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 6th 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 2014 Proceedings contains articles that summarize the information presented at all nine 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.

2014 Crop Production Clinics Schedule

January 7, Gering Civic Center, Gering
January 8, Sandhills Convention Center, North Platte
January 9, Adams County Fairgrounds, Hastings
January 14, Younes Conference Center, Kearney
January 15, The Auditorium, York
January 16, Beatrice Country Club, Beatrice
January 21, Atkinson Community Center, Atkinson
January 22, Lifelong Learning Center, Northeast Community College, Norfolk
January 23, ARDC, Saunders County Extension Office, Mead

Lowell Sandell
Weed Science Extension Educator
Practical, Profitable, and Environmentally Sound
<table>
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<tr>
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<th>Title</th>
<th>Department/Extension</th>
<th>Address</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erin Bauer</td>
<td>Extension Associate</td>
<td>Agronomy and Horticulture</td>
<td>Lincoln, NE</td>
<td>(402) 472-9548</td>
<td><a href="mailto:ebauer2@unl.edu">ebauer2@unl.edu</a></td>
</tr>
<tr>
<td>Fred Baxendale</td>
<td>Professor</td>
<td>Entomology</td>
<td>Lincoln, NE 68583</td>
<td>(402) 472-8699</td>
<td><a href="mailto:fbaxendale1@unl.edu">fbaxendale1@unl.edu</a></td>
</tr>
<tr>
<td>Jeff Bradshaw</td>
<td>Entomologist</td>
<td>Panhandle Research and Extension Center</td>
<td>Scottsbluff NE 69361</td>
<td>(308) 632-1230</td>
<td><a href="mailto:jbradshaw2@unl.edu">jbradshaw2@unl.edu</a></td>
</tr>
<tr>
<td>Chuck Burr</td>
<td>Extension Educator</td>
<td>Phelps-Gosper Counties</td>
<td>Holdrege, NE</td>
<td>(308) 995-4222</td>
<td><a href="mailto:cburr1@unl.edu">cburr1@unl.edu</a></td>
</tr>
<tr>
<td>Thomas Dorn</td>
<td>Extension Educator</td>
<td>Lancaster County</td>
<td>Lincoln, NE</td>
<td>(402) 441-7180</td>
<td><a href="mailto:tdorn1@unl.edu">tdorn1@unl.edu</a></td>
</tr>
<tr>
<td>Richard Ferguson</td>
<td>Soils Specialist</td>
<td>Agronomy and Horticulture</td>
<td>Lincoln, NE</td>
<td>(402) 472-1144</td>
<td><a href="mailto:rferguson1@unl.edu">rferguson1@unl.edu</a></td>
</tr>
<tr>
<td>Trenton Franz</td>
<td>Assistant Professor</td>
<td>School of Natural Resources</td>
<td>Lincoln, NE</td>
<td>(402) 472-8718</td>
<td><a href="mailto:trenton.franz@unl.edu">trenton.franz@unl.edu</a></td>
</tr>
<tr>
<td>Loren Giesler</td>
<td>Extension Plant Pathologist</td>
<td>Department of Plant Pathology</td>
<td>Lincoln, NE</td>
<td>(402) 472-2559</td>
<td><a href="mailto:lgiesler1@unl.edu">lgiesler1@unl.edu</a></td>
</tr>
<tr>
<td>Keith Glewen</td>
<td>Extension Educator</td>
<td>Saunders County</td>
<td>Ithaca, NE</td>
<td>(402) 624-8030</td>
<td><a href="mailto:kglewen1@unl.edu">kglewen1@unl.edu</a></td>
</tr>
<tr>
<td>Bill Gordon</td>
<td>Bill Gordon Consulting</td>
<td>PO Box 4197</td>
<td>Lawrence NSW 2460</td>
<td>website: ispray.com.au</td>
<td></td>
</tr>
<tr>
<td>Pierce Hansen</td>
<td>Extension Assistant</td>
<td>Agronomy and Horticulture</td>
<td>Lincoln, NE</td>
<td>(402) 472-9566</td>
<td><a href="mailto:phansen2@unl.edu">phansen2@unl.edu</a></td>
</tr>
<tr>
<td>Bob Harveson</td>
<td>Extension Plant Pathologist</td>
<td>Panhandle Research and Extension Center</td>
<td>Scottsbluff, NE</td>
<td>(308) 632-1230</td>
<td><a href="mailto:rharveson2@unl.edu">rharveson2@unl.edu</a></td>
</tr>
<tr>
<td>Susan Harvey</td>
<td>Research Technician</td>
<td>Entomology</td>
<td>Scottsbluff, NE</td>
<td>(308) 632-1250</td>
<td><a href="mailto:sharvey2@unl.edu">sharvey2@unl.edu</a></td>
</tr>
<tr>
<td>Paul Hay</td>
<td>Extension Educator</td>
<td>Gage County</td>
<td>Beatrice, NE</td>
<td>(402) 223-1384</td>
<td><a href="mailto:phay1@unl.edu">phay1@unl.edu</a></td>
</tr>
<tr>
<td>Gary Hergert</td>
<td>Nutrient Management and Soil Quality Specialist</td>
<td>Panhandle Research and Extension Center</td>
<td>Scottsbluff, NE</td>
<td>(308) 632-1372</td>
<td><a href="mailto:ghergert1@unl.edu">ghergert1@unl.edu</a></td>
</tr>
<tr>
<td>Kenneth G. Hubbard</td>
<td>Climatologist</td>
<td>School of Natural Resources</td>
<td>Lincoln, NE</td>
<td>(402) 472-8294</td>
<td><a href="mailto:khubbard1@unl.edu">khubbard1@unl.edu</a></td>
</tr>
<tr>
<td>Tom Hunt</td>
<td>Extension Entomologist</td>
<td>Haskell Ag Lab</td>
<td>Concord, NE</td>
<td>(402) 584-3863</td>
<td><a href="mailto:thunt2@unl.edu">thunt2@unl.edu</a></td>
</tr>
<tr>
<td>Jan Hygstrom</td>
<td>Program Coordinator</td>
<td>Agronomy and Horticulture</td>
<td>Lincoln, NE</td>
<td>(402) 472-1632</td>
<td><a href="mailto:jhygstrom1@unl.edu">jhygstrom1@unl.edu</a></td>
</tr>
<tr>
<td>Troy Ingram</td>
<td>Assistant Extension Educator</td>
<td>Merrick County</td>
<td>Central City, NE</td>
<td>(308) 946-3843</td>
<td><a href="mailto:troy.ingram@unl.edu">troy.ingram@unl.edu</a></td>
</tr>
<tr>
<td>Suat Irmak</td>
<td>Water Resources Engineer</td>
<td>Biological Systems Engineering</td>
<td>Lincoln, NE</td>
<td>(402) 472-4865</td>
<td><a href="mailto:tsirmak2@unl.edu">tsirmak2@unl.edu</a></td>
</tr>
<tr>
<td>Tamra Jackson-Ziems</td>
<td>Extension Plant Pathologist</td>
<td>Department of Plant Pathology</td>
<td>Lincoln, NE</td>
<td>(402) 472-2858</td>
<td><a href="mailto:tjackson3@unl.edu">tjackson3@unl.edu</a></td>
</tr>
</tbody>
</table>
Larry Schulze
Professor Emeritus
Agronomy and Horticulture
Lincoln, NE
(402) 450-6403
lschulze1@unl.edu

Jon Scott
Research Technologist
Haskell Ag. Laboratory
(402) 584-3846
jscott3@unl.edu

Ron Seymour
Extension Educator
Adams County
Hastings, NE
(402) 461-7209
rseymour1@unl.edu

Charles Shapiro
Soils Specialist
Haskell Ag Lab
Concord, NE
(402) 584-3803
chshapiro1@unl.edu

Tim Shaver
Nutrient Management Specialist
West Central Research and Extension Center
North Platte, NE
(308) 696-6714
tshaver2@unl.edu

Gary Stone
Extension Educator
Panhandle Research and Extension Center
Scottsbluff, NE
(308) 632-1230
gstone2@unl.edu

Martha Shulski
Assistant Professor
School of Natural Resources
Lincoln, NE 68583
(402) 472-6711
mshulski3@unl.edu

Robert Tigner
Extension Educator
Chase County
Imperial, NE
(308) 882-4731
rtigner2@unl.edu

Amy Timmerman
Extension Educator
Holt County
O’Neill, NE
(402) 472-6771
aziems2@unl.edu

Dirac Twidwell, Jr
Asst. Professor
Agronomy and Horticulture
Lincoln, NE
(402) 472-2811
dirac.twidwell@unl.edu

Simon van Donk
Water Resources Specialist
West Central Research and Extension Center
North Platte, NE
(308) 696-6709
svandonk2@unl.edu

Buzz Vance
Ag Programmer
Nebraska Department of Agriculture
Lincoln, NE
(402) 471-6853
buzz.vance@nebraska.gov

Monte Vandevreer
Extension Educator
Otoe County
Syracuse, NE
(402) 269-2301
monte.vandevreer@unl.edu

Allan Vyhnalek
Extension Educator
Platte County
Columbus, NE
(402) 563-4901
avyhnhalek2@unl.edu

Simon J. van Donk
West Central Research & Extension Center
North Platte NE 69101-7751
(308) 696-6709
simon.vandonk@unl.edu

Michael Van Liew
Hydrologic Computer Simulation Modeler
Biological Systems Engineering
Lincoln, NE 68583
(402) 472-0839
mvanliew2@unl.edu

