures) occur during the R1 (flowering) through R7 (mature pod) growth stages.

Symptoms

Typically, symptoms occur after midseason during the reproductive stages of crop development. Infected plants produce slightly smaller leaflets than healthy plants and have reduced vigor. As the disease advances, leaflets yellow, then wilt and turn brown. The brown leaves remain attached to the petioles (leaf stems). A light gray of silver discoloration will be visible in the taproot and lower stem when plants are split open. Black specs (microsclerotia) will be visible in this tissue of the stem and tap root. Outer tissues will have black, dusty microsclerotia. Plants in the driest parts of the field will typically show symptoms first. Upper pods may have poor fill and general low plant vigor. In some cases, the upper one-third of the plant may have only flat pods without seed.

Favorable Environmental Conditions

Charcoal rot thrives in the hottest, driest part of the growing season. This disease is most prevalent in southern states, but it can develop anyplace where hot, dry conditions exist. Charcoal rot develops when there is a high level of the pathogen in the soil and when plants are under stress from hot dry weather.

Management of Charcoal Rot

Resistance. Select soybean varieties that are not highly susceptible to charcoal rot. Plant short season varieties that will mature prior to drought stress.

Cultural Practices. Plants grown in conditions of high temperatures, drought or poor fertility are most susceptible. Any cultural practices that minimize plant stress will reduce the risk of charcoal rot. Reduce plant populations and optimize fertility levels, especially phosphorus. Good fertility won't control charcoal rot but it can reduce disease impact on yield.

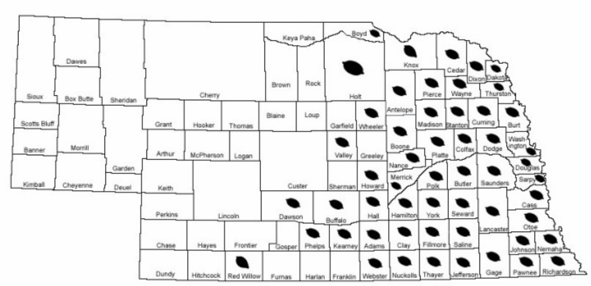
In fields with a history of charcoal rot, rotate out of soybeans for two years or more to reduce inoculum. Microsclerotia can survive for an indefinite time in soil. The benefit of rotation will vary with the field.

Fungicide application. Seed treatment fungicides have not been shown to help manage this disease.

Soybean Cyst Nematode (SCN) (*Heterodera glycines)*

This plant parasitic roundworm is an increasing production problem for Nebraska's soybean producers. SCN has been confirmed in 54 counties in eastern and central Nebraska representing over 90% of the state's soybean production (*Figure 1*). Originally found along the Missouri River, SCN has been identified as far west as Red Willow county in the past few years. However, based on the frequency and level of infestations in several of these counties, it would appear SCN has been present in these areas for a number of years and only recently has been identified.

Over 136,000 eggs per 100 cc (3.4 oz) of soil have been recorded in surveys of Nebraska fields. That translates to over 6,600 eggs per teaspoon of soil, each egg capable of hatching and initiating an infection in the roots. Once established in a field, SCN egg numbers continue to increase unless proper management actions are taken.



[ ] = SCN present in county.

Figure 1. Nebraska state map showing counties with SCN present as of November, 2012.

Symptoms

Often the first symptom of an SCN infestation is a healthy-looking soybean field that does not meet yield expectations. Frequently in SCN-infested fields, soybean yields will hit a plateau, or even start to decline, while corn or other non-host crop yields continue to increase. Yield losses as high as 30% have been documented in Nebraska on healthy looking soybean plants. If above-ground symptoms do appear, it usually starts as slight variations in plant height on healthy looking plants, progressing to slightly chlorotic plants, severely chlorotic and stunted plants, and plant death in extreme infestations. Other stress factors such as drought or high pH may intensify these symptoms.

The only visual sign of an SCN infestation is cysts, or swollen females full of eggs, on the roots during the growing season. Cysts will develop on the soybean roots about a month after emergence. They can be distinguished from Rhizobia (nitrogen) nodules because they are smaller, lemon shaped rather than round, and cream or light tan in color compared to nodules which are medium to dark brown. If observed, you can confirm SCN is present in a field, but because of their small size and relatively few cysts present in light SCN infestations, a visual observation alone should NOT be relied on to prove SCN is NOT present in a field. A good soil sample will detect SCN infestations easily missed by visual observations alone.

Management of SCN

Once detected in a field the following management actions should be followed.

Sanitation. Reduce soil movement between infested and non-infested fields. Anything that moves soil can also move SCN.

Resistance. Plant resistant varieties whenever soybeans are planted in infested fields.

Rotation of Host. Rotate soybeans with one or more non-host crop(s). Two or more years out of soybeans will further decrease SCN levels in the soil, but the greatest decrease comes the first year a field is planted to a non-host crop.

Rotate genetics. Know the source of SCN resistance (PI88788, Peking, Hartwig/Cyst-X) in the variety you select and rotate to another source of resistance the next time soybeans are planted in that field.

Frogeye Leaf Spot (*Cercospora sojina*)

Frogeye leaf spot is a fungal disease that is becoming more common in Nebraska. To date there have been only a few fields significantly affected and treated to protect soybean yield in Nebraska. 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.

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.

Table 1. Confirmed strobilurin fungicide-resistant strains of *Cercospora sojina* as of November 9, 2012.

State	County	Year Identified
Alabama	Limestone	2012
Arkansas	Chicot	2012
	Desha	2012
	Drew	2012
	Lawrence	2012
	Phillips	2012
	Poinsett	2012
	St. Francis	2012
Illinois	Alexander	2012
	Champaign	2012
	Gallatin	2010, 2011
	Jackson	2012
	Pope	2010, 2011
	Warren	2012
Kentucky	Ballard	2012
	Butler	2012
	Caldwell	2010
	Calloway	2011
	Carlisle	2011
	Daviess	2012
	Graves	2012
	Henderson	2012
	Hickman	2011
	Hopkins	2012
	Livingston	2011
	Marshall	2011
	McLean	2012
	Union	2012
	Webster	2012
Louisiana	Avoyelles	2012
	Concordia	2012
	East Carroll	2012
	Ouachita	2010
	Pointe Coupee	2010
	Rapides	2012
	Tensas	2012
Mississippi	Carroll	2012
	Coahoma	2012
Missouri	Pemiscot	2011
	Ste. Genevieve	2012
Tennessee	Dyer	2011
	Gibson	2010, 2011

	Lauderdale	2010, 2011
	Lawrence	2011

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 growth stage (pod set) 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 spread in the Mississippi valley (Table 1). 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.

Specialty Crops Update

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Introduction

This report will summarize some of the major and unusual disease occurrences encountered during 2012 for sugar beets, dry beans, sunflowers, field peas, safflower, chickpeas, and potatoes. Overall, conditions in western Nebraska in 2012 were very different from the previous 3 years. The winter was mild with little snow or moisture of any kind in general. 2012 in the Panhandle has been the hottest and the second driest year on record at approximately 5.5 inches of moisture (combined snow and rain) as of November 1.

These climatic conditions had a significant effect on the appearance of certain plant production problems experienced during the season. For example, rust was a non-issue on sunflowers and dry beans, unlike the much wetter and cooler 2009-2011 seasons. Goss' wilt in corn was very prevalent early in May and June. But it later became a non-issue when the summer became hot and dry.

Sugar Beets

Root rots

Root rot diseases in 2012 were not as problematic as in 2011, although the dry rot canker variant of Rhizoctonia root rot was again identified. This is a rarely occurring root rot that is atypical of the well-known Rhizoctonia root rot disease. It causes different symptoms but is still caused by *R. solani*. Little is known about the pathogen due to its seldom-seen status, but it has been sporadically observed throughout many of the irrigated western sugar beet growing areas, primarily in the central high plains of Nebraska, Colorado, and Wyoming. We are currently investigating comparative studies using these isolates and "typical" Rhizoctonia root and crown rot isolates.

Nematodes

Another unusual report concerns the occurrence of the false root-knot nematode. This is a pest that is native to western Nebraska, and caused severe production problems in the 1950s and 1960s, but has not been noted in Nebraska for at least a decade. Cyst nematodes continue to appear in fields scattered throughout the area, but were not overall damaging in 2012. We also conducted some trials this year for managing this pest with the use of a novel bacterial antagonist applied as a seed treatment.

Foliar Diseases

With the exception of some isolated outbreaks, Cercospora leaf spot (CLS) was not a damaging problem this year. The dry and warm weather is not favorable for disease development by the pathogen. When we see the most severe damage with the disease, night temperatures (midnight to 7 AM) will exceed 70 F, which we saw often this summer. However, high humidity or long periods of leaf wetness are also required, which was not often present this year.

However, another very unusual disease was found from numerous locations throughout western Box Butte County in 2012. Alternaria leaf spot, was noted late in the season causing substantial damage to foliage, but is also thought to have began late enough to not affect root and sugar yields. This potential yield problem was last seen in the 2009 season from several areas of Morrill County. In that situation, no deleterious effects on yield were recorded, but it was still an unknown and worrisome issue for those producers affected by the disease.

Dry Beans

Dry beans in 2012 were relatively unaffected by our traditional bacterial and fungal pathogens. The dry weather resulted in little bacterial blight problems, although wilt was identified from several isolated fields. Rust and white mold were also mild due to the hot and dry climate. The major issues seen in 2012 involved some insect (mites) and abiotic problems related to dry weather. Stands were affected early by an unknown symptom of wilting and death of plants in numerous areas throughout the state. Most of the instances occurred in fields previously cropped to corn. We think at this point that is was largely due to herbicide carry-over from 2011 due to the lack of moisture that would normally flush any remaining chemicals out of the profile.

Sunflowers

The normally prevalent rust disease was present and found on a small scale, but not like the last three years. The primary disease problem in 2012 was due to Rhizopus head rot. This is a disease we see commonly after heads experience some form of mechanical damage, including hail storms, or insect feeding damage. This year the disease was severe and widely distributed as a result of high levels of sunflower head moth feeding within sunflower heads.

An unusual root disease was also seen in one particular field that was caused by the soilborne pathogen *Pythium*. This was unusual due to the dry weather, but this particular field was irrigated and the disease was observed in field margins where water tended to accumulate.

Another interesting, but unusual problem was found in dryland fields. Several fields exhibited plants appearing to have been dug up by gophers or some other land-dwelling animals. As visiting with the producer, it was learned that these plants were in fact dug up, but by jackrabbits who were looking for water within the sunflower roots.

Potatoes

2012 saw us continue to participate with a relatively new potato disease called zebra chip, as part of the USDA-CSREES specialty crops initiative project. It has now been found in most potato-growing areas of the U.S. after first being observed in Mexico about 10 years ago. Although the disease has been tremendously destructive in Texas, it is not known how seriously it is affecting yields or quality in at this time in Nebraska.

The disease is caused by a bacterial pathogen and transmitted by potato psyllids. Once plants are infected, the pathogen induces a wilt of the vascular system causing chipping potatoes to have alternating light and dark brown patterns after being fried, hence the name for the disease being referred to as “zebra chip” This condition makes the tubers and chips produced from them taste bitter and therefore, unmarketable.

We continue to represent Nebraska with work in several areas, including monitoring the incidence and overall presence of both the psyllids and pathogen with sticky traps, evaluating the performance and response of several commonly grown cultivars to both the pathogen and the vector, and lastly creating extension-oriented educational publications for producers throughout the U.S.

Chickpeas

Ascochyta blight was not as prevalent this year, also due to the hot, dry 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 levels. 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 (Safflower and Field Peas)

Two other new potential alternative crops were monitored this year, and were noted to be mildly affected by several additional “new” diseases. Safflower, which is a crop related to sunflower that is grown as an oilseed crop was found infected at low levels by a rust disease, and an unidentified root rot. Several fields of field peas infected with a bacterial blight (caused by *Pseudomonas syringae*) were identified from Box Butte County. This pathogen is related to those causing halo blight and brown spot of dry beans, but are distinct and do not cross-infect. Like the situation with chickpeas and safflower, this disease fortunately became apparent late enough in the season to not affect yield or seed quality results.

Major Fusarium diseases on corn, wheat and soybeans in Nebraska

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Fusarium species have been associated with many important diseases of corn, wheat and soybean, causing significant yield loss in Nebraska; some produce mycotoxins that are harmful to both human and animal consumers. These pathogens are very common in agricultural field soil across the Midwest and cause numerous types of diseases.

***Fusarium graminearum* (*Gibberella zeae*)**

F. graminearum is an important pathogen of both corn and wheat at seed, seedling and mature stages. *F. graminearum* causes several diseases, such as Gibberella stalk rot, ear rot and kernel rot in corn, head blight (scab) of wheat, and seed rot and seedling diseases in both corn and wheat. Wheat-corn rotation is a popular dryland (non-irrigated) cropping system, and increases both wheat and corn diseases caused by *F. graminearum*.

***Fusarium verticillioides* (formerly *Fusarium moniliforme*)**

F. verticillioides is an important economic pathogen causing stalk rot, ear rot and kernel rot of corn. It is a different species from *F. graminearum*. Fusarium stalk rot in corn can be easily confused with Gibberella stalk rot, which can produce reddish discoloration of the internal stalk tissues.

Fusarium virguliforme

Fusarium virguliforme (formerly *Fusarium solani* f. sp. *glycines*) is a unique Fusarium species causing sudden death syndrome (SDS) of soybean. It was first discovered in Arkansas in 1971.

Multiple Fusarium species along or in combination cause seed, seedling and root diseases

Multiple Fusarium species existed in soil, some of them are common plant pathogens, which can damage seeds and seedlings and cause root rot. For instance, the following Fusarium species can cause seed and root rot on corn, wheat and soybeans, such as *F. oxysporum*, *F. solani*, *F. verticillioides*, *F. graminearum*, *F. culmorum*, *F. sublutinans*, *F. acuminatum*, *F. equiseti*, *F. merismoides*, *F. proliferaum*, *F. pseudograminearum*, and *F. semitectum*. Also in most of the time, Fusarium infects plant in combination with *Rhizoctonia*, *Phytophthora*, and *Pythium species*, which kill seeds before germination and cause seedling death under suitable condition for pathogens.

Most of the pathogenic Fusarium species are either soil borne or seed borne. The rest of the Fusarium species include saprophytic and endophytic (found within the plant without causing symptoms, for instance, *F. verticillioides* on corn). The majority of the growers in Nebraska use a wheat-corn, corn-soybean or corn-soybean-wheat rotation in combination with reduced-tillage or no tillage systems, which help prevent erosion, increase organic and soil water content. On the other side, crop residue left on the surface of the field will increase the diseases caused by Fusarium species to some extent. Also the wheat-corn rotation is used in pivot corners, so every three years the continuous irrigated corn is surrounded by wheat.

Fusarium diseases on corn

Gibberella stalk rot

Pathogens: *Fusarium graminearum*.

Symptoms: The inside stalk is pink to red discoloration, disease may produce small, round, black reproductive structures called perithecia on the surface of the stalk.

Conditions: Disease normally occurs at warm and wet weather in late summer, under stress such as drought, freezing and insect damage or herbicide injury.

Overwinter and Dispersal: the pathogens can over winter in crop residue, seed and soil. The pathogens can spread by soil and residue borne hypha and spores through root or stalk infection.

Management: Disease management includes seed treatment, planting less susceptible hybrids, avoiding crop stress and wounding, and crop rotation.

Gibberella ear or kernel rot

Pathogens: *Fusarium graminearum*.

Symptoms: Ear and kernel were characterized with reddish mycelium, starting usually on the tip.

Conditions: Disease normally occurs at cool and wet weather within 3 weeks after silking.

Overwinter and Dispersal: The pathogens can over winter in crop residue, seed and soil. The pathogens can spread by soil, air, and residue borne spores.

Management: Disease management includes seed treatment, planting less susceptible hybrids, avoiding crop stress and wounding, crop rotation, and harvesting early to prevent mold growth.

Fusarium stalk rot

Pathogens: *Fusarium verticillioides*.

Symptoms: The pith disintegrates; white fungal growth may develop on outside of the stalk, a pink discoloration inside rotted stalks, and lacks visible reproductive structures.

Conditions: Disease normally occurs at warm and wet weather after silking, under water stress and foliar diseases, insect or hail injury, and imbalanced fertility, such as high N to K ratio.

Overwinter and Dispersal: The pathogens can over winter in crop residue, seed and soil. The pathogens can spread by soil borne hypha and spores.

Management: Disease management includes seed treatment, planting less susceptible hybrids, avoiding crop stress and wounding, and balancing soil nutrient (avoid too much N), and crop rotation.

Fusarium kernel or ear rot

Pathogens: *Fusarium verticillioides*.

Symptoms: White, pink, to lavender mycelium on kernels scattered around ear. Some kernels may develop a “starburst” pattern.

Conditions: Disease normally occurs at hot and dry weather.

Overwinter and Dispersal: The pathogens can over winter in crop residue and soil. The pathogens can spread by soil borne hypha and airborne spores.

Management: Disease management includes seed treatment, planting less susceptible hybrids, avoiding crop stress and wounding, balancing soil nutrient, and crop rotation.

Fusarium root rot

Pathogens: *Fusarium oxysporum, F. verticillioides, F. graminearum et al.*

Symptoms: Complexes symptoms, roots are dark brown to black, discolored decaying or completely rotted.

Conditions: Diseases normally occur at cool wet weather, and stress.

Overwinter and Dispersal: The pathogens can over winter in crop residue and soil. The pathogens can spread by soil borne mycelium and spores through root infection.

Management: Disease management includes seed treatment with fungicides, minimizing stresses such as herbicide injury, foliar diseases, hail damage or drought, and crop rotation.

Fusarium diseases on wheat

Head blight (scab)

Pathogens: *Fusarium graminearum.*

Symptoms: Tan or brown discoloration at the base of a florets. Diseased spikelets become light tan or bleached. Orange clusters of spores on the glumes. Kernels are shriveled, white and chalky, and develop to pink discoloration.

Conditions: Disease normally occurs at intermediate to warm temperatures.

Overwinter and Dispersal: the pathogens can over winter in crop residue, seed and soil. The pathogens can spread by spores carried by air current.

Management: Disease management includes certified seeds with seed treatment, planting less susceptible varieties, balancing soil nutrient, and crop rotation with non-host, planting varieties with different flowering dates, and fungicide application at early flowering.

Fusarium seed and foot rot

Pathogens: *Fusarium graminearum*; *F. culmorum et al.*

Symptoms: Dark brown lesion around node of plants, whole stem base may become girdled by dark brown lesion. A cottony pink mycelium appears on stem base, plant produces white head when mature.

Conditions: Diseases normally occur at cool wet weather, under reduced tillage and stress.

Overwinter and Dispersal: the pathogens can over winter in crop residue and soil. The pathogens can spread by soil borne mycelium and spores through root infection.

Management: Disease management includes seed treatment with fungicides, planting adapted cultivars, controlling weeds in summer, and rotation with non-host crops.

Fusarium diseases on soybean

Sudden death syndrome (SDS)

Pathogens: *Fusarium virguliforme.*

Symptoms: Early symptoms are chlorotic mottling and crinkling of leaves, later lead tissue between the major veins turns yellow to brown. Interveinal cholorosis and necrosis are typical symptoms.

Conditions: Diseases normally occur at cool wet weather, under reduced tillage, stress such as infection by soybean cyst nematodes (SCN).

Overwinter and Dispersal: the pathogens can over winter in crop residue and soil, and infect through roots. The pathogens can spread by soil borne hypha and spores.

Management: Disease management includes planting tolerant varieties, delaying planting date, minimizing soil compaction and preventing soil movement.

Fusarium seed, root rot and wilt

Pathogens: More than 10 *Fusarium* spp.

Symptoms: Major symptom is characterized with seed decay, and brown to black cortical decay or vascular discoloration in roots. If root rot become severe, soybean plants develop foliar symptoms including stunting yellowing, wilting and defoliation.

Conditions: Disease normally occurs at cool wet weather, reduced tillage, and stress.

Overwinter and Dispersal: the pathogens can over winter in crop residue and soil. The pathogens can spread by soil borne mycelium and spores through root infection.

Management: Disease management includes seed treatment with fungicides, minimizing soil compaction, minimizing stress and injury by herbicides, iron deficiency, and hail injury, and planting soybean when soils are warmer.

Fusarium diseases and drought

2012 was a drought year with hot and dry weather, which influence Fusarium diseases in Nebraska. Drought can impact Fusarium diseases on corn, wheat and soybean at a certain level. Fusarium stalk rot, ear rot and kernel rot of corn caused by *Fusarium verticillioides*, are ones of the most common corn diseases, which cause significant yield losses and toxin contamination under drought and high temperature. Wheat root diseases, such as Fusarium crown rot caused by *Fusarium* spp., are also more severe under dry soil conditions. The early root infection can cause severe yield reduction under high temperatures in dry soils. However, sudden death syndrome (SDS) of soybean is not favored by drought conditions.

Overall management of *Fusarium* diseases

The pathogenic Fusarium species are soil borne microbes, which can survive in soil and crop residue for a long time. Fusarium pathogens constantly exist in soil and wait for the right condition to infect plants. Many factors can lead to disease development. Plant stress can increase the incidence and severity of the diseases. When plants are under stress, such as injury by herbicides, foliar diseases, hail damage and drought, or plants in soil with unbalanced fertility in macronutrients, nitrogen and potassium; Fusarium pathogens can easily penetrate and infect the stressed plants. Compacted soil also increase Fusarium diseases, therefore, minimizing soil compaction will help drainage, improve plant root growth, and reduce Fusarium diseases. If Fusarium infected grain is used as seed, fungicide seed treatments can be used to reduce seed rot and seedling diseases caused by *Fusarium* spp. Fungicide seed treatments can also reduce buildup of the Fusarium pathogens in soil. However, seed treatment is not suitable for the control of SDS of soybean. Cultural practice such as plowing can reduce Fusarium diseases, but plowing can increase soil erosion and loss of soil moisture. Another cultural practice is crop rotation with non-host crops such as wheat/corn with soybean/alfalfa rotation. Continuous cropping should be avoided, if the Fusarium diseases are severe in field, especially in reduced or no-till cropping systems. Again, SDS of soybean cannot by controlled by crop rotation. Using tolerant cultivars with different planting dates can help to reduce losses caused by Fusarium diseases.

In summary, since there is a lack of highly resistant or tolerant cultivars to Fusarium pathogens, integrated disease management should be adopted to manage Fusarium diseases. Therefore the following management strategies could be used to reduce losses caused by *Fusarium* spp.

- Minimize stress and injury by herbicides, foliar diseases, hail damage or drought
- Optimize soil fertility level
- Minimize soil compaction
- Seed treatment
- Crop rotation
- Planting tolerant cultivars

Nitrous Oxide and Nebraska Crop Production

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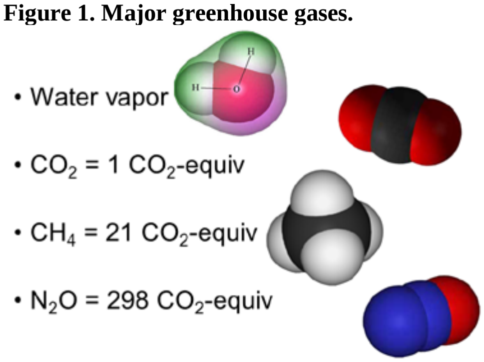
Weather variability and the implications for crop productivity are hot topics in Nebraska. Climate projections indicate sustained to increasing climate variability, with more prolonged periods of drought and an increase in severe precipitation events. As climate affects agricultural productivity, agricultural practices affect climate. Emission of nitrous oxide (N_2O) to the atmosphere is affected by agriculture. Our objective is to provide information on N_2O relative to crop production, the effects of alternative practices on N_2O emission, and current research in Nebraska.

Nitrous oxide (N_2O), together with water vapor, carbon dioxide (CO_2), and methane, is a gas that reflects heat back to earth giving a 'greenhouse effect' that prevents earth from being unbearably cold. These gases are often referred to as greenhouse or global warming gases. Water vapor is the most important of these but, unlike the others, has not increased because of human activity. Water vapor buffers against but does not eliminate the greenhouse effect of human induced increases in CO_2, CH_4, and N_2O concentrations. These gases differ in their global warming effect and are considered relative to CO_2 or as CO_2 equivalents (CO_{2e}). The CO_{2e} of N_2O is 298 to 310, depending on future time frame used. Therefore, one ton of N_2O in the troposphere equals about 300 t CO_2.

Figure 1. Major greenhouse gases.



Agriculture accounts for about 7% of total U.S. human-influenced net greenhouse gas emissions while electric power, transportation, and industry account for a total of about 81% of the emissions. About 40-50% of total global N_2O emissions are from natural ecosystems with the remaining due to human activity. Agriculture, however, accounts for about 79% and 35% of the human influenced N_2O and CH_4 emissions. In addition to its global warming potential N_2O is of concern because it is an ozone depleting gas. Agricultural N_2O emission is primarily due to the soil processes of denitrification and incomplete nitrification. Animal manure contributes less than 10% of agricultural N_2O emission and much of this is from urine-N, especially with high protein diets.

Denitrification occurs under anaerobic or low oxygen (aeration) conditions such as water logging. Denitrification is a major N loss pathway from flooded soils with nitrate (NO_3^-) reduced primarily to N_2, but also some N_2O. Both gases are emitted to the atmosphere. Denitrification is greater with higher soil NO_3^- levels, abundant decomposable carbon (fresh crop residues), poor aeration, and soil pH of 6 to 8. Dentrification is optimized at 86 F but increases rapidly as temperature rises from 36 to 77F.

Incomplete nitrification occurs under aerobic conditions where ammonium (NH_4^+) is converted to nitrite (NO_2^-) but not all nitrite is converted to nitrate with some loss as N_2O. This process of generating N_2O is less well understood than denitrification but is probably the main source of N_2O emission from Nebraska soils while denitrification is a relatively more important source in more humid areas, especially with fine texture and poorly drained soils. Incomplete nitrification as a source of N_2O is affected by the amount of NH_4^+ that undergoes nitrification and therefore by N application rate, timing of N application relative to crop N uptake, and use of nitrification inhibitors and controlled release N fertilizers. Incomplete nitrification also appears to increase as soil pH decreases and with low soil aeration.

In this paper, rates of N_2O emission are expressed in lb/ac/yr. Sometimes emissions are reported relative to yield (i.e., yield-scaled N_2O emissions) for comparison across more and less productive situations.

Research findings

In Nebraska, mean N_2O emissions measured over four years at the UNL-ARDC ranged from 3.0 to 3.8 lb/ac/yr (Table 1). Fertilizer N applied to the corn differed with cropping systems. Mean N_2O emissions were considerable even with no N applied. Losses from corn were twice those of soybean, and were more from corn following soybean than following corn. Emissions were increased by 40 to 140% with N applied at the UNL rate compared to no N applied and were greatest for continuous corn. The equivalent loss of applied N as N_2O ranged from 1.0 to 1.4%. The annual emissions of 4.2 to 5.4 equal approximately 1260 to 1590 lb/ac/yr CO_{2e}; for comparison, about 1500 lb CO_{2e} is emitted from using 75 gallon of gasoline.

In a study conducted north of East Campus in Lincoln, the 3-year average emission was 3.6 and 6.3 lb N_2O/ac/yr for continuous corn with mean N rates of 185 and 250 lb/ac/yr. The actual N_2O-N loss was equivalent to 1.2 and

1.4% of applied N for the normal and high N rate, respectively. Emission of N_2O for corn after corn was similar to corn after soybean. In this same study but for different years, N_2O emissions were found to be 3.2 times as high with an average N rate of 160 lb/ac compared to no N applied, and 2.5 times as high with 265 lb/ac N compared with the 160 lb/ac rate.

Table 1. Direct N_2O emissions with and without fertilizer N for continuous irrigated corn and irrigated and rainfed corn-soybean rotation; 2001 – 2004, UNL-ARDC.

Cropping system	Mean N rate	N_2O emission, lb/ac/yr		
	lb/ac/yr	SB	SB + corn	No N applied
Irrigated CCCC	213		5.4	2.3
Irrigated CSCS	92	2.3	5.3	2.6
Rainfed CSCS	50	1.7	4.2	3.3

Results from research on N_2O emissions are not fully consistent. The following is a synthesis of numerous studies conducted in the US and Canada.

Corn-soybean rotation compared to continuous corn

Annual emission is often more from the corn year in the corn-soybean rotation compared with continuous corn, but, overall, emission is generally less with the rotation than with continuous corn. Mean emission for the corn-soybean rotation in Iowa was about 2.2 and 7.9 lb/ac/yr for the soybean and corn years, respectively, and similar to the Nebraska emissions (Table 1).

Tillage

Tillage effect on N_2O emission varies. Emission was higher with conventional tillage compared to no-till over 3 years in Colorado, but several studies found no tillage effects on annual emissions. A summary of 15 comparisons in eastern Canada indicated twice as much N_2O emission with no-till compared to till but only 20% more with 3 clay soil site-years excluded.

Nitrogen rate

Nitrogen application rate is the single best predictor of N_2O emissions across the Corn Belt. Emission generally increases linearly or at an increasing rate with increasing N rate. Losses of N to emission have varied from 1 to 3.8% of applied N in the Corn Belt but less for the High Plains. Applying N fertilizer using the economic optimal N rate approach holds promise of reducing N_2O emissions by more than 50% relative to rates in excess of crop N uptake capacity.

Nitrogen fertilizer type and placement

Emission was greater with fertilizer N applied as anhydrous ammonia compared with UAN and least with broadcast and incorporated urea in a Minnesota study. In a related study, emission was 50% more with anhydrous ammonia compared with broadcast and incorporated urea. The greater emissions with anhydrous ammonia were attributed to incomplete nitrification due to high pH and high NO_2^- concentration during nitrification in the injection zone. Emission was also greater with anhydrous ammonia compared with calcium nitrate. In Missouri, N_2O emissions were less with strip till and deep band placement of N compared with no-till broadcast N but this effect did not occur in a Colorado study.

Inhibitors

Use of a nitrification inhibitor reduced N_2O emission by about 40% for urea surface applied to spring barley. In another study, emission of N_2O was cut by 50% for urea and UAN by treating with a combination of urease and nitrification inhibitors.

Controlled release fertilizer N

In four studies, emission were generally less with polymer coated urea (PCU) compared with uncoated: 1) emission was less with PCU compare with UAN, but was not significantly less compared with urea; 2) emission was 28% less with pre-plant application of PCU compared with split application of fertilizer N; 3) emissions was less with PCU than with urea or UAN; and 4) emission in irrigated no-till continuous corn was more than twice as much with urea compared with PCU.

Cover crops

Cover crop effects on emission have been inconsistent with no cover crop effect in Iowa or from a winter rye cover crop in Colorado.

Soil texture

The effect has been inconsistent. In eastern Canada, emission was higher for clay compared with clay loam and courser textures, but more from a sandy loam compared with a clay soil in another study in the US. The highest yield-scaled N_2O emissions have been reported on fine-textured soils in humid climates.

Manure application

The effects of manure application have been studied. 1) Emission was similar for UAN and slurry manure on a sandy loam soil but 5 times as much with slurry compared with UAN on clay soil. 2) Emission was 1.2, 0.4 and 0.3% of applied N with poultry manure, swine manure, and urea applied, respectively. 3) Emission with slurry manure was 0.7 to 2.9% of applied slurry N and 4) 1.2% in another study. 5) Emission was equivalent to 1.5% of irrigation applied swine slurry N.

Implications for N management: looking for win-win-win opportunities

Optimized N management strives to maximize profitability while avoiding excessive N loss to the environment. Losses of N of direct environmental and profitability concern are nitrate-N leaching to ground water, ammonia volatilization, N runoff to surface waters, denitrification, and N_2O emission. Research findings suggest numerous win-win-win management options that can reduce N_2O emissions per acre and per unit of production while improving profitability or at minor net cost and providing other environmental benefits (Table 2). The effect on profit cannot be estimated for all practices as it is dependent on the risk of N loss which is seldom well assessed.

Table 2. Opportunities for win-win-win solutions to N management that increase profit and/or decrease environmental harm.