D. Wangila
Entomology
Graduate Research Assistant
Stephen Wegulo
Extension Plant Pathologist
Department of Plant Pathology
Lincoln, NE
(402) 472-8735
swegulo2@unl.edu

Bob Wilson
Extension Weed Specialist
Panhandle Research and Extension Center
Scottsbluff, NE
(308) 696-6738
rwilson1@unl.edu

John Wilson
Extension Educator
Burt County
Tekamah, NE
(402) 374-2929
rwilson1@unl.edu

Charles Wortmann
Nutrient Management Specialist
Agronomy and Horticulture
Lincoln, NE
(402) 472-2909
cwortmann2@unl.edu

Bob Wright
Extension Entomologist
Department of Entomology
Lincoln, NE
(402) 472-2128
rwright2@unl.edu

C. Dean Yonts
Extension Irrigation Specialist/Engineer
Steve Young
West Central Research & Extension Center
North Platte NE 69101-7751
(308) 696-6712
steve.young@unl.edu

Gary Zoubek
Extension Educator
York County
York, NE
(402) 362-5508
gzoubek1@unl.edu
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Crop Insurance Aids Nebraska Wheat Growers in 2013, Revenue Guarantees Likely Lower in 2014 for all Crops

Monte Vandeveer, UNL Extension Educator, Otoe County

Lower wheat yields and prices led to significant insurance payouts for the 2013 crop in Nebraska. Corn and soybean yields have bounced back in 2013, but declining prices for corn mean some producers with revenue coverage may receive indemnities if they have even modest yield losses. Lower crop prices for 2014 crops indicate revenue guarantees from crop insurance will probably be significantly lower next year. Producers will also need to check how crop insurance coverage aligns with new safety net programs that may be created under a new Farm Bill.

Some results for 2013

Drought continued to affect many of Nebraska’s wheat growers, while corn and soybean yields recovered in 2013, particularly for dryland producers. Declining prices for corn and wheat also moved those with revenue coverage closer to their revenue guarantees.

Revenue coverage remains the most popular form of coverage in Nebraska, and in 2013 many Nebraska producers also selected higher levels of coverage than they had used in previous years.

Wheat: many growers experienced losses in 2013

The drought of 2012 persisted well into 2013 for much of the major wheat-growing areas of Nebraska, primarily the south central and southwest sections of the state. About 1.47 million acres were planted to wheat in Nebraska in the fall of 2012, nearly all of it non-irrigated. The state average yield for the 2013 crop has been preliminarily reported at 35 bu./acre, down from an average of 45 bu./acre the previous year.

More than 90% of wheat acres insured in Nebraska

Crop insurance participation has been significant in Nebraska for all crops for several years. For the 2013 wheat crop, about 1.35 million acres were insured, making for a participation rate of about 92 percent of planted acres.

Revenue coverage is the most popular form of insurance coverage among Nebraska wheat growers. About 92 percent of 2013 wheat acres were insured under the Revenue Protection (RP) plan, about 7 percent were insured under the Yield Protection (YP) plan, and just less than 1 percent of the acres were insured with the Revenue Protection – Harvest Price Exclusion (RP-HPE) coverage.

Producers selected higher coverage for the 2013 crop, compared to previous years. Figure 1 shows a breakdown of total acreage insured at each level of coverage for 2012 and 2013. For years, the 70% coverage level had been the most popular, but for the 2013 crop they reduced the share of acres insured at 65% and 70%, and increased the share of acres insured at 75% and 80%. This move toward higher coverage was made in spite of the high projected wheat price of $8.79, perhaps to obtain higher revenue guarantee levels.

Lower yields and prices in 2013 for wheat in Nebraska result in significant insurance payments

As mentioned, it was a tough year for yields in Nebraska wheat country, with the state average yield down about 10 bushels from the previous year and approximately 19 percent lower than the trend yield of near 43 bushels per acre. Drought was the primary contributor to this decline, as the dry conditions that began in 2012 lasted through the 2013 harvest for most Nebraska wheat growers.

Wheat prices also declined over the growing season. The RP plan in Nebraska uses mid-August to mid-September prices from the following year’s September winter wheat futures contract to set its projected price. The projected price for the 2013 crop was set at $8.79/bushel in fall 2012.

The harvest price under the RP plan in Nebraska is the average price in July for the September winter wheat futures contract. With wheat prices to some extent reflecting the decline in corn prices as confidence grew about the 2013 corn crop, the wheat harvest price came in at $6.99. This is just over 20 percent below the projected price, meaning that many growers with even small yield losses may have qualified for insurance indemnities.

With many growers experiencing more serious yield losses, coupled with the declining price, insurance payouts
were significant. Just over 60 percent of insured farm units received at least some payment for losses. As of early November 2013, RMA-USDA had reported indemnities of about $110 million to Nebraska wheat producers, making the average payout just over $81 per acre for each acre that was insured (the average payment per acre for those claiming losses would be higher, since not all acres were indemnified).

Another perspective on the extent of losses is the measure of insurance performance called the loss ratio, calculated as total indemnities / total premiums. For the 2013 wheat crop in Nebraska, the loss ratio was 2.13, using results as of early November. Considering that over 56 percent of total premiums were paid by government subsidies, farmers received back about $4.90 for every dollar they paid in premiums.

Corn: yields bounce back, but price falls in 2013

The disaster of the 2012 drought left many Nebraska corn producers grateful for their insurance coverage. Indemnities for lost corn production and rising corn prices amounted to nearly $1.2 billion in 2012, mitigating to some extent what would have been a disastrous year, particularly for dryland producers. Limited moisture during the winter months had farmers holding their collective breath as 2013 planting time approached and market prices remained attractive.

Corn producers also opt for higher coverage levels

In 2013 corn plantings remained strong, with about 10.2 million acres planted in Nebraska. Of these, about 9.05 million acres were insured, producing an insurance participation rate of approximately 89 percent.

Revenue coverage is also the clear favorite among insurance plans for corn growers. The breakdown across plans in 2013 is almost identical to that for wheat: about 91 percent of acres are insured under RP, just under 8 percent are insured with YP, and about 1.5 percent are insured with RP-HPE or one of the group risk (county-based) plans.

Likewise, Nebraska corn producers showed a clear interest in purchasing higher coverage levels for the 2013 crop. Figure 2 shows a comparison between 2012 and 2013 preferences. A year ago, roughly equal shares of the crop were insured at the 70% and 75% levels. However, in 2013 the 75% coverage level maintained its share at around 1/3 of

Soybeans: higher coverage levels chosen but no price change for revenue coverage

Nebraska soybean producers also received significant assistance from their crop insurance coverage in the 2012 drought, with total indemnities reaching about $308 billion. The 2013 planting period was also a tenuous one, as cool, wet conditions hampered planting in the eastern part of the state.

Soybean acres have highest insurance participation rate

Nebraska producers planted about 4.75 million acres of soybeans in 2013, and about 93 percent of these, or 4.43 million acres, were insured. Preferences for insurance plans match those seen for other crops: about 91 percent of acres are insured with RP, 8 percent with YP, and about 1 percent with other plans.

Soybean growers also ratcheted up their coverage for the 2013 crop. Figure 3 shows the change from 2012 to 2013. A year ago, roughly equal shares of the crop were insured at the 70% and 75% levels. However, in 2013 the 75% coverage level maintained its share at around 1/3 of
all acres, while acres insured at the 80% level now surpass those covered at the 70% level. These shifts in Nebraska participation more closely reflect the coverage patterns observed farther east in the Corn Belt.

**Figure 3. Nebraska soybean growers’ choice of coverage level for crop insurance, 2012 and 2013**

**Soybean harvest price matches the projected price**

As with corn, 2013 soybean yield estimates at the date of writing look much better than last year, but official estimates have yet to be announced.

Soybean prices varied widely during the growing season, but ended up near the levels seen prior to planting. The soybean projected price for insurance prior to sign-up in the spring is the average price during February of the November soybean futures contract. The February 2013 average price was $12.87/bushel. The soybean harvest price for revenue coverage is the October average of the same November soybean futures price. As it turned out, the October average price also ended up being $12.87. Thus, producers with revenue coverage were paid only if they had a substantial yield loss.

**What’s coming in 2014?**

Producers need to watch several things as we move into 2014 and face a variety of crop insurance-related decisions. Among the most important of these are the lower levels of revenue protection that revenue insurance will offer this year if prices remain at current levels. Another set of issues involve changes to the crop insurance program itself that are being considered in the new Farm Bill deliberations. Conservation compliance, premium subsidy levels, and limits on the overall premium subsidies received are among the topics here.

**Within-year and year-to-year price protection under revenue insurance**

Revenue insurance utilizes futures market prices to determine market values for the insured commodities. At sign-up, a projected crop price is calculated as the average price for a harvest-time futures contract during a one-month period prior to planting. For Revenue Protection coverage, a harvest price is also calculated as the average price for the same futures contract during a one-month period at harvest.

Because these market-based mechanisms are used to establish the crop price component for the revenue guarantee, revenue insurance offers good within-year price protection. However, there is no protection against year-to-year price changes, because each year’s revenue guarantee only reflects the price available that year. So revenue coverage won’t provide much help with longer-term price declines which reflect changing market conditions.