Practice	Profit	NO_3^--N leaching	NH_3^+-N volatiliz.	N erosion/ runoff	N_2O emission	Denitri-fication
Rotation	Var*	Decr	Decr	Var/ Decr	Var	Decr
No-till	Var	Var	Decr	Decr/Var	Var	Var
EONR†	Incr	Decr	Decr	Decr	Decr	Decr
AA vs other	Incr	Var	Decr	Var	Incr	Var
Injected vs surface	Var	Var	Decr	Var	Var	Var
Spring vs fall	Var	Decr	Var	Decr	Var	Var
In-season N	Var	Decr	Var	Decr	Decr	Decr
Nitrification inhibitors§	Var	Decr	NoCh	NoCh	Decr	Decr
Urease inhibitors§	Var	NoCh	Decr	NoCh	NoCh	NoCh
Controlled release§	Var	Decr	Decr	Var	Decr	Decr
Cover crops	Var	Decr	NoCh	Decr	Var	Var

*Var indicates variability in the directional effect of the practice, sometimes resulting in an increase (Incr), decrease (Decr), or no change (NoCh).

†EONR Economic optimal N rate compared with a higher rate.

§ The effect of inhibitors and controlled release fertilizers greatly depend on the risk of N loss for particular situations with N savings possibly sufficient in high risk situations to pay the added cost but probably insufficient in lower risk situations.

On-going N_2O emission research in Nebraska

USDA-ARS

The ARS-Nebraska unit has several studies of N_2O emission that are part of regional or national assessments including: 1) long term studies at the ARDC (rainfed and irrigated continuous corn studies, and a rainfed crop rotation study), 2) a long-term tillage study at Rogers Memorial Farm, 3) irrigated continuous corn at SCAL, and 4) two rainfed studies of perennial grasses as biofuel feedstock.

Effects of N management practices

Three years of field work have been completed to determine the effects of N management practices on N_2O emissions for corn and grain sorghum following soybean. The N treatments include N rate and application practice: injected band compared to broadcast surface applied, pre-plant compared with split-application with side-dress or fertigation, and use of inhibitors and PCU. Another study recently initiated in northeast Nebraska is examining the effects of N rate on N_2O emissions from a long-term cropping system trial.

Carbon sequestration and high yield studies

These studies now have yielded >10 years of data. The C sequestration study monitors greenhouse gas emissions in >100 acre fields for three cropping systems. The high yield study evaluates high corn and soybean yield practices. Some results were reported above.

Stover Harvest through Grazing and Baling and the Effects on Soil Properties

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Introduction

With extreme drought conditions persisting throughout much of Nebraska in 2012, there was a growing shortage of forages and pasture for beef production. Because of this there was an increased need for using corn stalks (or corn residue) as cattle feed. Corn residue removal, through grazing or baling, is widely practiced in Nebraska for a variety of reasons. However, the recent drought piqued interest about this practice and had many producers considering it for the first time. Corn stalks are an abundant and desirable feed resource. Grazing corn stalks with beef cows results in good cow performance and is an inexpensive winter feed. Baled corn stalks are a versatile feed that can work well in many situations, especially when combined with ethanol co-products. Crop residue is a valuable resource in terms of grazing and bailing, but it is also a valuable resource when returned to the soil. It is important that producers understand the importance of crop residue in terms of soil quality, and how removal can affect soil properties

Nutrient Cycling

Research has shown that crop residue is directly related to characteristics beneficial to soil quality and crop yields including; nutrient cycling, soil organic matter (SOM), and soil organic carbon (SOC) (Blanco-Canqui and Lal, 2009a). Production practices that remove crop residue deplete SOM and SOC pools over time. However, there is value in crop residue beyond soil quality (such as source stocks for bio-fuels and for animal feed) and finding a balance of what can be removed from the field without detrimental environmental effects is an important agronomic research focus. Benjamin et al. (2010) found that irrigated continuous corn can provide corn residue in excess of what is needed to maintain adequate SOM and SOC levels, suggesting that this residue could be harvested for other uses.

Blanco-Canqui and Lal (2009b) suggest that only about 25% of the corn residue might be available for removal, and Blanco-Canqui (2010) states that excessive residue removal (≥ 50%) adversely affects soil, environmental quality, and crop yields.

Removal of crop residue also reduces soil fertility because residue is an important reservoir of essential macro and micro-nutrient pools and crop residue recycles SOM. Rate of residue removal, rate of residue decomposition, residue quality, rate of fertilizer applied, soil characteristics, and climate all affect the amount of nutrients depleted from the soil when residue is removed (Blanco-Canqui and Lal, 2009a).

Crop residue removal often impacts N pools more than other nutrient pools (Blanco-Canqui and Lal, 2009a. Fixen (2007) estimated that crop residue removal reduces N pools by 20% in the U.S. Corn Belt. Blanco-Canqui et al., (2009b) found that total residue removal reduced the N pool by 732 lb/ac over a four-year period in a silt loam soil.

It is a common practice in areas of the Central and Western Great Plains for producers to graze cattle on corn residue after harvest or to collect corn residue and bale it for forage. These two methods remove large quantities of crop residue for value-added purposes. However, the effects of residue removal by grazing and/or baling on soil nutrients are largely unknown. Introducing cattle to the system also brings other variables into play. Nyiraneza et al. (2009) found that cattle manure applied to soils with low residue production increased water-stable aggregates, potentially mineralizable N, and soil nitrate levels. This suggests that the effects on soil nutrient cycling through the removal of corn residue by grazing and baling may be offset somewhat by manure placed back into the system. Potential increased bulk density and soil aggregate destruction by hoof traffic may also have an effect on soil quality.

Soil Bulk Density, Aggregation, and Water Infiltration

Soil physical properties such as bulk density and aggregation dictate the water infiltration characteristics of the soil. Crop residue management affects surface soil physical properties important to water capture and infiltration (Shaver et al., 2001, 2003). Management practices that minimally disturb the soil and produce, return, and leave more residue biomass on the soil surface have the potential to decrease soil bulk density and increase infiltration in the soil over time. Bulk density is an important soil property because it is directly related to soil porosity, which in turn affects water infiltration. Systems that produce and return more crop residue to the soil surface should reduce its bulk density because under no-till conditions the residue accumulates in the surface soil.

Soil compaction is often cited as a reason for not grazing. A multi-year study conducted in Iowa (Clark et. al., 2001) measured the yields of soybeans when soybeans were planted in a crop rotation the year following grazing of corn residue. These researchers measured characteristics such as soil bulk density, penetration resistance, aggregate stability, roughness, texture and type as well as post emergence soybean plant density and yield. Grazing did not affect aggregate stability or soil bulk density, but it did increase soil penetration resistance when grazing occurred during months when the ground was not frozen. Soil surface roughness was also affected by grazing, but the results were variable and not consistent from year to year. In spite of these effects, soybean plant densities were not affected nor were soybean yields in fields farmed with conventional tillage. These researchers recommended utilization of corn residue as a feed resource and dismissed concerns about detrimental effects on soil physical properties and subsequent crop productivity, especially if grazing is restricted to periods when the soil is frozen or if conventional tillage is applied to the field.

Work in Nebraska investigating the effects of grazing corn residue in the spring (e.g. when the ground was not frozen) farmed under ridge-till conditions suggests it is not detrimental to subsequent corn yields (Wilson et. al., 2003). While the existing research suggests corn residue removal by grazing is not detrimental to subsequent productivity and sustainability, the body of research is small and suggests the potential for interaction with multiple factors such as tillage practices and soil type.

Aggregation is an important soil physical property because it increases water infiltration, decreases wind and water erosion, and increases crop yield. Aggregation is affected by many factors, but most importantly by organic matter (from crop residue and roots) and soil texture. Aggregation is also a dynamic factor that is reduced by tillage. Increasing aggregation is important because of its effects on bulk density, porosity, and subsequently, infiltration of water into the soil, and water use efficiency of the system. It is also important in decreasing soil erosion. These factors are important to crop production and sustainability.

While crop residue directly affects soil properties such as bulk density, infiltration, and aggregation, the effects of corn residue removal by grazing and baling on soil properties are less clear. The foot traffic by the cattle combined with the residue removal could have a detrimental impact on soil physical properties that affect water infiltration by increasing bulk density and breaking down soil structure.

Water Evaporation

Surface residue acts as a barrier to minimize water evaporation. By removing this barrier through grazing and/or baling the potential for water loss increases because soil temperatures are increased. This can be a big issue in dryland cropping systems is the semi-arid western portion of NE. In drought conditions this issue is magnified. In many cases residue cover and related soil water savings can be the difference between a productive crop and no crop in the semi-arid west and this may become an important issue in eastern NE under drought conditions.

Residue Removal Considerations

There are several factors that should be considered when adopting corn residue removal practices, and some of which are specific to drought conditions. Generally, corn residue can be advantageously harvested from most corn fields in Nebraska without concern for undesirable consequences. Grazing and baling are different situations. Grazing corn stalks removes much less residue than does baling. Cows preferentially eat leaves and husks which are a fraction of the total residue. Responsible grazing is a good option for the extreme majority of corn acres in Nebraska. Baling residue produced on most fields can also be sustainably accomplished in most cases. Some factors to consider include:

- Producers should asses the suitability of the land to handle residue removal. Crop residue is a valuable resource in terms of soil conservation and soil quality. If the land is highly erodible corn residue should not be removed as this will increase the potential for erosion.

- Retaining adequate levels of corn residue is important for subsequent crops. The residue is vital for nutrient cycling, soil organic matter, soil water retention (minimizes evaporation), and soil structure (maximizes water infiltration). If large percentages of residue are removed crop yields in subsequent years may be adversely affected, especially during drought. Research is being conducted at UNL to determine acceptable removal rates; however, we do not have set guidelines yet. Currently we think that removal rates of 50% are acceptable on irrigated ground, however, this is likely site specific and will depend on how much residue is available to begin with. If the field has never been grazed more removal may be acceptable than on a field that is grazed annually.

- Geographic location should be considered. Eastern and western Nebraska have different climatic conditions. Light to moderate grazing may be acceptable on dryland corn in eastern Nebraska, but we generally do not recommend grazing on dryland farms in western Nebraska due to the significantly lower amounts of residue produced. During drought conditions grazing may not be appropriate on eastern Nebraska dryland operations either, since this year dryland corn in eastern Nebraska may look a lot like dryland corn in western Nebraska in 'normal' years.

- Leaving more crop residue on the soil decreases the potential for water loss from evaporation and runoff. If this drought is a one year occurrence then this may not be a big issue. However, if this is the beginning of a longer drought cycle it may be prudent to plan for the future. By leaving as much residue as possible, producers give themselves the best conditions for next year's crop. Also, the drought may reduce the amount of crop residue produced this year. Corn heights were shorter this year compared to non-drought years meaning there may be less residue overall. Therefore, we may want to remove less than in a typical year to maintain the status quo.

- Economics must be considered as well. While money is saved by using corn residue compared with other cattle feed, the corn residue itself has value, especially in terms of nutrients added to the soil, and water savings. University of Nebraska Nebguide G1846 is a valuable resource to help determine the economics and soil quality/erosion issues associated with corn residue removal and Nebguide G2000 is a good resource for determining water savings issues related to residue removal. Additionally, UNL EC 711 is a decision support tool bailing corn residue and UNL EC 290 is a decision support tool for grazing corn stalks.

Summary

Corn residue is a valuable resource available to crop and cattle producers which can be suitably utilized. Even during drought conditions responsible crop residue removal is appropriate and can help feed cattle in tough times. However, it is also important to be reasonable and think long term. The beneficial soil properties related to crop residue take many years to develop. This should be taken into account when deciding how much residue to remove.

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Weed Science Update 2013

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Corn Herbicides

Anthem™ ATZ [pyroxasulfone + fluthiacet + atrazine]. Anthem ATZ is a new premix from FMC for pre-emergence or early post-emergence control of annual grasses and some small seeded broadleaf weeds in corn. MOA: Pyroxasulfone is a seedling growth inhibitor (Group 15), fluthiacet is a PPO inhibitor (Group 14) and atrazine is a PSII inhibitor (Group 5). RUP. EPA Reg. No. 279-3449.

Armezon™ [topramezone (2,8 lb ai/gal)]. Armezon is a post-emergence herbicide from BASF for control of emerged broadleaf and grass weeds in field corn, popcorn and sweet corn. The recommended rate is 0.75 fl oz/A per growing season. It can be applied up to 45 days prior to corn harvest. Topramezone is a hppd-inhibitor (Group 27) EPA Reg. No. 7969-262.

Instigate™ [rimsulfuron (4.17%) + mesotrione (41.67%)]. Instigate is a new premix from DuPont for pre-plant and pre-emergence control of broadleaf and grass weeds in corn. It can be applied up to 14 days prior to planting or before corn emergence. It can be applied within a rate range of 5.25 to 7 oz/A before corn emergence. Group 2 and 27. EPA Reg. No. 352-873.

Lexar® EZ [S-metolachlor (1.74 lb ai/gal) + Atrazine (1.74 lb ai/gal) + mesotrione (0.224 lb ai/gal)]. **Lumax EZ** [S-metolachlor (2.49 lb ai/gal) + Atrazine (0.935 lb ai/gal) + mesotrione (0.249 lb ai/gal)]. Lexar EZ and Lumax EZ are Syngenta products Syngenta for pre-emergence control of annual grasses and broadleaf weeds in corn and grain sorghum. Group 14, 5 and 27. RUP. EPA Reg. No. 100-1414 for Lexar EZ and 100-1442 for Lumax EZ.

Parallel® Plus [atrazine (2.8 lb ai/gal) + metolachlor (2.7 lb ai/gal)]. Parallel Plus is a premix of atrazine and metolachlor from MANA for control of annual grasses and broadleaf weeds in corn. It can be applied pre-plant or pre-emergence. If a post-emergence treatment is required, the total atrazine applied may not exceed 3.57 qts of Parellel Plus/A in a season. Group 5 and 14. RUP. EPA Reg. No. 66222-132.

Realm™Q [rimsulfuron (7.5%) + mesotrione (31.25%)]. Realm Q is a new premix herbicide from DuPont for post-emergence use in field corn. It contains a safener (isoxadifen) and may be applied at 4 oz/A to emerged corn through 20” or V7 corn, whichever is more restrictive. Realm Q provides selective post-emergence control of annual grasses and broadleaf weeds. It may be tank mixed with glyphosate when used in glyphosate-tolerant corn or glufosinate in LibertyLink corn. MOA: rimsulfuron is an ALS inhibitor (Group 2) and mesotrione is a HPPD inhibitor (Group 27). EPA Reg. No. 352-837.

Zemax™ [S-metolachlor (3.34 lb ai/gal) + mesotrione (0.33 lb ai/gal)]. Zemax is a Syngenta product contains the active ingredients of Callisto (mesotrione) and Dual II Magnum (S-metolachlor). The double-mode-of-action herbicide can be applied from 14 days early pre-plant up to 30-inch corn. Zemax is also used in grain sorghum for pre-emergence control of many annual grass and broadleaf weeds. Group 15 and 27. EPA Reg. No. 100-1410.

Zidua™ [pyroxasulfone (85%)]. Zidua is an herbicide from BASF for pre-emergence control of annual grasses and some small seeded broadleaf weeds in corn. MOA: Pyroxasulfone is a seedling growth inhibitor. Application rates of Zidua may vary depending on soil texture. Group 15. EPA Reg. No. 7969-338.

Sorghum Herbicides

Huskie™ [pyrasulfotole (0.31 lb ai/gal) + bromoxynil (1.75 lb ai/gal)]. Huskie received a supplemental label for use in grain and forage sorghum. It may be applied post-emergence from 3 leaf to 12” tall sorghum at 12.8-16 oz/A. It is also acceptable for use in seed production. Group 27 and 5. EPA Reg. No. 264-1023.

Soybean Herbicides

Flexstar GT 3.5 [fomesafen (0.56 lb ai/gal) + glyphosate (2.26 lb ai/gal)]. Flexstar GT is a new premix herbicide from Syngenta for pre- and post-emergence control of certain grasses, broadleaf, and sedge weeds in soybean. A maximum of 3.5 pts/A may be applied in alternate years. MOA: fomesafen is a PPO inhibitor (Group 14) and glyphosate is an ESPS inhibitor (Group 9). EPA Reg. No. 100-1385.

Liberty® 280 SL [glufosinate-ammonium (2.34 lb ai/gal)]. Ignite received a supplemental label allowing for a single in-crop application up to 36 oz/A in LibertyLink soybeans. The maximum total use of Ignite is 65 oz/a in a growing season. The standard recommended rate is 22-29 oz/a from emergence, up to, but not including, bloom. Group 10. EPA Reg. No. 264-829.

OpTill® PRO [saflufenacil (17.8%) + imazethapyr (32%)] + [dimethenamid-P (6 lb ai/gal)]. It is one of the

Kixor based herbicides from the BASF. This co-pack features three modes of action Sharpen, Pursuit and Outlook herbicides (Group 2, 14, and 15). It provides both contact burndown and residual pre-emergence weed control in soybean. Group 14, 2 and 15. EPA Reg. No. 7969-332.

Herbicides Labeled for Use in Multiple Crops

Anthem™ [pyroxasulfone + fluthiacet]. Anthem is a new premix from FMC for pre-emergence or early post-emergence control of annual grasses and some small seeded broadleaf weeds in corn and soybean. MOA: Pyroxasulfone is a seedling growth inhibitor (Group 15) and fluthiacet is a PPO inhibitor (Group 14). EPA Reg. No.279-3450.

Autumn Super™ [iodosulfuron-methyl (6%) + Thiencarbazone-methyl (45%)]. Autumn Super is a herbicide from Bayer for burndown of existing vehetation 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. Up to 0.5 oz/A in a year may be applied. Idosulfuron and thiencarbazone are ALS inhibiting (Group 2) herbicides. EPA Reg. No. 264-1134.

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. Group 14 and 15. EPA Reg. No. 63588-93-59639.

Pyroxasulfone is a new herbicide active ingredient that will be marketed in Anthem, Fierce and Zidua herbicides. It is a preemergence, seedling growth inhibitor. Users should expect performance and control of a similar weed spectrum as obtained with other seedling growth inhibitors such as metolachlor, acetochlor, and dimthenamid-P (small seeded broadleaves and most annual grasses).

Trust® [trifluralin (4 lb ai/gal)]. Trust® is a trifluralin product from Winfield Solutions. It is labeled for pre-emergence control of annual grasses and some small seeded broadleaf weeds in multiple crops. MoA: Trifluralin is a seedling growth inhibitor. Group 3. EPA Reg. No. 1381-146.

Warrant [acetochlor (3 lb ai/gal)]. Warrant is an encapsulated formulation of acetochlor from Monsanto. Group 15. EPA Reg. No. 524-591.

Soybeans: Warrant herbicide can be applied pre-plant, at-planting or pre-emergence to soybeans at 1.25 to 2 qts/A. It can also applied post-emergence to glyphosate-resistant soybean in a tank mix with glyphosate.

Corn: It is now labeled for post-emergence application to field corn but it has only residual activity; therefore, weeds emerged at the time of application will not be controlled by this herbicide if applied alone. It can be applied from seedling emergence until the corn reaches 30 inches in height. The application rates are depending on soil texture ranging from 1.5 to 2.75 qts/A. Do not exceed 4 qts/A per season.

Herbicides in other Crops and Non-Crop Areas

Aminocyclopyrachlor is a new synthetic auxin herbicide active ingredient developed by DuPont. It controls many annual and perennial broadleaf species and some woody species. It is a component in Perspective, Streamline and Viewpoint.

Perspective™ [aminocyclopyrachlor (39.5%) + chlorsulfuron (15.8%)]. Perspective is a new premix from DuPont. It is for use in non-crop areas and controls many annual and perennial broadleaf species and some woody species. MOA: aminocyclopyrachlor is a synthetic auxin and chlorsulfuron is an ALS inhibitor. Group 4 and 2. EPA Reg. No. 352-846.

Streamline™ [aminocyclopyrachlor (39.5%) + metsulfuron (12.6%)]. Streamline is a new premix from DuPont. It is for use in non-crop areas and controls many annual and perennial broadleaf species and some woody species. MoA: aminocyclopyrachlor is a synthetic auxin and metsulfuron is an ALS inhibitor. Group 4 and 2. EPA Reg. No. 352-848.

Viewpoint™ [imazapyr (31.6%) + aminocyclopyrachlor (22.8%) + metsulfuron (7.3%)]. Viewpoint is a new premix from DuPont. It is for use in non-crop areas and controls many annual and perennial broadleaf species and some woody species. MoA: aminocyclopyrachlor is a synthetic auxin and metsulfuron and imazapyr are ALS inhibitors. Group 4 and 2. EPA Reg. No. 352-847.

Mobile Apps in Weed Science

A new smartphone application designed to estimate spray quality is now available from the University of Nebraska-Lincoln.

The Pesticide Application Technology Group at the University of Nebraska-Lincoln's West Central Research and Extension Center (WCREC) in North Platte, NE, is dedicated to investigating aspects of pesticide applications, with emphasis on efficacy and drift. Researchers are utilizing new technologies, including laser diffraction systems in a static chamber, a low-speed wind tunnel and a high-speed wind tunnel, to explore application methods and technologies, such as nozzle selection, adjuvant chemistry, sprayer set up, and wind speed. The goal is to understand how these factors and others interact to influence spray quality, pesticide efficacy and drift.

This application will allow custom applicators and growers the ability to easily predict the spray quality of their application before it's applied. Once installed, a user follows guided steps by first selecting the type of nozzle they are using. Once a nozzle is selected, the user inputs the spray angle (110^{o}), the orifice size, pressure and the solution from predetermined menu options. Once the data is entered, the user will get customized output for the DV_{10}, DV_{50}, DV_{90} and an overall classification of spray quality (fine, medium, course, extremely course, etc). The user will be able to save these results or email them to another person or company. The app will give the droplet size spectrum for the various input parameters which allow an applicator to have a sense of the potential of drift potential.

The application was sponsored in part by the Nebraska Soybean Board and is free to download on iPhone and Android mobile devices. In iTunes a search of the term "ground spray" should result in a link to the application. As the research program moves forward, more data points will be added such that any ground applicator can have access to the most up to date information on spray quality.

Impact of Carrier Rate on Herbicide Performance

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Introduction

Glyphosate-resistant weeds are becoming more prevalent due to increasing selection pressure from the increase in acres of glyphosate-tolerant crops which has forced many growers to use other herbicides. Herbicide programs that relied primarily on glyphosate for weed control often used carrier rates at low as 7.5 gallons per acre (GPA). These alternative herbicides often require a higher carrier volume when compared to glyphosate which can be burdensome to the applicator. Additionally, there is growing concern about off-target movement of pesticides and what can be done to mitigate pesticide drift.

Objective

The objective of this study was to measure the influence of carrier volume on droplet size and weed control using four different postemergence herbicides commonly used for weed control in soybeans that use different herbicide modes-of-action. Field studies were set up at the Soybean Management Field Day sites in 2012 to demonstrate the effect of carrier rate.

Methodology

RoundUp PowerMax (glyphosate at 32 oz/ac), Liberty (glufosinate at 22 oz/ac), Cobra (lactofen at 12.5 oz/ac), and Weedone (2,4-D at 32 oz/ac) were applied at different carrier volumes. The four herbicides are an EPSP synthase inhibitor, glutamine synthase inhibitor, PPO inhibitor, and synthetic auxin, respectively. The four herbicides were each sprayed with appropriate adjuvants and were each applied at five carrier volumes (5, 7.5, 10, 15, and 20 GPA). Droplet size of each treatment was evaluated at the wind tunnel facility in North Platte, NE, using a diffraction laser. Weed control ratings were recorded at three field sites located across Nebraska (Lexington, O'Neill, Platte Center) at 14 and 28 days after treatment. The sprayed plots were 5ft wide and 15ft long. Planted across each plot were rows of non-herbicide resistant corn and soybean, velvetleaf, quinoa, grain-type amaranth, and flax. Treatments were replicated four times at each site.

Results

Generally, the performance of systemic herbicides (glyphosate and 2,4-D) on weed control was not influenced by different carrier volumes. The abnormal behavior of the 10 GPA treatment on amaranth was likely because of the droplet size (and should be noted that it was not statistically different despite the 20% difference in efficacy). That treatment was applied with an XR11001 nozzle at 40 PSI which would produce a high amount of fine droplets when compared to the other treatments. These small droplets are more prone to drift and would potentially evaporate quicker limiting absorption by the plant. It is also partially understandable because of variability of glyphosate activity in general on the amaranth population. An interaction between the effect of carrier volume and the contact herbicides glufosinate and lactofen was observed. Herbicide efficacy in controlling velvetleaf increased from 52 and 37%, respectively, for the two contact herbicides, to 83 and 85% as carrier volume increased from 5 to 20 GPA. Control of the amaranth by glufosinate and lactofen increased from 56 and 81% to 80 and 100%, respectively. This is not too surprising since the Cobra and Liberty labels recommend 15 and 20 GPA, respectively. These results emphasize the need for producers and applicators to read the herbicide label. As applicators starting using products other than glyphosate for weed control, it will be important to understand the products that are being applied and what can be done to maximize the efficacy of those products.

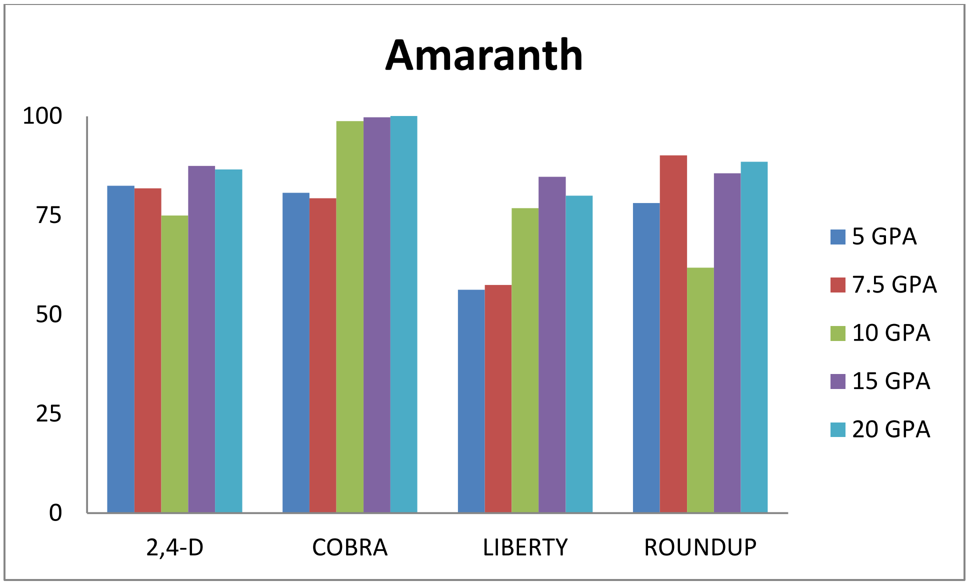


Figure 1. Visual ratings of 2,4-D, Cobra, Liberty and Roundup PowerMax injury on a grain type amaranth at 5, 7.5, 10, 15, and 20 GPA.

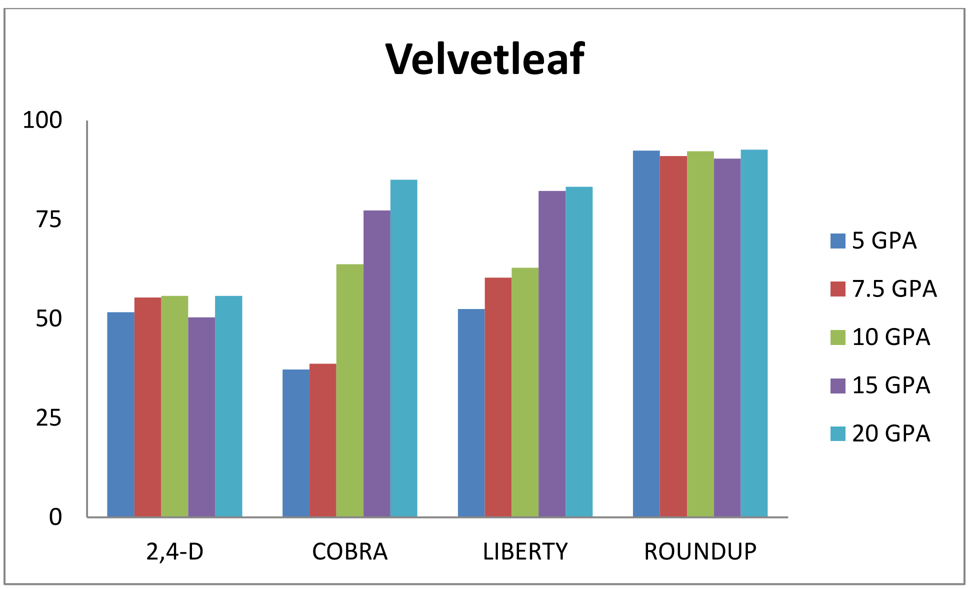


Figure 2. Visual ratings of 2,4-D, Cobra, Liberty and Roundup PowerMax injury on a velvetleaf at 5, 7.5, 10, 15, and 20 GPA.

Glyphosate-Resistant Kochia

Robert Wilson, Extension Weed Specialist
Greg Kruger, Extension Cropping Systems Specialist

Kochia has been a nemesis to producers in the west for many years. Just when growers think they have developed a new control strategy the weed adapts and it is back to the drawing board. Kochia is a successful weed because it can emerge early in the spring, has a rapid growth rate, can tolerate drought and salinity, produces abundant seed, and can distribute the seed with the aid of wind by tumbling across the landscape. In Nebraska kochia is more prevalent in the western half of the state where the plant has a competitive advantage. In central and eastern Nebraska other weed species such as waterhemp, ragweeds, velvetleaf, and annual grasses are better crop competitors than kochia. With that said, kochia has been reported as a problematic weed further east in 2012 than in past years.

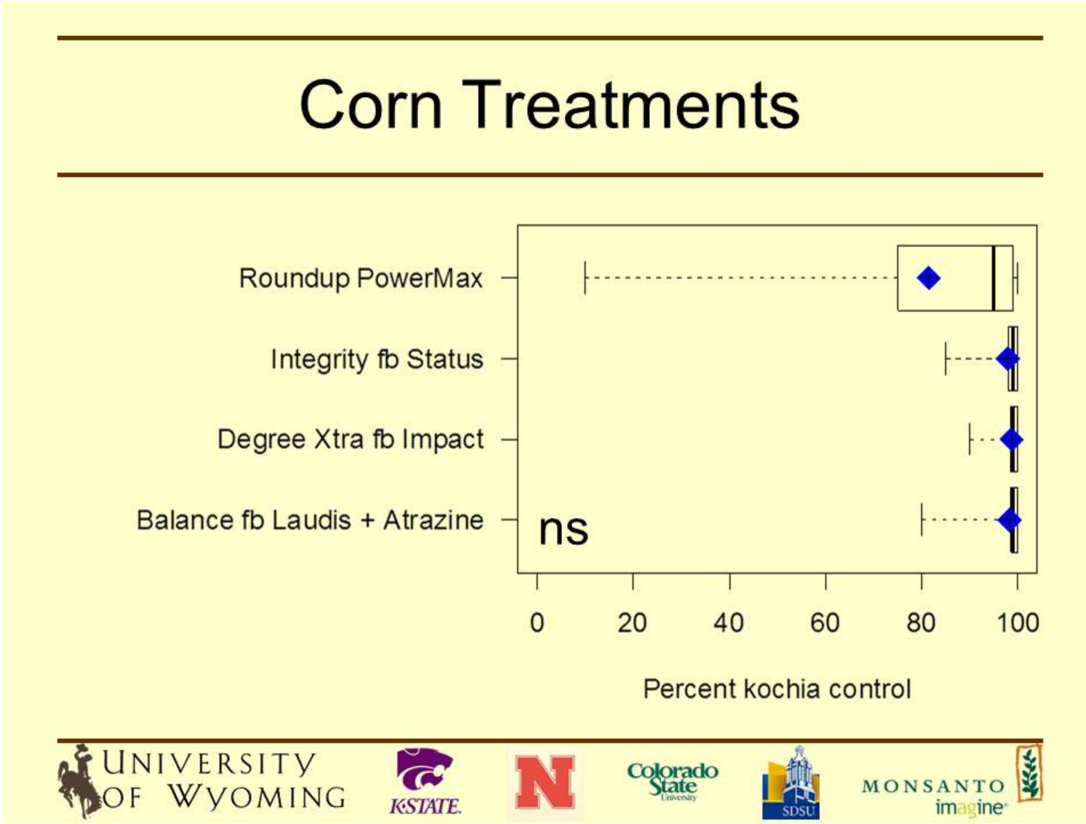
Researchers have been studying the ecology of kochia to enhance the effectiveness of control strategies. Kochia emergence starts as early as mid-March in central Kansas and by early April begins to emerge in Nebraska and Wyoming. Most of the seed (70 to 95%) produced the previous year emerges during the first 2 weeks in the spring. Emergence slows but some plants continue to emerge as late as July. Kochia seed viability is short, 1 to 2 years compared to pigweed and common lambsquarters which can remain viable in the soil for 10 or more years. Burial of seed in the soil to depths of 4 inches does not reduce viability but can significantly reduce germination. Kochia seed viability declines rapidly the first year after production with only 5 to 10% of the seed viable the second year after production. The control implications of these studies suggest the first flush of kochia needs to be controlled early in the growing season and later emerging plants will require extended periods of control. Using herbicides with soil residual can extend periods of weed control. In addition current farming practices appear to be selecting for later and more prolonged emergence of kochia. If kochia can be prevented from producing seed the soil seedbank can be depleted in several years.