**Lower prices suggest lower revenue guarantees for insured crops in 2014**

Current market signals indicate that the revenue guarantees provided by revenue-based crop insurance will be significantly lower this year. This year’s projected price for winter wheat is already set. The projected price for the wheat crop to be harvested in the summer of 2014 was calculated as the average price from August 15, 2013, to September 14, 2013, using the September 2104 hard red winter wheat futures contract. This average price came in at $7.11, 19 percent below the previous year’s price of $8.79/bushel.

The projected prices for the 2014 corn and soybeans crops will be established in February 2014. While much can happen before the end of February, current market signals indicate lower prices, and hence lower revenue guarantees, can be expected for these crops, as well.

As this is written in early November 2013, the December 2014 corn futures contract is trading in the range of $4.75, about 16 percent below the $5.65 projected price for the 2013 crop. The November 2014 soybean futures contract is trading around $11.60, about 10 percent below the 2013 price of $12.87/bushel.

**New Farm Bill debate has discussed some changes to crop insurance**

At this writing, the new Farm Bill is being discussed by House and Senate delegates in conference committee. Several changes related to crop insurance had been discussed during the lengthy legislative deliberations to date. One such proposal was tying conservation compliance to crop insurance participation, since compliance was formerly tied to the now-eliminated Direct Payment program. No decision has yet been made as this is being written.

Another change under discussion was a proposal to lower the level of premium subsidies provided by the Federal government. While this item did not make it into final legislation, the Senate version of the Farm Bill did include provisions which would limit premium subsidies to high-income producers. This would be somewhat
analogous to payment limitations in USDA’s various commodity programs. Different limits have been proposed, but the most commonly mentioned one reduces the premium subsidy by 15 percentage points for farmers with more than $750,000 Adjusted Gross Income. No decision has been made by the conference committee on this matter, as well.

**Other safety net features of the new Farm Bill**

Finally, it should be mentioned that the new Farm Bill is making crop insurance the foundation of the farmer safety net provided by government programs. The Direct Payments and Counter-Cyclical Payments programs will be eliminated, and while marketing loans have been retained, loan rates have been set well below expected market price levels.

In the new policy regime, crop insurance is intended to provide protection for the first 75 to 80 percent of farmers’ expected revenues, while other, new programs will be used to provide higher levels of protection. These programs are called Agricultural Risk Coverage in the Senate version and Revenue Loss Coverage in the House version, and both provide protection based on 5-year Olympic average yields and prices.

The House draft version also proposed a price support program called Price Loss Coverage which would establish fixed price protection levels, rather than using an average from recent years. Finally, both House and Senate versions created an additional form of crop insurance called the Supplemental Coverage Option, which would provide higher levels of coverage based on county yields. Once the final legislation is established, be watching for more information on these new programs.
Land Values

Ag land values based on sales continued to climb the past year. The rate of increase has clearly slowed as 2013 progressed. Figure 1 shows the all class land value for Nebraska from 1960 to 2013. The values shown are inflation adjusted to the value of the year 2000. Note that the high land values achieved in 1980 were eclipsed in 2011.

The recent value increases build on the extremely large gains of recent years. The result is a doubling of Nebraska’s all-land market value level over the past three years. (See Table 1). In most areas of the state, the grazing land value gains were significantly below those of the cropland classes, a reflection of severe drought, high input costs, and income shortfalls for the state’s cattle industry.

Who is buying the land?

More than four out of five buyers in recent months have been active farmer buyers who are adding the purchased parcels to their existing operations. In several of the regions, active farms essentially dominated the buyer side of the recent market.

Influencers for land values

Many factors contribute to the rise in land values within the strong agricultural land market. It turns out that the crop prices over the past 12 months were the biggest contributor to the increase in land values. The other top factors supporting land values include: purchasing the land for expansion, interest rates, financial health of current owners, returns to alternative investments, and the amount of land offered for sale.

Table 1: 2013 Values and Recent Trends by Land Class in Nebraska*

<table>
<thead>
<tr>
<th>Land Class</th>
<th>2013 Average Value Dollars/Acre</th>
<th>1-Year Change Percentage</th>
<th>3-Year Change Percentage</th>
<th>5-Year Change Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland Cropland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Irrigation Potential</td>
<td>3010</td>
<td>25</td>
<td>97</td>
<td>106</td>
</tr>
<tr>
<td>Irrigation Potential</td>
<td>5270</td>
<td>21</td>
<td>102</td>
<td>116</td>
</tr>
<tr>
<td>Grassland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tillable</td>
<td>1230</td>
<td>22</td>
<td>84</td>
<td>89</td>
</tr>
<tr>
<td>Nontillable</td>
<td>695</td>
<td>19</td>
<td>64</td>
<td>54</td>
</tr>
<tr>
<td>Hayland</td>
<td>1585</td>
<td>27</td>
<td>96</td>
<td>86</td>
</tr>
<tr>
<td>Irrigated Cropland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravity</td>
<td>6835</td>
<td>27</td>
<td>109</td>
<td>128</td>
</tr>
<tr>
<td>Center Pivot**</td>
<td>7590</td>
<td>30</td>
<td>115</td>
<td>140</td>
</tr>
<tr>
<td>All Land</td>
<td>3040</td>
<td>25</td>
<td>102</td>
<td>115</td>
</tr>
</tbody>
</table>

*Annual UNL Nebraska Farm Real Estate Market Developments Surveys.
**Value of pivot not included in per acre value.
I have already had landlords and tenants, but especially tenants, contact me regarding what the cash rents will be for 2014. The question is generally, “What should I charge (or pay) for cash rent next year?” The best answer that I can give is “it depends.” If that sounds like a non-answer, let me explain.

Logically, if you look at the top rents mentioned at places of socialization, such as places where people gather for coffee, it seems to me that rent should go down some. The economics just does not support $350.00 per acre for dryland rent, or $500.00 per acre for irrigated ground cash rent.

If you want to get into a ball park figure, let’s look at where the rent might be based on average yields and expected commodity price levels for 2014. For illustration and discussion, I am using eastern Nebraska data. Too many times, the landlord wants to calculate rent on the best yield and the price of about $8.00 per bushel, which is the best price of the last year. The tenants want to calculate rent on the poorest yielding year of the last ten years and the lowest price of the last year, which might be about $3.90 per bushel. Neither point of view is fair, or realistic.

I have suggested that a starting point for rent should be about 30% of the gross revenue per acre, which would be paid to the landlord. I also insist that this calculation be completed by taking an average yield times a fall 2014 price at the local elevator or grain processor. So, an average irrigated corn yield of 200 bushels per acre times an expected fall 2014 price of about $4.40 would be $880.00 gross revenue per acre. That multiplied by 30% would be a suggested rent of $264.00 per acre. This would be the starting point for negotiating rent for 2014.

Now having said that, rent will be determined by what the tenant is willing to pay and what the landlord is willing to accept, and not by a suggested calculation. True economics of a particular commodity is still determined by supply and demand. With land economics, the demand is still exceeding supply from what I am able to determine. As long as this situation exists, cash rents will probably still remain strong for the state. So, a specific rent on a specific farm will vary. This proves why I am right with my original answer. Where will cash rent be in 2014? “It depends!”

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**Table 2: Reported Cash Rental Rates for Various Types of Nebraska Farmland and Pasture: 2013**

<table>
<thead>
<tr>
<th>Type of Land</th>
<th>Agricultural Statistics District</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Northwest</td>
</tr>
<tr>
<td><strong>Dryland Cropland:</strong></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>40</td>
</tr>
<tr>
<td>% Change</td>
<td>3</td>
</tr>
<tr>
<td>High</td>
<td>54</td>
</tr>
<tr>
<td>Low</td>
<td>29</td>
</tr>
<tr>
<td><strong>Gravity Irrigated Cropland:</strong></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>b</td>
</tr>
<tr>
<td>% Change</td>
<td>b</td>
</tr>
<tr>
<td>High</td>
<td>b</td>
</tr>
<tr>
<td>Low</td>
<td>b</td>
</tr>
<tr>
<td><strong>Center Pivot Irrigated Cropland:</strong></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>225</td>
</tr>
<tr>
<td>% Change</td>
<td>13</td>
</tr>
<tr>
<td>High</td>
<td>265</td>
</tr>
<tr>
<td>Low</td>
<td>170</td>
</tr>
<tr>
<td><strong>Pasture:</strong></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>13</td>
</tr>
<tr>
<td>% Change</td>
<td>0</td>
</tr>
<tr>
<td>High</td>
<td>17</td>
</tr>
<tr>
<td>Low</td>
<td>9</td>
</tr>
</tbody>
</table>

**SOURCE:**
- *Reporters’ estimated cash rental rates (both averages and ranges) from the 2013 UNL Nebraska Farm Real Estate Market Developments Survey.*
- *Insufficient number of reports.*
- *Cash rents on center pivot land assumes landowners own total irrigation system.*
Climate Information for Agricultural Decisions in Nebraska

Tapan B. Pathak, Extension Educator in Climate Variability, University of Nebraska-Lincoln

Introduction

It is evident that the technological improvements in agriculture have changed the way producers make decisions for their farms. Producers are proactively adapting to the new scientific information obtained through university Extension for making real-time decisions in order to enhance productivity and minimize risks. It is evident that climate has significant influence on agricultural productions; effective use of climate information in agricultural decision also becomes a top priority effort. In this report, agricultural climatology information is provided with examples of how such information can be incorporated into the agricultural decision that producers make at different time-scales.