In situations where applicators are relying solely on postemergence herbicides for weed control (which is not recommended) or where they are using residual herbicides plus postemergence herbicides for burndown applications, it is imperative to manage kochia in a timely manner. Kochia has the ability to grow rapidly under favorable environmental conditions. Furthermore, kochia has a very small leaf area making it difficult to get coverage and ultimately effective control with many postemergence herbicides. As the weed gets larger, the effectiveness of postemergence herbicides diminish.

Kochia in Nebraska has developed resistance to five major herbicide families: triazines⑤ (atrazine, metribuzin), imidazolinones② (Pursuit, Raptor), sulfonylureas② (Ally, Permit, UpBeet), growth regulators④ (2,4-D, dicamba), and EPSP synthetase inhibitors⑨ (glyphosate). Because of this range in resistance kochia may carry double or triple sacks of herbicide-resistant genes. Research results suggest if you have resistance to glyphosate⑨ you probably also have resistance to imidazolinones and sulfonylureas②, but kochia plants have generally been susceptible to atrazine⑤ and dicamba④.

Kochia is a strong competitor in both rainfed and irrigated crops. A typical scenario with center pivot irrigation is to have an irrigated crop in the center and rainfed winter wheat or fallow on the pivot corners. In rainfed sites corn or soybeans are included in a rotation with winter wheat and fallow. Kochia control must be implemented in all crops and fallow. Kochia control can come from tillage, crop competition, and herbicides. Researchers from five states used their collective experience to develop best management practices for kochia control in corn, soybeans, sugarbeet, wheat, and fallow. Kochia control was greatest in corn (96%), followed by soybean (85%), fallow (83%), wheat (80%), and sugarbeet (32%). The results of these studies are presented in the following figures.

Effective kochia control relies on several weed management principles: manage weeds when they are small, rotate herbicide families, utilize herbicides with soil residuals, tankmix herbicides with different modes of action, don't use glyphosate alone, add diversity to cropping systems, and take advantage of tillage.


Corn Treatments
Roundup PowerMax
Integrity fb Status
Degree Xtra fb Impact
Balance fb Laudis + Atrazine
ns
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UNIVERSITY OF WYOMING
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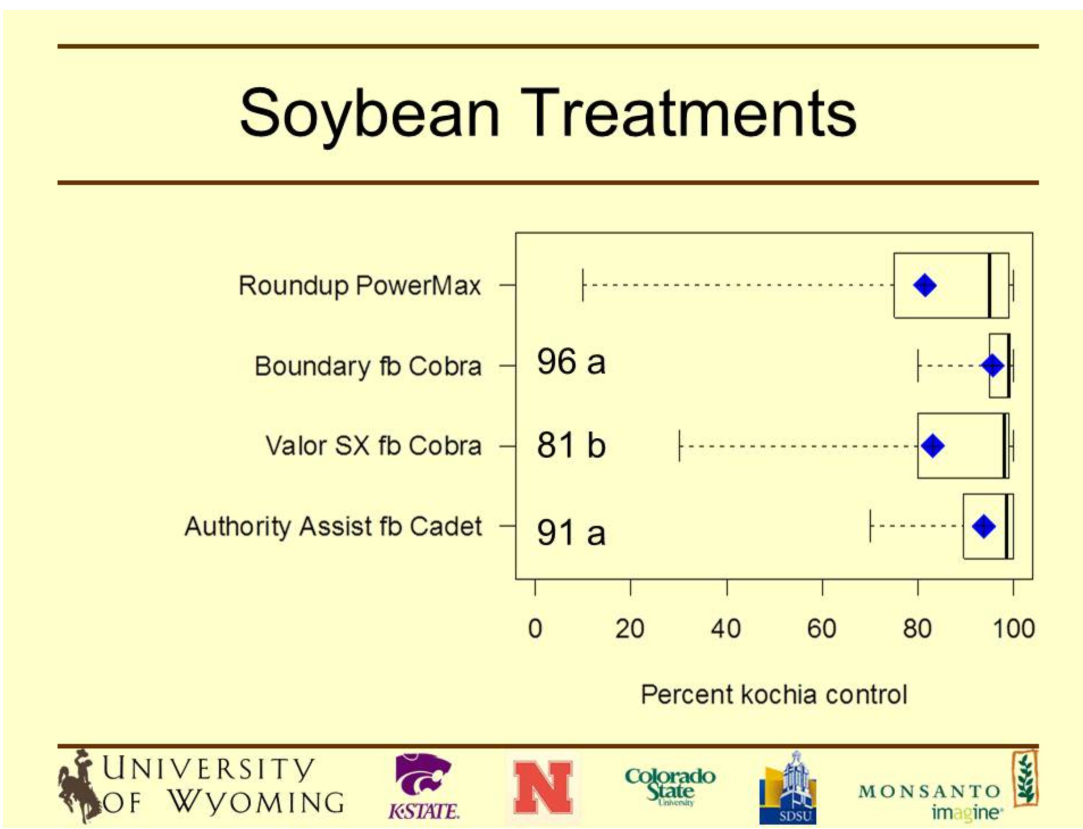
Soybean Treatments
Roundup PowerMax
Boundary fb Cobra
Valor SX fb Cobra
Authority Assist fb Cadet
96 a
81 b
91 a
0
20
40
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80
100
Percent kochia control
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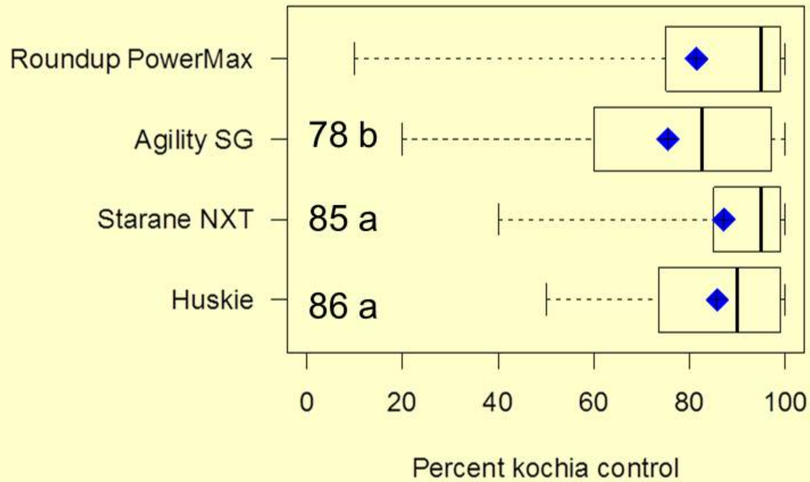
Wheat Treatments



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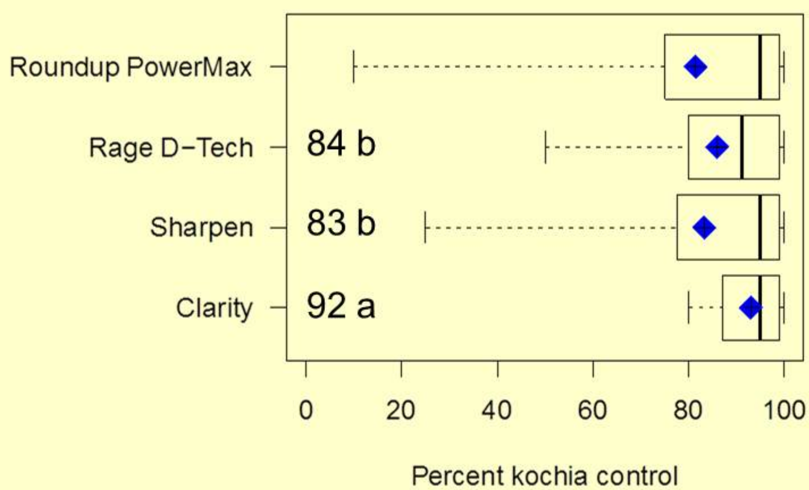
Fallow Treatments



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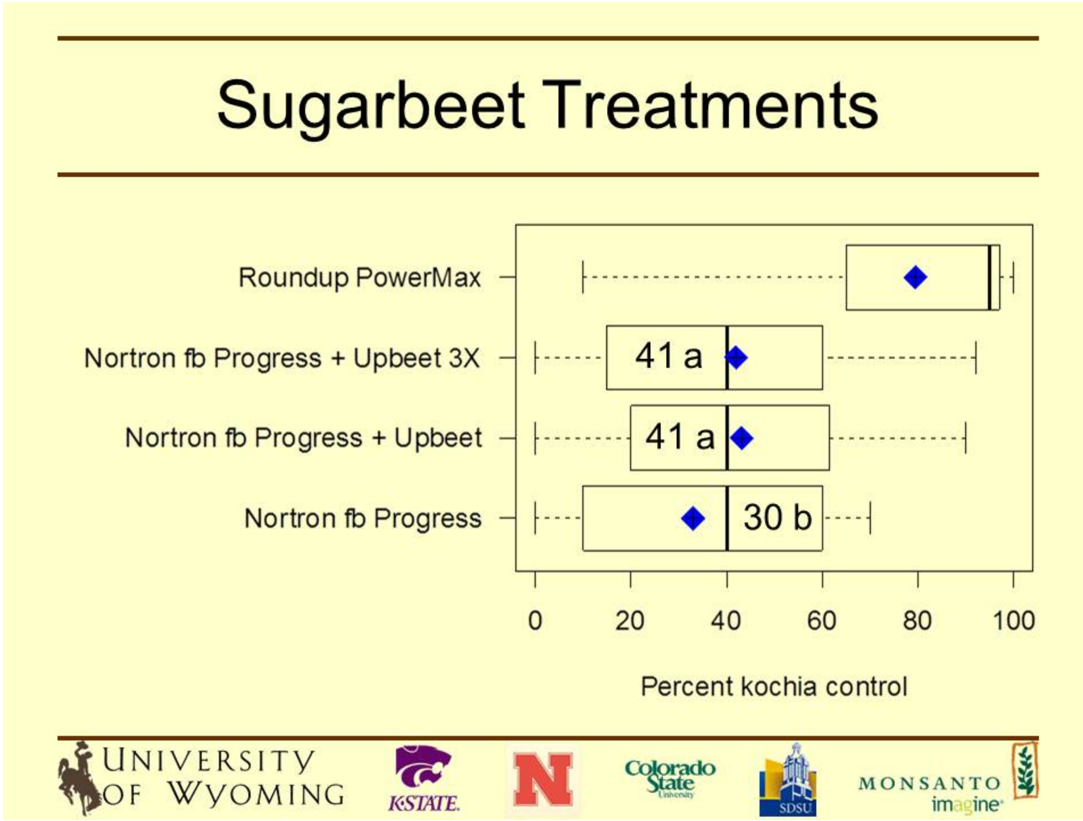
Sugarbeet Treatments
Roundup PowerMax
Nortron fb Progress + Upbeet 3X
Nortron fb Progress + Upbeet
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41 a
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Percent kochia control
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K-STATE
Colorado State University
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Glyphosate-Resistant Giant Ragweed in Nebraska

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Extensive use of glyphosate and Roundup Ready (RR) crops has changed farming practices over the last 15 years. In 2008, more than 155 million cropland acres were treated with glyphosate in the United States. Soybeans were the first RR crop introduced in 1996; current RR crops registered for use and sale include soybean, corn, canola, alfalfa, cotton, and sugarbeets. Glyphosate and RR crops gained popularity because they simplified weed management approach; broad spectrum weed control coupled with low weed control cost and maximum crop safety. But the threat of developing weed resistance is now questioning the long-term use of glyphosate and RR crops. In the last three decades, growers overwhelmingly continued to use glyphosate as the only herbicide for weed control, creating increased level of selection pressure on weed populations and evolving glyphosate-resistant (GR) weeds.

In 1998, rigid ryegrass was the first weed species reported to be GR (Powles et al. 1998). Since then, 21 GR weeds have been confirmed worldwide, 13 of them in the United States including palmer amaranth, spiny amaranth, common waterhemp, common ragweed, giant ragweed, hairy fleabane, horseweed, junglerice, goosegrass, kochia, Italian ryegrass, rigid ryegrass, poa annua, and johnsongrass (Vencill et al. 2012; Heap 2012). Compared to ALS and triazine-resistant biotypes the total number of glyphosate-resistant weed species is low, but this number is increasing at an alarming rate primarily because of the heavy reliance of glyphosate use on glyphosate tolerant crops for both burndown and postemergence weed control. From these facts, it is evident that weed resistance to herbicides will be the number one challenge farmers will face in the future.

Giant ragweed is an early emerging summer annual commonly found throughout the row crop production system in the Midwest and eastern Corn Belt. Although giant ragweed has been around for many years, it has become a major weed in the last two decades. One of the reasons for its increased prevalence is the rapid rate at which evolution of herbicide resistance occurred in this weed species (Owen and Zelaya 2007; Patzoldt and Tranel 2002). Before the advent of RR soybeans, ALS-inhibiting herbicides were widely used for giant ragweed control. Extensive use led to the development of ALS-resistant giant ragweed by 1996. With the widespread adoption of RR crops glyphosate has been continuously used for weed control, which has selected giant ragweed to glyphosate resistance as well. Currently, giant ragweed populations resistant to glyphosate (EPSP Synthase inhibitors–Group 9 herbicides) and ALS- (Acetolactate Synthase inhibitors–Group 2 herbicides) inhibiting herbicides have been identified. There has been confirmed report of a two way multiple resistance in giant ragweed to glyphosate and ALS-inhibiting herbicides in Ohio and Minnesota.

GR giant ragweed biotypes have been reported in 11 U.S. States and in Ontario, Canada (Heap 2012). In Nebraska, giant ragweed biotypes were found to be glyphosate-resistant in 2010. Greenhouse bioassays conducted in fall 2011 identified glyphosate resistance in giant ragweed populations in Butler, Nemaha, Richardson, and Washington counties. The current suspected GR giant ragweed population was found in a corn and soybean crop production system with history of glyphosate use for weed management in David City, NE. Therefore, field studies were conducted to determine and characterize the level of glyphosate resistance and to evaluate control of GR giant ragweed population with alternative herbicides. Additionally, separate field and greenhouse trials were conducted to evaluate burndown efficacy of some commonly used preemergence (PRE) herbicides in corn and soybeans, respectively, for GR giant ragweed control.

Giant ragweed resistance to glyphosate

Field experiments were conducted in 2012 in David City, NE at a site with suspected GR giant ragweed population. Dose response studies were conducted with five glyphosate rates (0, 1X, 4X, 8X, and 16X) applied postemergence (POST) to 4” and 8” tall giant ragweed. Weed control was assessed visually at 21 days after treatment (DAT) using a scale ranging from 0 (no weed control) to 100% (complete weed control). The experiments were conducted twice with four replications. Based on visual injury ratings, glyphosate alone dose response curves were described for 4” and 8” tall giant ragweed (Figure 1) and ED_{80} (80% control) and ED_{90} (90% control) were determined (Table 1). The ED_{90} values at 21 DAT for 4” and 8” tall giant ragweed were 307 and 786 oz/A, respectively. The resistance level was calculated by dividing ED_{90} (90% control) value of herbicide by respective labeled rate of 22oz/A of glyphosate. The estimated level of glyphosate resistance for 4” and 8” tall giant ragweed 21 DAT was 14X and 36X, respectively. This means, with a label rate of 22 oz/A (1X) 90% suppression of a susceptible population can be achieved, however in order to achieve the same level of control of a 4-inch tall GR giant ragweed population 14 times the label rate is required. Therefore, the level of resistance was confirmed from 14 to 36 times the label rate depending upon the application timing.