Soil temperature for spring planting

To ensure better germination, one of the key factors to consider is optimum soil temperature. Regardless of the climate zone or year, seeds require optimum soil temperatures to germinate and sustain early development. Averaging soil temperatures over a decade provides insight for timing spring planting for different crops. Attached NebGuide (G2122) provides information on: 1. when does the soil temperature become suitable for planting agricultural and horticultural crops in Nebraska? 2. Are the optimum soil temperatures for planting spring and summer crops shifting to earlier or later dates?

Growing degree day accumulations for corn under spring and fall freeze risks

Growing degree days (GDD) are an important measure to track growth and development of corn. Since GDD are based on temperature, the total number of GDDs accumulated during a growing season may vary considerably from one location to another. Average GDD accumulations under various freeze risk scenarios provide useful information for corn producers selecting an appropriate corn hybrid along with planting and harvest dates for corn. For this analysis, GDD accumulations were calculated based on an 86/50 range, with understanding that corn does not grow when the temperature is above 86°F or below 50°F. Tables 1-3 summarize GDD accumulations under three spring and fall freeze risks scenarios — low, medium, and high for Lincoln, Norfolk, and Scottsbluff area.

- Low freeze risk corresponds to a 10% chance of freeze impacting corn in spring/fall.
- Medium freeze risk corresponds to a 50% chance of freeze impacting corn in spring/fall.
- High freeze risk corresponds to a 90% chance of freeze impacting corn in spring/fall.

Here is an example of how to use above table for agricultural decisions. Table 3 shows an outlook for Scottsbluff, which lies in a different climate zone. Scottsbluff only accumulated 2219 GDD under the low freeze risk scenario. So, for instance, if you wanted to plant a 2400 GDD corn variety in Scottsbluff, you would assume a medium to high risk of freeze. Please note that this summarized data is based on 30-year averages. While assessing current trends and making decisions for your operation, also consider year-to-year variability.

Growing degree day tool – Useful to Usable (U2U) project

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers, is an integrated research and extension project working to improve farm resilience and profitability in the North Central Region by transforming existing climate...
information into usable knowledge for the agricultural community. Research team of the U2U project has developed a tool for tracking long-term average GDD as well as comparing it with recent and/or current year in order to obtain site specific information. With few clicks on the map, user can obtain specific information about timing of silking and black layer, total GDD accumulations compared to long-term averages, as well as coinciding last spring and first fall freeze. User can provide input on GDD start date, comparison year, corn maturity days, and freeze temperature in order to obtain GDD information for 30-year average, current year, and any other year or interest. Figure 1 provides a snapshot of the tool. This tool can be accessed through www.agclimate4u.org.

Fall freeze information for harvesting decisions

In order to make harvesting decisions, fall freeze statistics play an important role. There may be years when spring planting of crops are delayed due to conditions such as prolonged spring frost or wetter than normal conditions. In such scenarios, getting information on earliest, average, and last fall freeze occurred in long-term (30 years) could be useful to plan ahead of time for harvesting decisions. The maps show the earliest fall freeze, median fall freeze, and latest fall freeze that occurred in the last 30 years using freeze statistics from 139 stations across Nebraska. Data was obtained from the High Plains Regional Climate Center. Note: The map shows a few spots that do not match the general trend over the region. This is because data from those weather stations report temperatures from immediate surroundings and may have been influenced by the microclimate around those weather stations. These frost maps should be used to assess both worst case and best case scenarios when making local harvesting decisions.
Soil Temperature: A Guide for Planting Agronomic and Horticulture Crops in Nebraska

Tapan B. Pathak, Assistant Extension Educator
Kenneth G. Hubbard, Climatologist
Martha Shulski, Assistant Professor

Over the last decade there has been a shift toward soil temperatures warming earlier, allowing farmers to plant sooner.

Year to year climate variability is an unavoidable issue for agriculture in Nebraska. Since agricultural practices rely heavily on climatic conditions, it is risky to make certain agricultural management decisions based on the calendar date. One such decision is when to plant agronomic and horticulture crops.

To ensure better germination, one of the key factors to consider is optimum soil temperature. Regardless of the climate zone or year, seeds require optimum soil temperatures to germinate and sustain early development. Farmers who plant before optimum temperatures are reached risk productivity loss due to seed death or poor germination, and limited initial growth that might occur because of the lower soil temperature.

The minimum soil temperature for planting a given crop is reached on different dates from year to year. Averaging soil temperatures over a decade provides insight for better management decisions. The main research questions for this study were:

1. When does the soil temperature become suitable for planting agricultural and horticultural crops in Nebraska?
2. Are the optimum soil temperatures for planting spring and summer crops shifting to earlier or later dates?

Minimum Soil Temperature for Crop Germination

Soil temperature plays an important role in seed germination. Adequate soil temperatures for germination range widely for different crops. For example, the optimum soil temperature for planting field corn is 55°F. Once the soil temperature has remained at or above 55°F for five to seven consecutive days, corn will likely germinate more quickly and have a more uniform stand. If planted before the soil temperature is 55°F, corn germination and emergence may get delayed for several days and growth may be compromised. Meyer and Dutcher (1998) summarized the recommended minimum soil temperature of selected agronomic and horticulture crops (digitalcommons.unl.edu/extensionhist/733). Temperature ranges specified in Table 1 are based on cited literature and should be used as a general guideline.

Table 1. Recommended minimum temperatures needed for germination of selected agricultural crops.

<table>
<thead>
<tr>
<th>Agronomic Crops</th>
<th>Minimum Soil Temperature at Planting (°F)</th>
<th>Horticultural Crops</th>
<th>Minimum Soil Temperature at Planting (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring wheat</td>
<td>37</td>
<td>Spinach</td>
<td>38</td>
</tr>
<tr>
<td>Spring barley</td>
<td>40</td>
<td>Radish</td>
<td>40</td>
</tr>
<tr>
<td>Rye</td>
<td>41</td>
<td>Lettuce</td>
<td>41</td>
</tr>
<tr>
<td>Oats</td>
<td>43</td>
<td>Onion</td>
<td>41</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>45</td>
<td>Pea</td>
<td>42</td>
</tr>
<tr>
<td>Spring canola</td>
<td>50</td>
<td>Potato</td>
<td>45</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>50</td>
<td>Cabbage</td>
<td>45</td>
</tr>
<tr>
<td>Field corn</td>
<td>55</td>
<td>Carrot</td>
<td>46</td>
</tr>
<tr>
<td>Soybean</td>
<td>59</td>
<td>Sweet Corn</td>
<td>55</td>
</tr>
<tr>
<td>Sunflower</td>
<td>60</td>
<td>Pepper</td>
<td>57</td>
</tr>
<tr>
<td>Millet</td>
<td>60</td>
<td>Snap Beans</td>
<td>57</td>
</tr>
<tr>
<td>Sorghum</td>
<td>65</td>
<td>Tomato</td>
<td>57</td>
</tr>
<tr>
<td>Dry bean</td>
<td>70</td>
<td>Cucumber</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pumpkin</td>
<td>60</td>
</tr>
</tbody>
</table>
Soil temperature data were obtained from the High Plains Regional Climate Center’s Automated Weather Data Network (AWDN) stations (www.hprcc.unl.edu). At 49 AWDN stations across the state, the date when five-day running average soil temperatures reached selected temperatures between 40°F and 70°F were recorded and averaged for 10 years (2000-2009). Spatially distributed maps showing the days when the optimum soil temperatures were reached were created using ArcGIS inverse distance weighted spatial interpolation (Figure 1). Figure 1 shows the general distribution across the state when the average soil temperature becomes warm enough for germination. For example, based on the average soil temperature for the last 10 years, we can expect that a 55°F soil temperature will be reached between April 6 and April 10.
26 across Nebraska. Since field corn requires a minimum soil temperature of 55°F to properly germinate, the earliest time to plant would be in the second week of April in southeast Nebraska, the third week of April in central Nebraska, and the fourth week of April in most of the Panhandle. Similarly, the average earliest planting time for other crops can be found in Figure 1 and Table I.

It is important to understand that the soil temperature maps shown in Figure 1 provide an average trend using the last 10 years of data to provide generalized results. When making planting decisions, year to year soil temperature variations also should be recognized. Soil temperature maps can be obtained from the High Plains Regional Climate Center (www.hprec.unl.edu).

**Shifts in Planting Dates Between Previous Two Decades**

In order to understand if soil temperatures have changed over time, the dates when soil temperature averages reached the temperatures specified in Table I during the last two decades were examined.

In Figure 2, red shaded areas indicate that average soil temperatures occurred earlier during the 2000-2009 period than in the 1990-1999 period. In other words, red indicates temperature shift towards earlier soil warming and a potential for Earlier planting dates, and blue indicates the opposite. The maps for 55, 60, 65 and 70°F indicate areas with significantly Earlier planting dates in the most recent decade (red) due to warmer soil temperatures.

**Figure 2. Deviations in planting dates observed in the decade (2000-2009) with respect to the previous decade (1990-1999). Red color indicates that the average planting dates shifted earlier in 2000-2009 compared to 1990-1999.**
The spatial maps show a very prominent trend; the dates when soil temperature averages reach a specific temperature between 50 and 70°F have shifted one to three weeks earlier than in the previous decade. The mean values (Table II) from 29 AWDN stations also showed a shift of a week or more in the planting date for 55 and 60°F average soil temperatures. Crops such as corn, soybean, and sorghum fall under the 55 to 60°F average soil temperature planting guideline and may experience earlier planting in the future. This study also shows that the earlier shift isn’t consistent for all temperature thresholds. The date when average soil temperature reached the 40°F planting threshold used for spring barley, spring wheat, and other cool season crops occurred at a slightly later date in the 2000-2009 period when compared to 1990-1999, but only by one day at most locations (Table I).