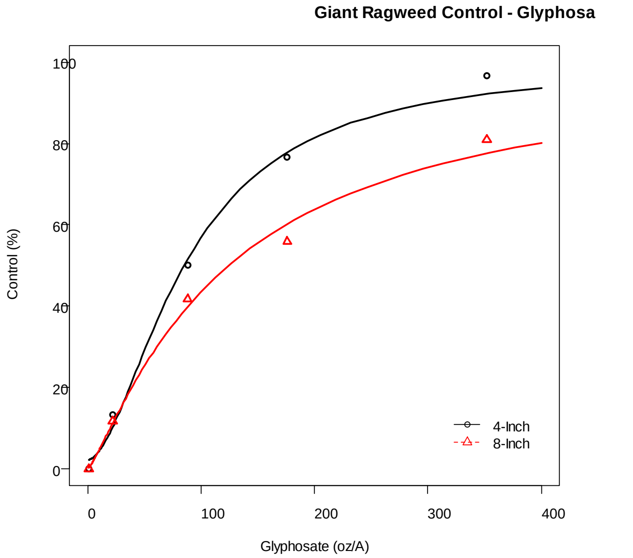

Figure 1. Glyphosate dose response curves for control of 4-inch and 8-inch tall giant ragweed at 21 DAT based on visual injury ratings in 2012 at David City, NE.

Table 1: Values of ED_{80} (80% control) and ED_{90} (90% control) for control of 4-inch and 8-Inch tall giant ragweed with glyphosate at 21 DAT.

Weed Species	Height (Inch)	ED_{80} (±SE)	ED_{90} (±SE)	Resistance Level
Giant	4”	193 (36)	307 (88)	14X
Ragweed	8”	398 (120)	786 (360)	36X

GR Giant ragweed control with Glyphosate+Saflufenacil and Glyphosate+Dicamba applied early postemergence (EPOST)

Dose response studies were described for glyphosate (22 oz/A) tank-mixed with four saflufenacil doses (0, 0.5X, 1X, 2X, and 4X) applied EPOST at two growth stages (4” and 8”) (Figure 2). Visual weed control was estimated 21 DAT. Based on visual evaluation, glyphosate+saflufenacil dose response curves were described for 4” and 8” tall giant ragweed (Figure 2) and ED_{80} (80% control) and ED_{90} (90% control) were determined (Table 2). The ED_{90} values at 21 DAT for 4” and 8” tall giant ragweed were 21 and 24 oz/A, respectively. Saflufenacil rates higher than the label rate were required for control of GR giant ragweed at 21 DAT indicating saflufenacil might not be a viable option for control of GR giant ragweed because of its the resilient re-growth.

Table 2: Values of ED_{80} (80% control) and ED_{90} (90% control) for control of 4-inch and 8-Inch tall giant ragweed with glyphosate (22 oz/A) tankmixed with Saflufenacil at 21 DAT.

Weed Species	Tankmix	Height (Inch)	ED_{80} (±SE)	ED_{90} (±SE)
Giant	Glyphosate+	4”	8 (5)	21 (22)
Ragweed	Saflufenacil	8”	9 (4)	24 (17)

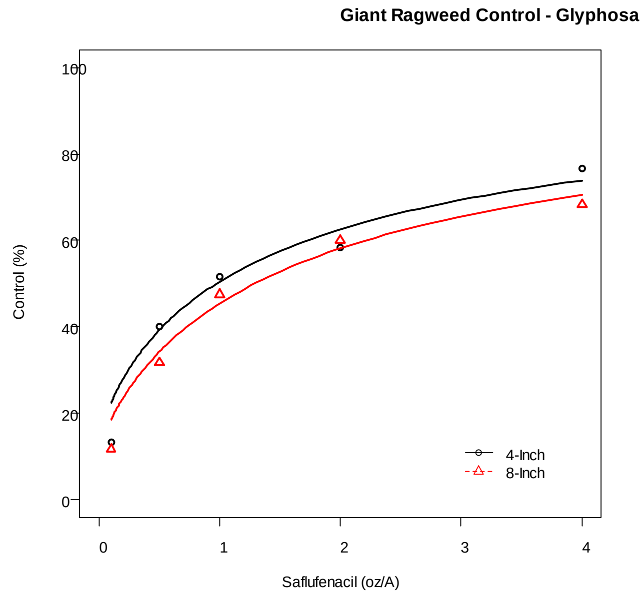

Figure 2. Dose response curves of glyphosate (22 oz/A) tankmixed with Saflufenacil for control of 4-inch and 8-inch, tall giant ragweed at 21 DAT based on visual injury ratings in 2012 at David City, NE.

Similarly, dose response curves were determined for glyphosate at the recommended rate (22 oz/A) tankmixed with 4 rates of dicamba (0, 1X, 2X, 4X, and 8X) applied EPOST to 4” and 8” tall giant ragweed (Figure 3). The dose response curves were used to estimate the ED_{80} (80% control) and ED_{90} (90% control) (Table 3). The ED_{90} values at 21 DAT were 5 and 9 oz/A for two growth stages, 4” and 8”, respectively. These values indicated that at both growth stages, GR giant ragweed was controlled by glyphosate+dicamba at the label rates.

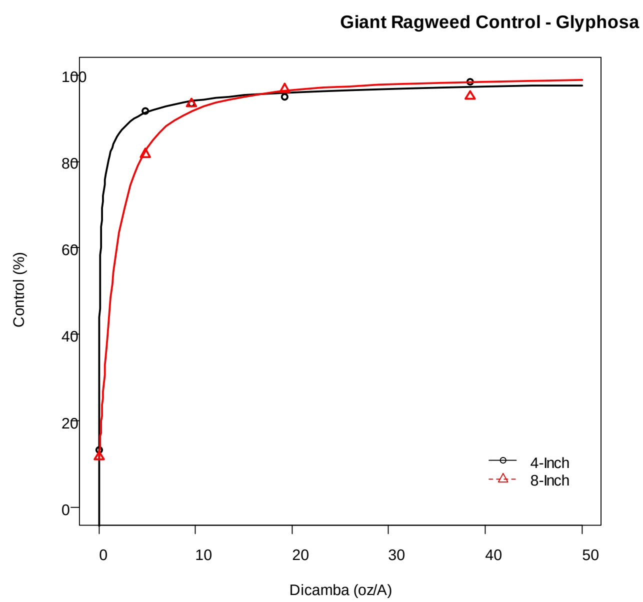

Figure 3. Dose response curves of glyphosate (22 oz/A) tankmixed with Dicamba for control of 4-inch and 8-inch tall giant ragweed at 21 DAT.

Table 3: Values of ED_{80} (80% control) and ED_{90} (90% control) for control of 4” and 8” tall giant ragweed with glyphosate (22 oz/A) tankmixed with Dicamba at 21 DAT.

Weed Species	Tankmix	Height (Inch)	ED_{80} (±SE)	ED_{90} (±SE)
Giant	Glyphosate+	4”	1 (2)	5 (3)
Ragweed	Dicamba	8”	5 (1)	9 (2)

These results conclude that the suspected giant ragweed population was glyphosate-resistant because the label glyphosate use-rates did not provide desired control. Repeated overuse of glyphosate alone has selected for glyphosate resistance in this giant ragweed population. The resistance level of this population ranged from 14 - 36X at growth stages of 4” and 8”. From the control standpoint, glyphosate (22 oz/A) tankmixed with dicamba provided good control at both application timings 21 DAT.

Burndown efficacy of PRE active ingredients of corn and soybean on GR giant ragweed control

After evaluating the options for post-emergence control, we wanted to evaluate if there is an effective burndown program for control of GR giant ragweed.

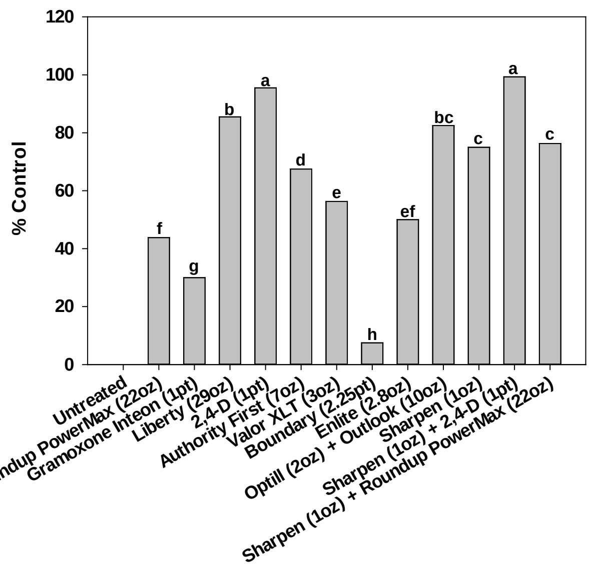

Figure 4. Burndown efficacy of commonly used soybean Burndown/PRE herbicides on GR giant ragweed 21 DAT in the field.

Field studies were conducted in David City, NE to evaluate commonly used burndown/PRE herbicides in soybeans to control GR giant ragweed (Figure 4). Visual estimates recorded 21 DAT indicated that applications of 2,4-D (1 pt/A) and Sharpen (1 oz/A)+2,4-D (1 pt/A) provided at least 96 % control of GR giant ragweed (Figure 1). GR giant ragweed control with Sharpen (1 oz/A), Liberty (29 oz/A), Gramoxone Inteon (1 pt/A), Valor XLT (3 oz/A), and Boundary (2.25 pt/A) provided lower control by 24, 16, 70, 43, and 92%, respectively than Sharpen (1 oz/A)+2,4-D (1 pt/A) tank-mix,

GR giant ragweed seeds were collected from three different locations in NE. Greenhouse studies were conducted to evaluate efficacy of some common corn burndown/PRE (Figure 5) and PPO (Protoporphyrinogen Oxidase inhibitor–Group 14 herbicides) with and without 2,4-D (Figure 6 and 7) on three different GR giant ragweed populations. Herbicide applications were conducted when the plants were 3-4” tall. Control was visually evaluated 28 DAT (Figure 5). Glyphosate injury to the GR giant ragweed population was consistent in the greenhouse and in the field, about 30-40%. The ALS-inhibiting herbicides (e.g. Python, Resolve SG) were unimpressive and provided variable control (Figure 5). Atrazine at 2 lbai/A provided 42% higher control than the lower rate. Although Callisto (3 and 6 oz/A) and Sharpen (3oz/A) provided at least 97% control, plants started to re-grow from the lower nodes at the time of harvest indicating that these treatments did not provide complete control.

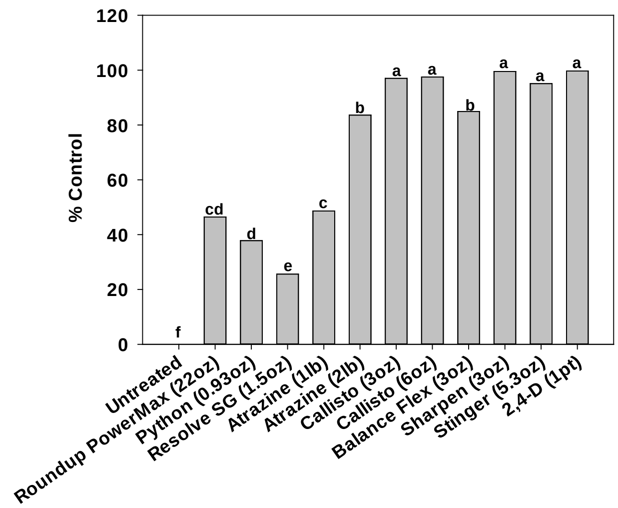

Figure 5. Burndown efficacy of commonly used corn Burndown/PRE herbicides on GR giant ragweed 21 DAT in the greenhouse.

A separate greenhouse trial was conducted to evaluate the PPO-inhibiting herbicides with and without 2,4-D. The results from these trials indicated that the PPO-inhibiting herbicides alone were not effective in controlling GR giant ragweed as a burndown, especially at the soybean rates. At 28 DAT, control with Sharpen (1oz/A), Valor (3 oz/A), and Spartan (12 oz/A) was 47, 23 and 15%, respectively. GR giant ragweed plants in all these treatments started re-growth 14 DAT (Figure 6 and 7). However, when these PPO-inhibiting herbicides were tank-mixed with 2,4-D the efficacy improved tremendously. For Valor+2,4-D, compared to Valor alone, the control was 321% higher when tank-mixed with 2,4-D. For Sharpen + 2,4-D, control was 107% higher than Sharpen alone, and for Spartan + 2, 4-D, control was 55% higher than Spartan alone. These tankmixed treatments of PPO-inhibiting herbicides and

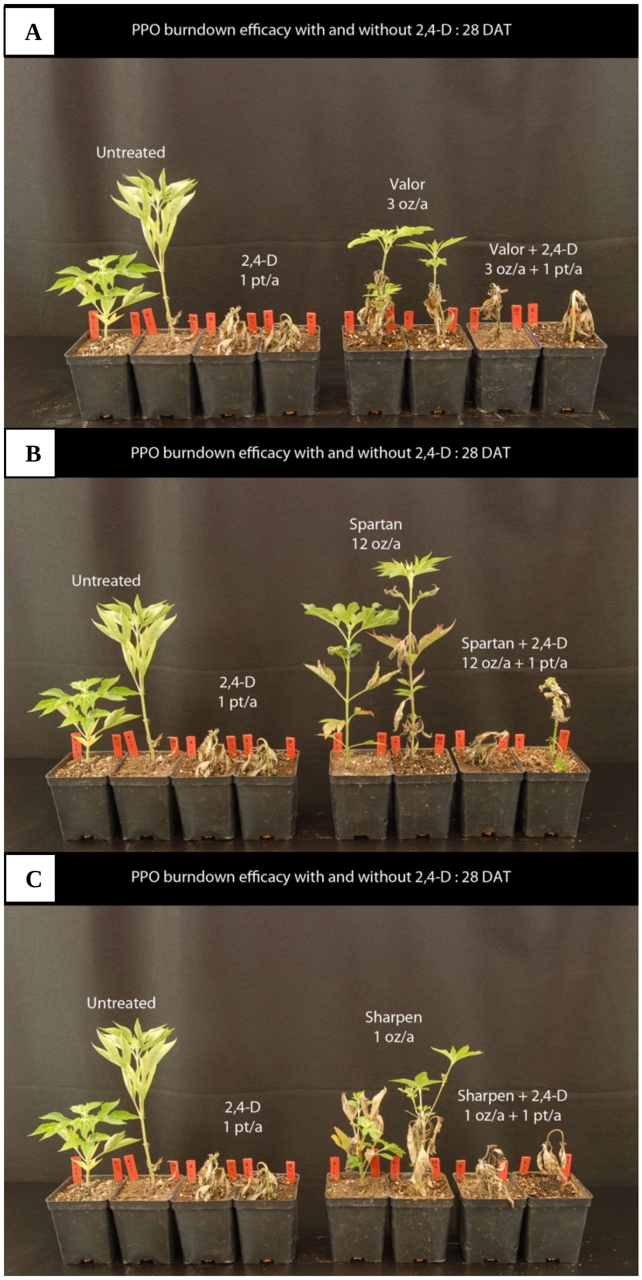

Figure 6. (A-C) Necrosis observed in a GR giant ragweed population from Richardson county when Valor+2,4-D, Spartan+2,4-D, and Sharpen+2,4-D were tankmixed compared to treatments where Valor, Spartan and Sharpen were applied alone.

2,4-D were not significantly different from 2,4-D applied alone.

To summarize, the burndown efficicay trial indicated that we have limited options with respect to control of GR giant ragweed. Basically, PPO-inhibiting herbicides tankmixed with 2,4-D provided the best control from the commonly used corn and soybean burndown/PRE herbicides.