Table II. Day on which soil temperature averages reached select values from 40-70°F across 29 AWDN soil temperature stations in Nebraska.

<table>
<thead>
<tr>
<th>Year</th>
<th>40°F</th>
<th>45°F</th>
<th>50°F</th>
<th>55°F</th>
<th>60°F</th>
<th>65°F</th>
<th>70°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1999</td>
<td>68</td>
<td>81</td>
<td>96</td>
<td>114</td>
<td>127</td>
<td>138</td>
<td>152</td>
</tr>
<tr>
<td>2000-2009</td>
<td>69</td>
<td>82</td>
<td>93</td>
<td>105</td>
<td>118</td>
<td>134</td>
<td>146</td>
</tr>
<tr>
<td>Difference</td>
<td>1</td>
<td>1</td>
<td>-3</td>
<td>-9</td>
<td>-9</td>
<td>-4</td>
<td>-6</td>
</tr>
</tbody>
</table>

Can Shift be Attributed to Climate Change?

The earlier planting dates in the most recent decade occurred because of an increase in soil temperatures. The trend over this short period is consistent with a changing climate but cannot be separated from natural climate variability. For a climate change trend, soil temperature data need to be evaluated over a larger period of time, such as 100 years, but measured soil temperature data is not available for that span of time in Nebraska. Another plausible inference of recent increased soil temperature could be the prolonged drought conditions that were experienced in Nebraska in last decade. Soil moisture is deficient during drought conditions, which typically act as a driver for increasing soil temperature. Although increased soil temperature is difficult to distinguish from climate variability, it can be used as a precursor to alert decision makers of a possible evolving trend.

The general trend supports the fact that the spring planting season has been arriving earlier in the year for warmer season crops like corn, soybean, and sorghum. The spring planting season for spring wheat, spring barley, and oats has been coming later in the year. If climatic conditions are closely monitored and farmers can plant earlier, the benefit would be that a longer-season hybrid could be selected with a corresponding higher yield potential. Similar analysis is recommended for analyzing freeze risk and length of growing season. If the freeze distribution is not shifting at the same rate as soil temperature, it may increase a risk to agricultural production. Conversely, if freeze analyses also show similar pattern as soil temperature, more confidence in earlier planting can be obtained.

This publication has been peer reviewed.

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Index: Climate & Weather
Crop Effects
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Switchgrass for Biomass Energy

Rob Mitchell¹ and Marty Schmer²

¹USDA-ARS Grain, Forage, and Bioenergy Research Unit, Lincoln, NE 68583  
²USDA-ARS Agroecosystem Management Research Unit, Lincoln, NE 68583


Introduction

Switchgrass (Panicum virgatum) has a long history of production for hay, forage, and conservation purposes. Recently, attention has been given to switchgrass as a model perennial grass for bioenergy production to reduce foreign oil dependence, boost rural economies, reduce fossil fuel emissions, reduce erosion on marginally productive cropland, and enhance wildlife habitat. Long-term studies have demonstrated that best management practices will maintain productive, profitable, and sustainable switchgrass stands for more than 10 years on marginally productive cropland in the eastern half of Nebraska.

Switchgrass is a perennial warm-season grass that is native to most of North America except for areas west of the Rocky Mountains and north of 55° N latitude. Switchgrass grows 3 to 10 feet tall and is adapted to a wide range of habitats and climates. Root depth of established switchgrass can reach 10 feet, but most of the root mass is in the top 12 inches of soil.

Switchgrass has distinct lowland and upland ecotypes. Upland ecotypes occur in upland areas that are not subject to flooding, whereas lowland ecotypes are found on flood plains and other areas that receive run-on water. Generally, lowland plants have a later heading date and are taller with larger and thicker stems. Lowlands and uplands have been crossed to produce true F1 hybrids that have a 30 to 50% yield increase over the parental lines. The F1 hybrids were intermated for two generations to stabilize the population, then bred for one cycle of selection for improved yield and low lignin, resulting in the 2013 release of ‘Liberty’ switchgrass, the first biomass-specific cultivar for the Great Plains and Midwest.

Establishing stands

Successful stand establishment during the seeding year is mandatory for economically viable switchgrass bioenergy production. Weed competition is the major reason for stand failure in the seeding year. Switchgrass is readily established when quality certified seed of an adapted cultivar is used with the proper planting date, seeding rate, seeding method, and weed control. In the central Great Plains, plant switchgrass 2 or 3 weeks before to 2 or 3 weeks after the recommended planting dates for corn, typically from late April to early June. Plant switchgrass at 30 pure live seed (PLS) per ft² (~5 PLS pounds per acre) based on the quality of the seedlot. For best results, plant into soybean stubble with a properly-calibrated no-till drill with depth bands that plant seeds 0.25” to 0.5” deep followed by press wheels. Typical row spacing is 6 to 10 inches. If planting after crops that leave heavy residue like corn, graze or bale the stalks, or use tillage to reduce the residue. If tillage is required, the seedbed needs to be packed to firm the soil similar to planting alfalfa. The packed soil needs to be firm enough so that walking across the field leaves only a faint footprint. Apply 8 ounces of quinclorac per acre immediately after planting to control early season grassy and broadleaf weeds. The most cost-effective method to control broadleaf weeds in switchgrass fields during the planting year is to apply 2,4-D at 1 qt. acre⁻¹ after switchgrass seedlings have about four leaves. After the planting year, successfully established stands require limited herbicide applications.

Soil tests are recommended prior to planting. Since switchgrass is deep rooted, take soil samples from each 1-foot increment to a depth of 5 feet. N fertilizer is not recommended during the planting year since N encourages weed growth, increases competition for establishing seedlings, and increases establishment costs. Adequate levels of phosphorus (P) and potassium (K) will be available in most agricultural fields. If warranted by soil tests, P and K can be applied before seeding to encourage root growth and promote rapid establishment. If soils test medium, low, or very low for P, apply 10, 20, or 40 pounds of P per acre, respectively. Switchgrass can tolerate moderately acidic soils but optimum seed germination occurs when soil pH is between 6 and 8.
With good weed management and favorable precipitation, a crop equal to about half of potential production can be harvested after frost at the end of the planting year, with 75-100% of full production achieved the year after planting.

Managing established stands

Although switchgrass survives on low fertility soils, it does respond to fertilizer, especially N. The amount of N required by switchgrass is a function of the yield potential of the site and cultivar. Yield and stands will decline over years if inadequate N is applied, since harvesting removes large quantities of N. For example, harvesting 5 tons acre\(^{-1}\) of switchgrass DM after frost with a crude protein concentration of 4% (0.64% N) will remove 64 pounds of N acre\(^{-1}\). Not all removed N has to be replaced with fertilizer N because of atmospheric deposition and soil mineralization, but this will vary with location and soil. In general, for post-frost harvests, about 50 to 65 lbs of N acre\(^{-1}\) yr\(^{-1}\) should be applied to meet expected yield goals. In Nebraska and Iowa, ‘Cave-In-Rock’ switchgrass yields increased as N rate increased from 0 to 270 pounds of N acre\(^{-1}\), but residual soil N increased if more than 100 pounds of N acre\(^{-1}\) was applied. Soil testing should be conducted periodically to monitor soil N levels. Apply N at switchgrass green up to minimize cool-season weed competition.

Controlling broadleaf weeds with herbicides typically is needed only once every 3 or 4 years in an established, well-managed stand. For broadleaf weeds, the most effective and economical approach is with 2,4-D applied as early in the growing season as possible to reduce the impact of weed interference on switchgrass yield. In some cases, cool-season grasses may invade switchgrass stands and reduce yield. Harvesting after senescence in autumn but while cool-season grasses are growing, then applying glyphosate is an effective method to reduce cool-season grasses and winter annuals. Make certain switchgrass is dormant when glyphosate is applied or stands could be damaged.

Maximizing biomass recovery, matching feedstock quality to the conversion platform, and maintaining productive stands are the primary harvesting objectives. Productive stands are maintained indefinitely with proper harvest timing, cutting height, and adequate N fertility. In the first 9 years of a long-term study, switchgrass biomass was greatest in plots fertilized with 100 pounds of N acre\(^{-1}\) and harvested at a 4-inch stubble height after frost. A single harvest after frost to a 4" stubble height has maintained stand productivity and persistence, even during drought, and is the harvest BMP for the Great Plains and Midwest.

Switchgrass can be harvested and baled with commercially-available haying equipment. Self-propelled harvesters equipped with a rotary head (disc mowers) are best for harvesting high-yielding (>6-ton per acre) switchgrass fields. Round bales tend to have less storage losses than large square bales (>800 lbs) when stored outside, but square bales tend to be easier to handle and load a truck for transport without road width restrictions. After harvest, poor switchgrass storage conditions can result in storage losses of 25% or greater in a single year. In addition to storage losses in weight, biomass quality may degrade to the point of being in unacceptable condition for a biorefinery. Switchgrass grown for biomass may have to be stored for a full year or longer since biorefineries will operate 365 days a year. Some type of covered storage is needed to protect the biomass.

Potential yield

Switchgrass yield depends on factors like precipitation, fertility, soil, location, and genetics. Most switchgrass research has been conducted on forage-type cultivars, which, in the Great Plains and Midwest, are entirely represented by upland ecotypes with lower yield than lowland ecotypes. Yields reported for forage-type upland cultivars like Cave-In-Rock, ‘Shawnee’, and ‘Trailblazer’ do not capture the full yield potential of switchgrass. For example, in Nebraska the bioenergy-specific cultivar ‘Liberty’ released in 2013 produced 8.1 tons acre\(^{-1}\) year\(^{-1}\), which was 2.4 tons acre\(^{-1}\) year\(^{-1}\) greater than Shawnee. Knowing the origin of a cultivar is important since switchgrass is photoperiod sensitive. Planting a switchgrass cultivar too far north of the cultivar origin area (>300 miles) can result in winter stand loss. Planting a switchgrass cultivar south of its origin area results in less biomass because the shorter photoperiod causes plants to flower too early.

Growing switchgrass must be profitable for farmers, it must fit into existing farming operations, it must be easy to store and deliver to the ethanol plant, and extension efforts must be provided to inform farmers on BMPs, all of which have been addressed for switchgrass. Harvesting after frost is a time when most farmers have completed corn and soybean harvests and handling switchgrass as a hay crop is not foreign to most producers. The economic opportunities of switchgrass for small, difficult to farm, or poorly-productive fields will be attractive to many farmers.

There are potential difficulties with large-scale switchgrass monocultures. Concerns arise for potential disease and insect pests, and the escape of...
switchgrass as an invasive species. Most pathogen issues will not be fully realized until large areas are planted to switchgrass. However, the broad genetic diversity available to switchgrass breeders, the initial pathogen screening conducted during cultivar development, and the fact switchgrass has been a native component of central US grasslands for centuries will likely limit the negative pest issues. Switchgrass has been used for decades in the Great Plains and Midwest for pasture and conservation purposes and no invasive problems have been identified.

**Production cost**

An economic study based on the 5-year average of 10 farms in Nebraska, South Dakota, and North Dakota indicated farmers can grow switchgrass at a farm gate cost of $60/ton. However, farmers with experience growing switchgrass had 5-year average costs of $43/ton, and one farmer grew switchgrass for $38/ton. These costs include all expenses plus land costs and labor at $10/hour. Each big round bale represents 50 gallons of ethanol assuming 80 gallons per ton of switchgrass, with a farm gate cost of $0.75/gallon at $60/ton. This research from 50 production environments indicates that growing switchgrass for cellulosic ethanol is economically feasible in the central and northern Great Plains. Fuel and land prices have increased since this study so these increased input costs need to be considered when determining production costs.

**Environmental and Sustainability Issues**

Sustainable biomass energy crops must be productive, protective of soil and water resources, and profitable for the farmer. Numerous studies have reported that switchgrass will protect soil, water and air quality, provide fully sustainable production systems, sequester C, create wildlife habitat, increase landscape and biological diversity, increase marginal farmland production, and increase farm revenues. Switchgrass root density in the surface 6-inches is 2-fold greater than alfalfa, more than 3-fold greater than corn, and more than an order of magnitude greater than soybean. In a 5-year study in Nebraska, the potential ethanol yield of switchgrass averaged 372 gallons acre⁻¹ and was equal to or greater than that for no-till corn (grain + stover) on a marginally-productive dry-land site. Growing switchgrass on marginal sites likely will enhance ecosystem services more than on productive sites.

**Feasibility**

Switchgrass for bioenergy has several challenges. A stable and consistent feedstock supply must be provided year-round to the ethanol or power plant. For the producer, switchgrass must be profitable, it must fit into existing farming operations, it must be easy to store and deliver to the plant, and extension efforts must be provided to inform farmers on the BMPs. However, switchgrass has potential for improvement, and presents a unique opportunity for cultural change on the agricultural landscape. There are numerous environmental benefits to switchgrass that can improve agricultural land use practices such as stabilizing soils and reducing soil erosion, improved water quality, increased and improved wildlife habitat, and storing C to mitigate greenhouse gas emissions. All of these benefits can be achieved, provided that switchgrass cropping systems are fully developed and accepted by farmers. Switchgrass and other perennial grasses may be used in conjunction with corn stover and wheat straw to meet feedstock demands.

Growing seed to meet potential bioenergy demand will not be an issue. Switchgrass has many desirable seed characteristics and can produce viable seed during the seeding year, especially under irrigation. Established seed fields can grow 500 to
1,000 pounds of seed per acre with irrigation, and the seed is easily threshed, cleaned, and planted with commercial planting equipment. Seed production systems are well-established and a commercial industry for switchgrass seed has existed for over 50 years.

**Summary**

Contrary to popular belief, switchgrass is not a new or novel crop, but has more than 75 years of research and farming experience. Currently available plant materials and production practices can reliably-produce 6-8 tons per acre in the central Great Plains and Midwest. New cultivars and management practices will significantly increase yields similar to the yield increases achieved in corn in the last 30 years. The availability of adequate acres of cropland and the relative profit potential will determine the feasibility of growing switchgrass. BMPs and plant materials are available to achieve sustainable and profitable biomass production, for both farmers and bio-refineries, to help meet the energy requirements of the nation and reduce our dependence on foreign oil.

**Table 1.** Dry matter (DM) yield, acres required to grow 625,000 tons of dry matter per year, and the percent of the land base required to provide feedstock for a 50-million gallon cellulosic ethanol plant for different herbaceous perennial feedstocks in the Great Plains and Midwest.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Yield, DM tons/acre</th>
<th>Acres need to grow 625,000 DM tons/year</th>
<th>Percent of land in 25-mile radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIHD prairie(^1)</td>
<td>1.75</td>
<td>357,000</td>
<td>28</td>
</tr>
<tr>
<td>Managed native prairie(^2)</td>
<td>2.5</td>
<td>250,000</td>
<td>20</td>
</tr>
<tr>
<td>Shawnee switchgrass(^3)</td>
<td>5</td>
<td>125,000</td>
<td>10</td>
</tr>
<tr>
<td>Liberty switchgrass(^4)</td>
<td>8.1</td>
<td>77,160</td>
<td>6.1</td>
</tr>
<tr>
<td>Hybrid switchgrass(^5)</td>
<td>9.4</td>
<td>66,489</td>
<td>5.3</td>
</tr>
</tbody>
</table>

\(^1\)Low-input, high-diversity man-made prairies.
\(^2\)Native tallgrass prairie burned and fertilized in late spring to promote warm-season grasses.
\(^3\)Shawnee is an upland forage-type switchgrass cultivar released in 1995.
\(^4\)Liberty switchgrass is a bioenergy-specific cultivar released in 2013.
\(^5\)F1 hybrid of ‘Summer’ and ‘Kanlow’ switchgrass could be commercially available in less than 10 years.
Conserving Beneficial Insects in Cropping Systems

Jeff Bradshaw, Entomology Specialist
Johan Pretorius, Graduate Research Assistant

One role of Integrated Pest Management is to facilitate the use of multiple tools, tactics, and strategies for the management of pests and pathogens. The outcome of this pest management scheme includes reduced economic and environmental costs. Many of the pests we manage are arthropods. However, recent research has also generated a renewed interest in the services and benefits that some groups of arthropods provide within our agricultural systems. Broadly speaking, these benefits (e.g., pollination, pest suppression, etc.) are often referred to as a kind of "ecosystem service". To better understand how to integrate pest and production management processes in agricultural systems we have begun to identify which arthropods might serve as a natural resource to render ecosystem services in our production systems in western Nebraska. In other words, if we manage pest arthropods, could we also manage beneficial arthropods?

In light of this question, one aspect of crop production to consider is tillage. There has been much research concerning the impact of various forms of tillage on weeds, pest insects, and plant pathogens. In the past some of these tillage practices have been recommended for the suppression of pest insects that overwinter within crop residue (e.g., the European corn borer). However, recent popular literature suggests there are broadly-applicable benefits in "soil health" or "plant health" to reduced tillage. The outcome of this management of pests and pathogens. The initial finding makes sense as ecologists have found that less disturbed systems generally favor greater species diversity.

What Beneficial Arthropods Are Found In The Soil?

Through the past three years of sampling at Mitchel Station, we have learned that at least four groups of chiefly beneficial arthropods are most abundant on or within those soils: Araneae (spiders), Chilopoda (centipedes), Carabidae (ground beetles), and Staphylinidae (rove beetles). The species within these groups are largely predatory on other arthropods. However, the ground beetles are a diverse group that will prey on other insects (e.g., root aphids and root worms), and also feed on weed seeds. Out of all of these most abundant groups, ground beetles were by far the highest in number (in 2012, 3,734 individuals were collected in one season of 360 samples).

Through sampling these arthropods in the soil, we found that just one season of a zone-tillage operation conserved more spiders, centipedes, and rove beetles compared to a spring plow operation in sugar beets following corn. The reduced tillage operation allowed for, presumably, more corn residue and complex soil structure that facilitated an increase in habitat and shelter for these groups. However, there were no differences in total ground beetle numbers. We had this result even while the total number of sampled ground beetles was large (3,734), with about 40 species of ground beetles at this one location just in 2012 alone! Thus, it was surprising to find no differences in ground beetle numbers given that the larvae of this group live in the soil; however, this family is known to be very diverse and likely does not tell the entire story. Therefore, we took a closer look at the function of these dominant species that we collected within these two tillage conditions.

What Are All of These Ground Beetles Doing?

Analyzing the data a little closer we found that 2 species dominated our samples, Harpalus eraticus and Elaphropus anceps (Table 1). Contrary to the overall analyses, all of the less common or rare species appear to be conserved with reduced tillage. This initial finding makes sense as ecologists have found that less disturbed systems generally favor greater species diversity.