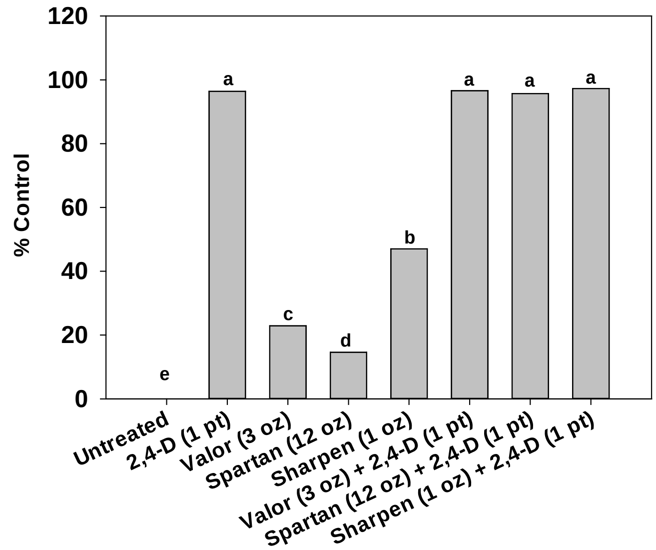

Figure 7. PPO burndown efficacy with and without 2,4-D for GR giant ragweed control 28 DAT in the greenhouse.

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HPPD-Resistant Waterhemp in Nebraska

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Stevan Knezevic, Integrated weed Management Specialist
Jon Scott, Weed Science Technologist

Weed resistance to herbicides is a global problem. There are hundreds of herbicides registered for use throughout the world, but they affect less than 20 molecular target sites. An enormous effort has been expended by the industry to find new herbicide target sites; however, no new molecular target site has been discovered in the past 20 years (Duke and Dylan 2011). Currently there are 393 herbicide resistant biotypes (124 dicots and 87 monocots) confirmed worldwide (Heap 2012). The United States has more than 30% of the biotypes that are resistant to at least one herbicide mechanism of action. Waterhemp was among the first weed species identified with multiple resistance in the United States. There has been confirmed report of three-way multiple resistance in waterhemp to ALS (Acetolactate Synthase inhibitors–Group 2 herbicides), PSII (Photosystem II inhibitors–Group 5 herbicides), and PPO-(Protoporphyrinogen Oxidase inhibitor–Group 14 herbicides) inhibiting herbicides in western Illinois; glyphosate (EPSP Synthase inhibitors–Group 9 herbicides), ALS, and PPO-inhibiting herbicides in Missouri; and ALS, PSII, and HPPD-(Carotenoid Biosynthesis inhibitors–Group 27 herbicides) inhibiting herbicides in Iowa (Patzoldt et al. 2002; Legleiter and Bradley 2008; McMullan and Green 2011; Heap 2012). <u>This is a cause of major concern because when weed species start stacking several forms of resistance, the number of viable herbicide options gets greatly reduced.</u>

In past, triazine-resistant weed biotypes were of great concern, which now numbers 69 species worldwide. In recent years, the interest has shifted to ALS and glyphosate-resistant weeds which include 116 and 21 confirmed resistant biotypes worldwide, respectively (Vencill et al. 2012). Heightened concern for ALS resistance is the fact that numerous herbicides use the same site of action on multiple crops.

Glyphosate resistance is the newest type of resistance, resulting in 21 confirmed cases of glyphosate-resistant weeds in the last 15 years. The widespread adoption of glyphosate-tolerant crops and repeated use of glyphosate alone has placed a spotlight on weed populations resistant to glyphosate. We have already seen this in case of glyphosate-resistant weeds found in the state of Nebraska-marestail (horseweed), giant ragweed, and kochia.

HPPD-Resistant Waterhemp

Waterhemp is a summer annual weed species. Although sparse 30 years ago, waterhemp is identified as one of the most problematic weed species for the crop production in the Midwestern United States in the last 20 years. A number of factors contribute to the rise in waterhemp problems; these include reduced tillage, extended germination of waterhemp, less use of residual herbicides, and fast spread of herbicide-resistant biotypes. Overall, waterhemp populations have been reported to be resistant to six mechanism of actions including ALS, PSII, PPO, glyphosate, HPPD and 2, 4-D (Synthetic Auxins–Group 4 herbicides) inhibiting herbicides (Heap 2012; McMullan and Green 2011; Hausman et al. 2011; Bernards et al. 2012), three of these have been confirmed in Nebraska.

In 2011, waterhemp was confirmed resistant to HPPD-inhibiting herbicides in Nebraska as the first weed species to have evolved resistance to this mechanism of action. Resistance occurred in a seed corn production system where HPPD-inhibiting herbicides were repeatedly used for the last five years. <u>This basically gives us evidence that waterhemp can develop resistance to any herbicide used extensively for its control</u>. Repeated use of same mechanism of action can easily result in the evolution of weed resistance, irrespective of the type of herbicide used.

Therefore, three separate field trials were conducted in 2012 to determine the level of waterhemp resistance to (1) post-emergent (POST) application of three HPPD herbicides, (2) pre-emergent (PRE) application of mesotrione and tankmixes, and (3) alternative control options for HPPD-resistant waterhemp in corn and soybean. Dose response curves were developed for POST applications of HPPD-inhibiting herbicides e.g. Callisto (mesotrione), Laudis (tembotrione), and Impact (topramezone) and PRE applications of Callisto, Lumax, and Callisto in a tankmix with atrazine and metholachlor, and from those curves ED_{50}, ED_{60} and ED_{80} was determined (doses needed for 50, 60 and 80% weed control) and compared the level of resistances to the recommended labeled rates across the HPPD-inhibiting herbicides used.

Study 1: Waterhemp resistance to POST application of HPPD herbicides

Field bioassays were conducted at locations in eastern Nebraska where a total of five rates of Callisto (0, 1X, 2X, 4X, and 8X of label rates) were applied at three growth stages (3”, 6”, and 12” tall) of HPPD-resistant waterhemp population. Visual weed control ratings were done at 6, 13 and 23 days after treatment (DAT) for 3” tall waterhemp, 13, 20 and 26 DAT for 6”, and 14 and 20 DAT for 12” tall waterhemp based on a scale of 0 to 100 (where 0=no injury and 100=plant death). Based on visual ratings, Callisto dose response curves were described for 3 inch tall waterhemp (Figure 1) and ED_{80} (80% control) and ED_{90}

Table 1. Values of ED_{80} (80% control) and ED_{90} (90% control) for control of 3-inch tall waterhemp with Callisto at 6, 13, and 23 DAT based on visual ratings in 2011.

Weed species	Height (Inch)	DAT	ED_{80} (±SE)	ED_{90} (±SE)	Resistance Level
			Callisto (oz/A)		
Waterhemp	3"	6	18 (3)	47 (14)	16X
		13	21 (3)	39 (9)	13X
		23	17 (6)	39 (21)	13X

(90% control) values were determined (Table 1). The ED_{90} values at 6, 13, and 23 DAT were 47, 39, and 39 oz/A respectively. The resistance level was calculated by dividing ED_{90} (90% control) value of herbicide by respective labeled rate of 3 oz/A of Callisto. Depending on the visual rating dates, the resistance level for 3-inch tall waterhemp to Callisto ranged between 13-16 times the labeled rate. For example, a 90% suppression of 3-inch tall waterhemp was achieved with 13 times the labeled rate at 23 DAT.

Similarly, for 6-inch and 12-inch tall waterhemp, Callisto, Laudis, and Impact dose response curves were described based on visual ratings (Figure 2), which were utilized further to determine the ED_{50}, ED_{60}, ED_{70}, and ED_{80} values for control of 6-inch (Table 2) and 12-inch (Table 3) tall waterhemp. The ED_{80} values of 6-inch tall waterhemp at 26 DAT of Callisto, Laudis and Impact were 39, 31, and 7 oz/A, respectively (Table 2). The ED_{90} values were not calculated due to lack of high enough rates of herbicide to provide 90% control. ED_{50} is an effective dose that provides 50% weed control, while ED_{80} provides 80% control. The effective doses were compared and the resistance level was determined by dividing ED_{80} (80% control) value of herbicide by the respective labeled rate (e.g. 3 oz/A of Callisto, 3 oz/A of Laudis and 1 oz/A of Impact). The estimated level of resistance at 26 DAT for 6-

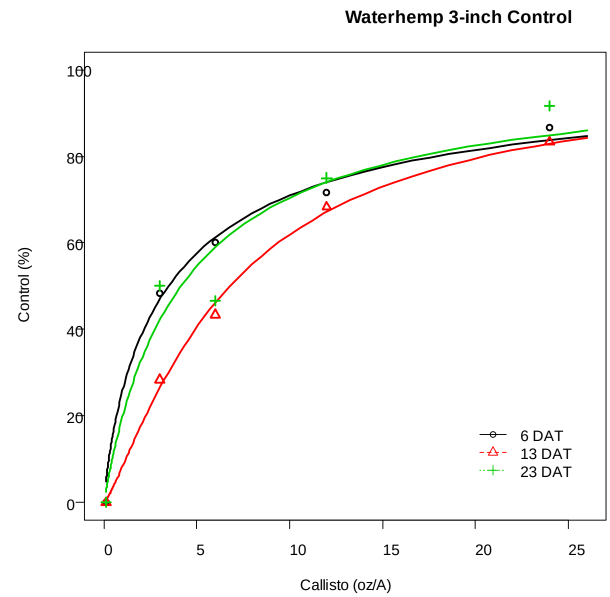

Figure 1. Visual injury estimate of Callisto dose response curves for 3-inch tall waterhemp at 6, 13, and 23 DAT.

Table 2. Values of ED_{50} (50% control), ED_{60} (60% control), and ED_{80} (80% control) for control of 6-inch tall waterhemp with Callisto, Laudis, and Impact at 13, 20, and 26 DAT based on visual ratings in 2012.

Weed Species	Height (Inch)	DAT	ED_{50} (±SE)	ED_{60} (±SE)	ED_{80} (±SE)	Resistance Level
			Callisto (oz/A)			
Waterhemp	6”	13	9 (1)	14 (2)	38 (4)	13X
		20	10 (1)	16 (2)	44 (6)	15X
		26	9 (2)	14 (2)	39 (6)	13X
			Laudis (oz/A)			
	6”	13	4 (1)	7 (1)	21 (7)	7X
		20	5 (1)	8 (2)	27 (16)	9X
		26	7 (1)	11 (2)	31 (6)	10X
			Impact (oz/A)			
	6”	13	0.6 (0.2)	1 (0.2)	4 (0.7)	4X
		20	1 (0.1)	2 (0.1)	4 (0.4)	4X
		26	2 (0.2)	3 (0.3)	7 (2)	7X

inch tall waterhemp to Callisto, Laudis and Impact was 13X, 10X, and 7X, respectively (Table 2).

In 12-inch tall waterhemp, ED_{50}, ED_{60}, and ED_{70} were the best estimated values for 50, 60, and 70% control (Table 3). These were the best estimates because the herbicide rates were not high enough to provide 80 and 90% control, and this growth stage was too tall to be controlled effectively by the labeled rates anyway. Thus, the overall resistance was not determined due to poor weed control and the precise estimate of resistance level at 12-inch could not be provided. The ED_{70} values at 20 DAT of Callisto, Laudis, and Impact were 112, 49, and 9 oz/A (Table 3). Although these estimated values might look high, they hold truth from the biological standpoint, and confirm that we have the waterhemp population resistant to the HPPD-inhibiting herbicides in Nebraska.

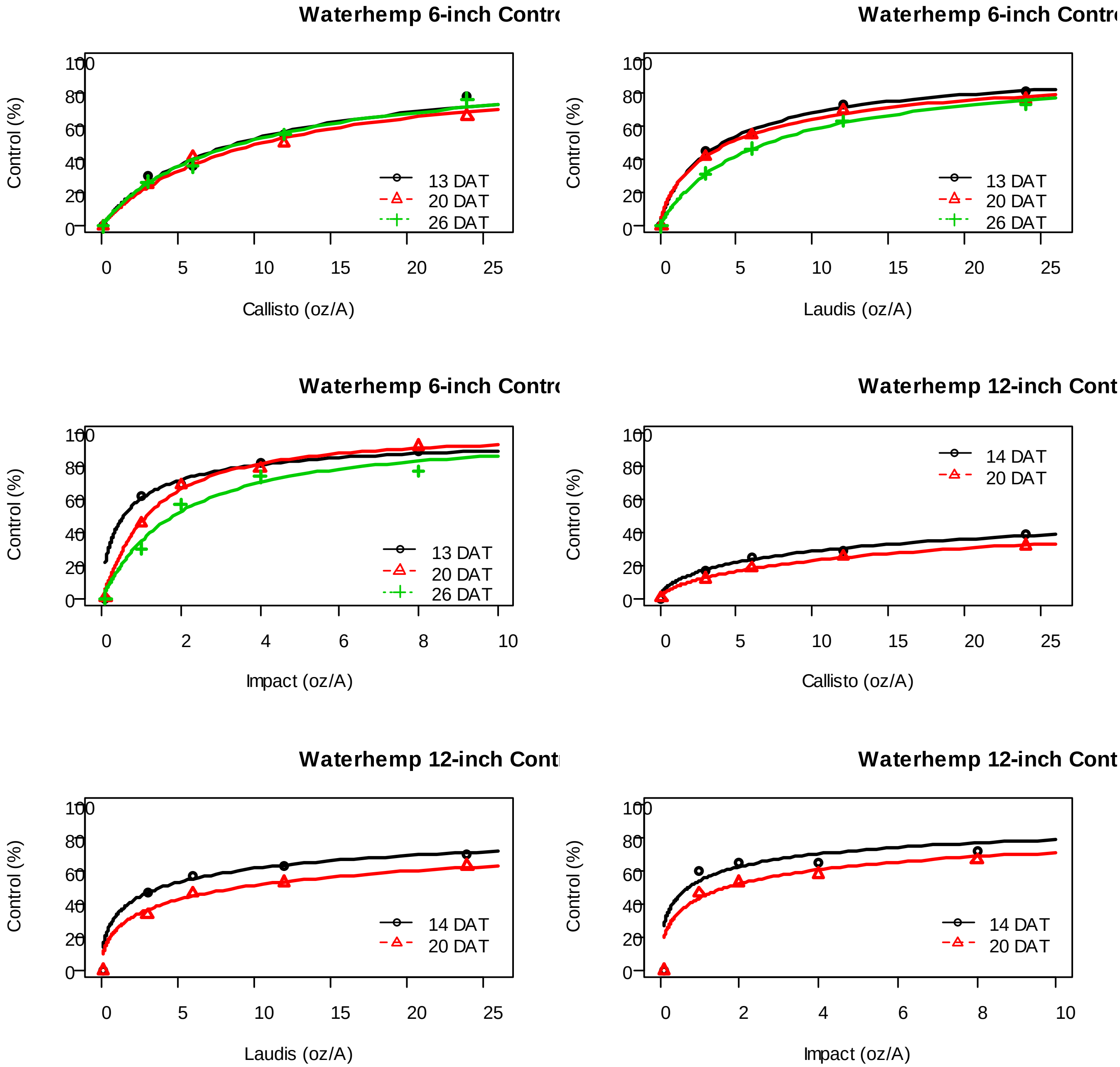

Figure 2. (A-C) Dose response curves of post-emergent applications of Callisto, Laudis, and Impact for 6-inch tall waterhemp, and (D-F) 12-inch tall waterhemp at 13, 20, and 26 DAT, and 14 and 20 DAT, respectively, based on visual injury ratings in 2012.

Table 3. Values of ED_{50} (50% control), ED_{60} (60% control), and ED_{70} (70% control) for control of 12-inch tall waterhemp with Callisto, Laudis, and Impact at 14 and 20 DAT based on visual ratings in 2012.

Weed Species	Height (Inch)	DAT	ED_{50} (±SE)	ED_{60} (±SE)	ED_{70} (±SE)
				Callisto (oz/A)	
Waterhemp	12”	14	19 (4)	37 (13)	75 (37)
		20	31 (7)	57 (17)	112 (45)
				Laudis (oz/A)	
	12”	14	4 (0.5)	9 (1)	21 (3)
		20	9 (1)	20 (2)	49 (6)
				Impact (oz/A)	
	12”	14	1 (0.1)	2 (0.3)	4 (1)
		20	2 (0.3)	4 (1)	9 (1)

In conclusion, the waterhemp population was determined to be resistant to POST applications of Callisto at all the three different growth stages (3", 6" and 12"), and the level of resistance for 3-inch and 6-inch tall waterhemp was 13 times the labeled rate. The 6-inch and 12-inch tall waterhemp were also resistant to Laudis and Impact at the labeled rates. The resistance level for 6-inch tall waterhemp to Laudis and Impact was 10X and 7X, respectively.