Table 1. Percentage abundance of the seven most numerous ground beetle species collected in two tillage systems in 2012. The percentage abundance of the remaining species is indicated as 'other'.

<table>
<thead>
<tr>
<th>Carabidae species</th>
<th>Zone tilled</th>
<th>Spring plow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harpalus eraticus Say</td>
<td>34.1</td>
<td>49.0</td>
</tr>
<tr>
<td>Elaphropus anceps Say</td>
<td>23.3</td>
<td>25.4</td>
</tr>
<tr>
<td>Harpalus pensylvanicus</td>
<td>9.63</td>
<td>5.02</td>
</tr>
<tr>
<td>Amara carinata</td>
<td>6.18</td>
<td>4.00</td>
</tr>
<tr>
<td>Cicindela punctulata</td>
<td>4.10</td>
<td>4.88</td>
</tr>
<tr>
<td>Bembidion quadrimaculatum</td>
<td>6.48</td>
<td>2.83</td>
</tr>
<tr>
<td>Harpalus amputatus</td>
<td>2.08</td>
<td>1.61</td>
</tr>
<tr>
<td>Other</td>
<td>13.9</td>
<td>7.17</td>
</tr>
</tbody>
</table>

However, functionally, rare species may provide less benefit to a system relative to the more dominant species. Therefore, we focused further study on our two dominant species mentioned above that make up more than 50% of the species we see in our studied cropping system.

Interestingly, we already know a little about our two dominant species. Elaphropus anceps (Fig. 1)
is a generalist predator that has been shown to reduce the establishment of pest insects. It is a small insect (~2 mm) that could easily move into and through soil cracks and crevices to consume, for example, root-feeding insects. On the other hand, *Harpalus eraticus* (Fig. 2) is a slightly larger ground beetle (~20 mm) that feeds almost exclusively on seeds, particularly seeds found on the soil surface, such as weed seeds. We conducted some further studies to determine the functional role of these and other dominant ground beetles on pest predation in and weed seed consumption under our western Nebraska conditions.

**Some Ground Beetles are Voracious Predators**

To measure predation rates of pest insects by beneficial insects, we conducted studies in the lab and in the field. For our field studies, we constructed special cages that excluded mammals but that would allow ground beetles to enter the cages. Within these cages we placed three moth larva that we pinned to modeling clay. We found significantly higher predation of moth larvae at night than in the day (ground beetles are nocturnal, so this finding provides additional evidence that ground beetles are active predators in these systems). Additionally, through laboratory studies we confirmed that some of the most dominant species of ground beetles do feed on root aphids as well as pea aphids. However, we did not find a difference in predation rates of moth larvae between tillage systems.

**Some Ground Beetles are Voracious Weed Seed Feeders**

We conducted studies in the lab and in the field to measure weed seed consumption by our dominant, seed-feeding ground beetles. For our field studies, we used the same cages as in the predation study. Within these cages we placed 20 or 30 weed seeds (depending on the seed size) of four weed species: barnyard grass, lambsquarters, kochia, and yellow foxtail. These seed-consumption cages were placed in an experimental design in sugar beet fields (following corn) that had been subjected to a spring plow or zone-tillage practice.

With these field studies we found the rate of weed seed consumption to be significantly lower in plots under a spring plow operation than fields that were subjected to zone tillage (Fig. 3). Additionally, ground beetles appear to consume barnyard grass, kochia, and yellow foxtail at a significantly higher rate than lambsquarters. So, even though the abundance of these insects does not differ between tillage conditions, the function of these weed seed consumers is dramatically increased under a reduced-tillage condition. This indicates that we might be able to manage production systems to benefit an increase in beneficial insects that suppress weed production. Therefore, reduced tillage may conserve the function of some characteristics of healthy ecosystems for the benefit of crop production.
Figure 3. Mean probability of weed seeds being removed for the four weed species tested in each tillage practice. Different letters denote statistical differences in removal rates between different weed species (α = 0.05). YF = yellow foxtail, BG = barnyardgrass, KH = kochia, LS = lambsquarters.
Insect Resistance Management

Thomas Hunt, UNL Entomology Extension Specialist, Concord NE
Robert Wright, UNL Entomology Extension Specialist, Lincoln NE

Insect resistance to insecticides or other control tactics is not new. It has been a problem faced by farmers for years. There are now over 540 instances where insect and mite species have developed resistance to pesticides, with some developing resistance to several pesticides. Resistance to cultural insect management has even occurred, as exemplified by the appearance of crop rotation-resistant corn rootworm. The consequences of resistance include higher frequency and rates of insecticide application (and so higher costs to the farmer), increased applicator exposure, increased environmental contamination, and the loss of effective pest management tools.

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

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

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

The Solution: Insect Resistance Management

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

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

Factors Affecting Resistance Development

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

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

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

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

**Insect Resistance Management Tactics**

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

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

Many farmers are familiar with the structured refuge concept that was initiated with the use of Bt transgenic corn targeting European corn borer. Farmers were required to plant a certain percentage of their farm to non-Bt corn, either in blocks or strips, to act as refuge for Bt susceptible corn borers. Currently, we are seeing the use of “seed-mixture” refuges for IRM designed for corn rootworm. For example, non-Bt corn seed is mixed with Bt transgenic corn seed to provide in-field refuge for Bt susceptible rootworms. Another tactic with which farmers are becoming familiar is the pyramiding of more than one transgene toxins that target a single insect pest. These two tactics, refuge and transgene pyramids, are used together for European corn borer and corn rootworm IRM. See a “Handy Bt Trait Table” developed by Michigan State University and the University of Wisconsin at: [http://labs.russell.wisc.edu/cullenlab/files/2013/11/Handy_Bt_Trait_Table.pdf](http://labs.russell.wisc.edu/cullenlab/files/2013/11/Handy_Bt_Trait_Table.pdf) for more details on current IRM for transgenic corn.

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

- **Use of action or economic thresholds.** Almost all significant crop insect pests have action or economic thresholds. If thresholds are used, you only expose the insect pests to a selection pressure when it is necessary to prevent economic loss. An insecticide’s mode of action is presented on the label, or go to: [www.irac-online.org/documents/moa-classification/?ext=pdf](http://www.irac-online.org/documents/moa-classification/?ext=pdf) for more information.

- **Rotation of insecticides.** This relies on rotating insecticides with different modes of action. Using different modes of action reduces the selection pressure for any given mode of action, and possibly kills any insects that have survived the previously used mode of action. This is particularly important if you are treating a field more than once a growing season, or have yearly pest problems.

- **Rotation of control tactics.** Use of other effective control tactics (e.g. biological, cultural, host plant resistance) can further reduce selection pressure of single tactics.

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

**Figure 1. Long term IRM tactic for corn rootworm**

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

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

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

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

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

The remedial action plan is designed to mitigate resistance should it occur and is most important with respect to current insect resistant transgenic crops. For these crops it is the responsibility of the registrant company, but it is always to have a plan of action ready should a particular tactic fail due to resistance. Hopefully, adequate IRM will prevent the need of remedial action plans.
2013 Crop Insect Issues

Robert Wright, and Tom Hunt, Extension Entomologists
UNL, Lincoln and Concord NE

Stink bugs on corn and soybeans

We continue to receive reports of stink bugs in Nebraska corn and soybean. Both crops are particularly sensitive to stink bugs during the reproductive stage. Although insect pest problems have been relatively minor this year, farmers should stay vigilant and continue to scout corn and soybean. Planting dates were late this year in many areas and cool weather has slowed plant growth, leading to delayed maturity in many areas. These late maturing crops may remain vulnerable to pest injury longer than usual.

In the past, stink bugs have not been considered a significant pest of corn or soybean in Nebraska, but they are significant economic pests to a variety of crops in the southern United States. Over the past 15 years there appears to be a general trend of increasing stink bug populations in more northern states, including Nebraska.

Nebraska Stink Bugs

Based on stink bug surveys made in Nebraska in 2009-2011, four main species can be found in soybeans and corn:

- green stink bug,
- brown stink bug,
- onespotted stink bug, and
- red-shouldered stink bug.

All are shield-shaped as nymphs and adults. In general, adult green stink bugs are bright green, and adult brown stink bugs are brown with a yellow or light green underside. Green stink bug nymphs change color and pattern as they grow, but brown stink bug nymphs are yellow to tan with brown spots down the center of the abdomen. The onespotted stink bug looks similar to the brown stink bug, except it has a small spot on the underside of the abdomen. The red-shouldered stink bug is green and has a red stripe across the base of the wings. Another brown stink bug, the spined soldier bug, is a beneficial predatory insect.

General Stink Bug Biology

Adult stink bugs overwinter primarily in leaf litter, under bark, or in wood piles. We believe that the green stink bug does not overwinter in Nebraska, but migrates north in late spring to early summer. We typically begin to find the green stink bug in July. Brown, one-spotted, and red-shouldered stinkbugs, as well as a few other recently collected species, appear to overwinter in Nebraska.

In the spring, adult stink bugs leave the overwintering sites and feed on a variety of wild and cultivated hosts. In Nebraska crops, the first significant numbers of bugs appear in the spring in wheat, followed by alfalfa. After feeding a few days, stink bugs mate and lay clusters of eggs. As the season progresses, female stink bugs are attracted to a variety of flowering plants, including corn and soybean. Populations peak during the pod-filling stages of soybean and ear-filling stages of corn. There are likely one to two generations in Nebraska, depending on species.