Study 2: Control of HPPD-resistant waterhemp with mesotrione tankmixed with metolachlor+atrazine applied preemergence (PRE)

Dose response curves of Callisto, Callisto tankmixed with fixed rates of metolachlor (1.75 pt/A) and atrazine (0.625 qt/A), and Lumax applied PRE were described (Figure 3), and ED_{50}, ED_{60}, and ED_{80} values were determined (Table 4). The resistance level was determined by dividing ED_{80} (80% control) value of herbicide by respective PRE labeled rate of Callisto (6oz/A) and Lumax (3 qt/A). The resistance level estimated for Callisto in a tank mix (fixed rates of metochlor and atrazine in 2.5 qt of Lumax) were 1, 3, 8 and 14 times the labeled rate at 20, 30, 40 and 50 DAT, respectively. The estimate of the level of resistance was lower at 20 DAT due to better waterhemp control by metolacholor for the initial 20 days. However, as the metolachlor activity diminishes, the rating of watehemp control was reduced at later rating dates, ultimately resulting in higher estimates of resistance level. Similarly, for the preemergence dose response of Lumax, the ED_{80} values were 4, 4.3, 6, and 17 qt/A at 20, 30, 40 and 50 DAT, respectively. The level of resistance was 1X at 30 DAT due to the metolachlor activity for up to 30 days. At 40 DAT, resistance level doubled (2X) as 6 qt/A provided 40 days of control. Resistance level increased up to 6X as the metolachlor activity diminishes by 50 DAT. Previously, a separate study conducted in this field indicated that this waterhemp population is also suspected to be triazine-resistant.

To summarize, we have observed resistance in both POST applications of HPPD-inhibiting herbicides and PRE applications of Callisto (mesotrione), Callisto tankmixes and Lumax. These results are of great concern because much of corn production depends on HPPD-inhibiting herbicides. These herbicides are still useful, but their use pattern must be carefully managed.

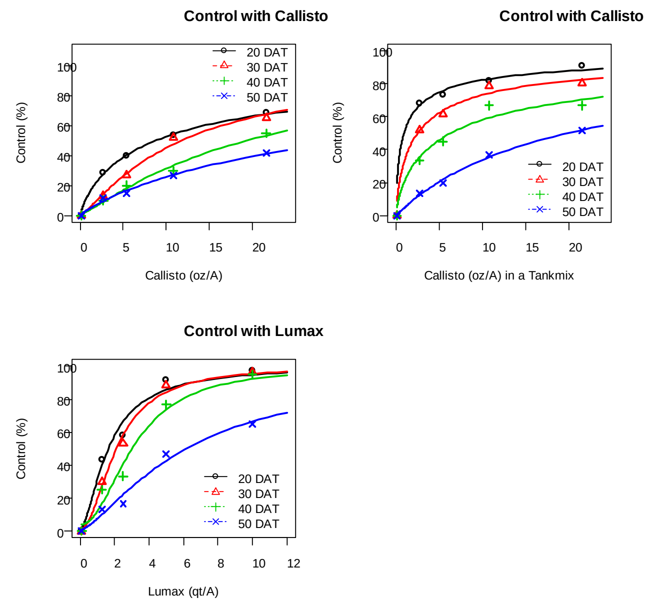

Figure 3. Dose-response curves of PRE application of Callisto, Callisto tankmixed with metolachlor+atrazine, and Lumax at 20, 30, 40, and 50 DAT based on visual injury ratings in 2012.

Table 4. Values of ED_{50} (50% control), ED_{60} (60% control), and ED_{80} (70% control) for control of pre-emergent waterhemp with Callisto, Callisto in a tankmix, and Lumax at 20, 30, 40, and 50 DAT based on visual injury ratings in 2012.

Weed Species	DAT	ED_{50} (±SE)	ED_{60} (±SE)	ED_{80} (±SE)	Resistance level
			Callisto (oz/A)		
Waterhemp	20	9 (2)	14 (3)	48 (16)	8X
	30	12 (2)	16 (2)	39 (8)	7X
	40	20 (2)	27 (3)	62 (14)	10X
	50	32 (7)	50 (15)	147 (78)	25X
			Callisto in a tankmix (oz/A)		
	20	1 (0.4)	2 (0.6)	8 (2)	1X
	30	2.5 (1)	4 (1)	17 (6)	3X
	40	6 (2)	11 (3)	45 (12)	8X
	50	20 (4)	30 (7)	82 (35)	14X
			Lumax (qt/A)		
	20	1.7 (0.2)	2 (0.2)	3.9 (0.4)	1.3X
	30	2 (0.2)	3 (0.2)	4.3 (0.4)	1.4X
	40	3 (0.4)	4 (0.4)	6 (1)	2X
	50	6 (1)	8 (1)	17 (3)	6X

Study 3: Control of HPPD-resistant waterhemp in corn and soybean

Different combinations of PRE (Table 5), POST (Table 6), and PRE followed by POST (Table 7) herbicides were evaluated to control HPPD-resistant waterhemp.

Tankmixes of Fierce (3 oz/A)+Lumax (2.7 qt/A); Lumax (2.7qt/A)+Harness (1.5 pt/A)+Aatrex (1.93 pt/A); Valor (1.5 oz/A)+Lumax (2.7 qt/A); Tricor (4oz/A)+Lumax (2.7 qt/A), Lumax (2.7 qt/A)+ Harness (0.68 or 1.5 pt/A); and Zidua (2.5 oz/A)+Sharpen (3oz/A) provided good PRE control (>80%) at 21 DAT.

Table 5. Visual estimates (% control) at 21, 38, and 62 DAT for different herbicide products applied preemergence to control HPPD-resistant waterhemp.

ID	Product	Rate Units	21 DAT	38 DAT	62 DAT
1	Fierce	3 oz/A	99	96	85
	Lumax	2.7 qt/A			
2	Fierce	3 oz/A	97	93	75
3	Lumax	2.7 qt/A	96	77	23
	Harness	1.5 pt/A			
	Aatrex	1.93 pt/A			
4	Valor	1.5 oz/A	94	85	45
	Lumax	2.7 qt/A			
5	Harness Xtra	2.7 qt/A	92	57	38
6	Tricor	4 oz/A	92	63	33
	Lumax	2.7 qt/A			
7	Sharpen	3 floz/A	88	58	23
	Lumax	2.7 qt/A			
8	Lumax	2.7 qt/A	91	50	20
	Harness	0.86 pt/A			
9	Verdict	16 floz/A	87	50	22
10	Corvus	5.6 floz/A	87	57	17
	Aatrex	1.6 qt/A			
11	Aatrex	3.2 pt/A	86	50	17
	Verdict	16 floz/A			
12	Corvus	5.6 floz/A	86	52	30
13	Lumax	2.7 qt/A	85	67	37
	Harness	1.5 pt/A			
14	Zidua	2.5 oz/A	83	65	38
	Sharpen	3 oz/A			
	Aatrex	1 pt/A			
15	Zidua	1.68oz/A	81	53	18
	Lumax	2.7 qt/A			
16	Lumax	2.7 qt/A	77	47	18
	Aatrex	1.93 pt/A			
17	Verdict	15 oz/A	77	58	30
	Outlook	5 oz/A			
18	Prowl H_2O	3 pt/A	77	40	20
	Lumax	2.7 qt/A			
19	Lumax	2.7 qt/A	72	43	18
20	Rimsulfuron	1 oz/A	67	30	10
	Bicep II Magnum	2.1 qt/A			
21	Surestart	2.5 pt/A	67	28	10
22	Anthem ATZ	32 oz/A	53	32	10
LSD			10	19	20

For POST control, several tretments provide good control, including: Touchdown (36 floz/A); Callisto Xtra (20 floz/A)+Liberty (29floz/A); Callisto Xtra (20 floz/A)+Bromoxynil (1.5 pt/A); Tricor (4 oz/A)+Callisto Xtra (20 floz/A); and Range D-Tech (8oz/A) provided promising control (>70%) at 26 DAT.

Table 6. Visual estimates (% control) at 6, 13, and 26 DAT for different herbicide products applied postemergence to control HPPD-resistant waterhemp.

ID	Product	Rate Units	6 DAT	13 DAT	26 DAT
1	Touchdown	36 floz/A	96	98	94
2	Callisto Xtra	20 floz/A	96	94	82
	Liberty	29 floz/A			
3	Callisto Xtra	20 floz/A	92	82	70
	Bromoxynil	1.5 pt/A			
4	Tricor	4 oz/A	90	83	78
	Callisto Xtra	20 floz/A			
5	Range D-Tech	8 oz/A	88	78	73
6	Callisto	3 oz/A	83	67	58
	Cadet	0.9 oz/A			
7	Peak	1 oz/A	80	68	53
	Callisto Xtra	20 floz/A			
8	Callisto Xtra	20 floz/A	78	77	68
	Clarity	16 floz/A			
9	Status	10 oz/A	77	77	72
	Callisto Xtra	20 floz/A			
10	Status	5 oz/A	75	75	63
	Callisto Xtra	20 floz/A			
11	Callisto Xtra	20 floz/A	75	73	62
	2,4-D Amine	1.05 pt/A			
12	Callisto Xtra	20 floz/A	68	57	43
	Basagran	2 pt/A			
13	Callisto Xtra	20 floz/A	65	43	23
14	Callisto	3 oz/A	65	48	32
	Atrazine	1 qt/A			
	Accent	0.5 oz/A			
	Resolve	0.36 oz/A			
15	Capreno	3 oz/A	62	45	28
16	Callisto	3 floz/A	33	25	17
17	Accent	0.67 oz/A	13	7	15
	Atrazine	1 qt/A			
18	Permit	1 oz/A	10	12	15
LSD			4	5	12

In PRE followed by POST applications, we evaluated 25 tankmix options. Out of 25 treatments, the following provided good control: Lumax (2.7 qt/A)+Aatrex (1.93 pt/A) or Lumax (2.7 qt/A)+Harness (1.5 pt/A) applied PRE followed by Status (5 oz/A)+Aatrex (0.8 pt/A); Lumax (2.7 qt/A)+Aatrex (1.93 pt/A) followed by Touchdown total (32 floz/A) or Aatrex (0.8 pt/A)+Liberty (29 floz/A) or Aatrex (0.8 pt/A)+Liberty (29 floz/A)+Status (5 oz/A) or Aatrex (0.8 pt/A)+Liberty (29 floz/A)+Dual II Magnum (1 pt/A); Zidua (1.68 oz/A)+Lumax (2.7 qt/A) followed by Status (5 oz/A)+Aatrex (1qt/A); Lexar (1.75 qt/A) followed by Status (5 oz/A)+Aatrex (1 pt/A)+Halex GT (3.6 pt/A) or Aatrex (1 pt/A)+Halex GT (3.6 pt/A)+Roundup Powermax (22 oz/A); and Bicep II Magnum (2.1 qt/A) followed by Impact (1 oz/A)+Roundup Powermax (22 oz/A).

Table 5. Visual estimates (% control) at 31 Days after PRE treatment and 15 and 31 days after POST treatment of herbicide products applied to control HPPD-resistant waterhemp.

	Product (PRE)	Rate Units	Growth Stage	31 DAT	Product (POST)	Rate Units	Growth Stage	15 DAT	31 DAT
1	Lumax	2.7 qt/A	PRE	92	Status	5 oz/A	POST	92	94
	Aatrex	1.93 pt/A	PRE		Aatrex	0.8 pt/A	POST		
	Harness	1.5 pt/A					POST		
2	Corvus	5.6 oz/A	PRE	90	Status	5 oz/A	POST	87	87
	Aatrex	1 qt/A	PRE						
3	Lumax	2.7 qt/A	PRE	89	Callisto Xtra	16 floz/A	POST	77	60
	Aatrex	1.93 pt/A	PRE						
	Harness	1.5 pt/A	PRE						
4	Lumax	2.7 qt/A	PRE	85	Callisto Xtra	24 floz/A	POST	77	60
	Harness	1.5 pt/A	PRE						
5	Lumax	2.7 qt/A	PRE	83	Status	5 oz/A	POST	83	87
	Harness	1.5 pt/A	PRE		Aatrex	32 floz/A	POST		
6	Zidua	1.68 oz/A	PRE	78	Callisto Xtra	24 floz/A	POST	73	48
	Lumax	2.7 qt/A	PRE				POST		
7	Lumax	2.7 qt/A	PRE	78	Status	5 oz/A	POST	100	100
	Aatrex	1.93 pt/A	PRE		Touchdown Total	32 floz/A	POST		
8	Lumax	2.7 qt/A	PRE	77	Touchdown Total	32 floz/A	POST	98	98
	Aatrex	1.93 pt/A	PRE						
9	Lumax	2.7 qt/A	PRE	75	Aatrex	0.8 pt/A	POST	97	92
	Aatrex	1.93 pt/A	PRE		Liberty	29 floz/A	POST		
10	Lumax	2.7 qt/A	PRE	73	Status	5 oz/A	POST	95	93
	Aatrex	1.93 pt/A	PRE		Aatrex	0.8 pt/A	POST		
					Liberty	29 floz/A	POST		
11	Lumax	2.7 qt/A	PRE	73	Aatrex	0.8 pt/A	POST	97	96
	Aatrex	1.93 pt/A	PRE		Dual II Magnum	1 pt/A	POST		
					Liberty	29 floz/A	POST		
12	Lumax	2.7 qt/A	PRE	72	Status	5 oz/A	POST	83	83
	Aatrex	1.93 pt/A	PRE		Aatrex	0.8 pt/A	POST		
13	Lumax	2.7 qt/A	PRE	68	Callisto Xtra	16 floz/A	POST	60	35
	Aatrex	1.93 pt/A	PRE						
14	Zidua	1.68 oz/A	PRE	67	Status	5 oz/A	POST	82	82
	Lumax	2.7 qt/A	PRE		Aatrex	2 pt/A	POST		
15	Bicep II Magnum	2.1 qt/A	PRE	65	Anthem	5 oz/A	POST	63	58
					Status	2.5 oz/A	POST		
16	Lexar	1.75 qt/A	PRE	60	Status	5 oz/A	POST	86	80
					Aatrex	1 pt/A	POST		
					Halex GT	3.6 pt/A	POST		
17	Bicep II Magnum	2.1 qt/A	PRE	58	Cadet	0.75 oz/A	POST	62	50
					Status	2.5 oz/A	POST		
18	Lumax	1.5 qt/A	PRE	53	Aatrex	1 pt/A	POST	75	60
					Halex GT	3.6 pt/A	POST		
19	Lumax	1.5 qt/A	PRE	50	Status	5 oz/A	POST	80	73
					Aatrex	1 pt/A	POST		
					Halex GT	3.6 pt/A	POST		
20	Lexar	1.75 qt/A	PRE	50	Aatrex	1 pt/A	POST	82	65
					Halex GT	3.6 pt/A	POST		
21	Lumax	2.7 qt/A	PRE	48	Roundup PowerMax	22 oz/A	POST	98	94
22	Lumax	2.7 qt/A	PRE	47	Status	2.5 oz/A	POST	42	47
23	Lumax	2.7 qt/A	PRE	35	Status	5 oz/A	POST	67	68
24	Bicep II Magnum	2.1 qt/A	PRE	32	Impact	1 oz/A	POST	58	38
					Atrazine	1 pt/A	POST		
25	Bicep II Magnum	2.1 qt/A	PRE	28	Impact	1 oz/A	POST	95	88
					Roundup PowerMax	22 oz/A	POST		
	LSD			20				9	14

Managing to avoid herbicide resistance

To minimize the development of weed resistance to herbicides do not use the group of herbicides with the same mechanism of action. Most new herbicides provide good weed control for the initial few years of their use, but overtime they will not provide the same level of control. Repeated use of same mechanism of action puts tremendous selection pressure on the surviving weed population; as a result the weeds either evolve resistance, or shift to be more tolerant to label rate. There are a several options to avoid the risk of herbicide resistance. Respect the rotation, both crop and herbicide mechanism of action, tank-mix multiple effective herbicides with different mechanism of action, use full label rates, and use an integrated weed management approach including tillage and crop rotation, as explained in the Guide for Weed Management in Nebraska. Additionally, keep in mind that the lowest risk of evolving herbicide resistance occurs when both PRE and POST herbicide applications are a part of systems approach to manage herbicide resistant weeds.

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