Stink Bug Injury to Corn and Soybean

Stink bugs have piercing and sucking mouthparts and feed by piercing a plant part (or another insect in the case of the spined soldier bug), injecting digestive enzymes, and removing fluids.

Corn. Nymphs and adult stink bugs injure vegetative stage corn by feeding at the base of the seedling corn plant. Feeding results in irregular shaped, oblong holes with yellow margins in the leaves as they emerge from the whorl, twisting of the whorl, and in some cases, death of the growing point. Nymphs and adult stink bugs damage reproductive stage corn by piercing the husk and feeding on the developing kernels from the beginning of kernel formation through milk stage, although they can feed through the hard dough stage. Damage appears as missing or shrunken kernels. Severe damage causes ears to curve (banana ears).

Soybeans. Nymphs and adult stink bugs injure soybeans by puncturing various soybean plant parts and extracting plant fluids. They prefer young tender
growth and developing seeds. As they feed they inject digestive enzymes, which cause deformation and abortion of seeds and pods, and predispose the feeding site to various pathogens. In addition, stink bugs can cause delayed maturity and deformed leaf growth. Yield and quality losses depend on when the bugs injure soybean, and can be severe.

Injury often appears first on field borders as the stink bugs move into the field (both corn and soybean). With time the stink bugs can move throughout the field.

Management of Stink Bug in Corn and Soybean

In general, thresholds are based on counts of large nymphs (1/4 inch or greater) and adults, as those are the most damaging stages. Green stink bugs are more numerous in soybeans and brown stink bugs more numerous in corn, but don’t be surprised to find a mix of species.

Note that the following thresholds are single values and do not explicitly consider changing crop prices and treatment costs. This is because there is not a comprehensive data base from which to develop these types of thresholds. These thresholds are set low enough to account for price and cost fluctuations. However, if you believe you have a robust and rapidly increasing population, you may want to lower the thresholds slightly (for example, to one bug per five plants instead of one bug per four plants for the early reproductive stage corn).

Field Corn

Florida recommends that “for corn in the early silk through milk stage, treatment may be justified when there is one stink bug per five plants. From the end of milk through the hard dough stages, treatment may be justified when there is an average of one stink bug per plant. Only stink bugs 1/4 inch or longer should be considered when determining thresholds.”

Georgia recommendations note that “corn is most sensitive to stink bug injury during ear elongation before pollen shed. The treatment threshold at this stage is one bug per four plants (25% infested plants). Once pollination occurs, feeding though the husk causes damage to individual kernels. Kernels are susceptible to damage up until the milk stage (R3) and possibly early dough stage (R4). The threshold at this time is one bug per two plants (50% infested plants).”

Research is ongoing in Nebraska, but until we have more definitive information, we recommend using the following treatment threshold:

- 1 stink bug per 4 plants (25% infested plants) prior to pollination, and
- 1 stink bug per 2 plants (50% infested plants) after pollination up to early dough stage.

Soybeans

Thresholds for stink bugs on soybeans vary considerably by state, and also do not explicitly consider variable costs of control or market value. They range from 0.3 per row-foot (Illinois) to 3 per row-foot (Wisconsin), or 0.2 per sweep (Indiana) to 6 per sweep (Ohio) and are not consistent with respect to timing, row spacing, or soybean use (seed or grain). Again, while we don't have definitive research data specific to Nebraska, we believe the following treatment thresholds are appropriate:

- 1 stink bug per row-foot during the reproductive stages, and
- if using a sweep net, 3.6 stink bugs per 15 sweeps (i.e., 0.25 bugs/sweep).

If thresholds are met, the standard insecticides registered for corn or soybean should be effective.

Japanese Beetles or False Japanese Beetles?

We have received many questions about the Japanese beetles as they were emerging this summer. This introduced insect has been expanding its range in southeastern and south central Nebraska and now is more frequently being found in corn and soybean fields, as well as in yard and gardens.

Japanese beetles can contribute to defoliation in soybeans, along with a complex of other insects, such as bean leaf beetles, grasshoppers, and several caterpillar species.

Japanese beetles also may feed on corn silks, similar to corn rootworm beetles, and may interfere with pollination if abundant enough to severely clip silks before pollination. University of Illinois Extension recommends: “An insecticidal treatment should be considered during the silking period if:

1. there are three or more Japanese beetles per ear,
2. silks have been clipped to less than ½ inch, AND
3. pollination is less than 50% complete.”

Again, similar to corn rootworm beetles, they will scrap off the surface green tissue on leaves before silks emerge, but prefer silks once they are available.

Japanese beetles adults are about ½ inch long and have a metallic green head and thorax. A key characteristic to look for is a series of white tufts of hair on each side of the abdomen.

In some cases people have mistaken the Japanese beetle for its look-alike, the false Japanese beetle, or sand chafer, *Strigoderma arboricola*, which is a native Nebraska insect found across most of the state. Sand chafers are commonly found along the Platte River valley and other river valleys in Nebraska. False Japanese beetle adults are about the same size as Japanese beetles, but do not have a metallic green head. They may vary in color from coppery brown to black. They may have some white hairs on the side of the abdomen but they are not organized into tufts of hair.

They are often noticed because of their habit of landing on people; they seem to be attracted to people wearing light-colored clothing. They have not been reported to cause economic damage to crops as adults, although the immature white grub has been reported to cause damage to potato tubers.

**Avoid insurance applications of insecticides.**

We have received several reports of Banks grass mites in central and western Nebraska corn this summer. This occurs as Banks grass mites move out of early spring hosts such as wheat, brome grass, or pastures. Depending on the stage of the corn when it is infested, the number of mites, and whether they are only in field edges or throughout the field, it may not pay to treat.

Paul Hay, UNL Extension Educator, Beatrice, reported several soybean fields with infestations of twospotted spider mites, usually on field borders.

Spider mite survival is often greatly reduced by the presence of several predatory insects and mites in both corn and soybeans. Given the projected hot, dry conditions for most of the state, conditions are favorable for spider mite growth.

As we move into July and August, growers may consider adding an insecticide with a herbicide or fungicide application as “insurance” against potential yield loss from insects. Unfortunately, most of these insecticides have broad activity against insects and mites, including those predatory species which feed on spider mites. There is a long history of mid-season foliar insecticide use resulting in increased spider mite populations later in the season in corn and soybeans, as well as other crops. Mid-season elimination of predatory and parasitic insects through insecticide applications also may encourage late-season survival of soybean aphids.

**We do not recommend insurance applications of insecticides in the absence of economically damaging levels of insect pests.** This is especially true in a dry summer, with spider mites already beginning to show up in Nebraska corn and soybeans.

**New Pesticide Labels Will Better Protect Bees and Other Pollinators**

In an ongoing effort to protect bees and other pollinators, the U.S. Environmental Protection Agency (EPA) has developed new pesticide labels that prohibit use of some neonicotinoid pesticide products where bees are present.

“Multiple factors play a role in bee colony declines, including pesticides. The Environmental Protection Agency is taking action to protect bees from pesticide exposure and these label changes will further our efforts,” said Jim Jones, assistant administrator for the Office of Chemical Safety and Pollution Prevention.

The new labels will have a bee advisory box and icon with information on routes of exposure and spray drift precautions. This announcement affects products containing the neonicotinoids imidacloprid, dinotefuran, clothianidin and thiamethoxam. The EPA will work with pesticide manufacturers to change labels so that they will meet the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) safety standard.

In May, the U.S. Department of Agriculture (USDA) and EPA released a comprehensive scientific report on honey bee health, showing scientific consensus that there are a complex set of stressors associated with honey bee declines, including loss of habitat, parasites and disease, genetics, poor nutrition and pesticide exposure.
The agency continues to work with beekeepers, growers, pesticide applicators, pesticide and seed companies, and federal and state agencies to reduce pesticide drift and advance best management practices. The EPA recently released new enforcement guidance to federal, state and tribal enforcement officials to enhance investigations of bee kill incidents.

More on the EPA’s label changes and pollinator protection efforts:

http://www.epa.gov/opp00001/ecosystem/pollinator/index.html

View the infographic on EPA’s new bee advisory box: http://www.epa.gov/pesticides/ecosystem/pollinator/bbee-label-info-graphic.pdf

**IRAC smart phone app for insecticide mode of action information**

Not repeatedly using insecticides with the same mode of action is an important principle in Insecticide Resistance Management. There is an increasing diversity of insecticide modes of action available for use on crops, and products are now available combining two or more active ingredients, often with different modes of action. A new smart phone app has been developed that allow users to look up this information quickly from their phone.

The IRAC (Insecticide Resistance Action Committee; http://www.irac-online.org) has developed a Mode of Action Classification App for mobile devices. It is an easy-to-use, searchable database which allows the user to identify insecticide active ingredients and their respective Mode of Action groups without the need for a data connection once the app has been downloaded. The user can either scroll through and open up each of the groups and classes to see the active ingredients listed or use the filter function to select a particular group, class or active to find out where they fit within the classification.


**National Corn Growers Association Offers IRM Mobile App**

**Name of App:** IRM Mobile App

**Developer:** National Corn Growers Association, with assistance from Monsanto, DuPont Pioneer, Syngenta, and Dow AgroSciences; app information is available on the NCGA website.

**Availability:** Apple and Android mobile apps as well as a desktop version are available. **Cost:** Free

**Purpose of App:** To help corn growers follow the appropriate Insect Resistance Management (IRM) requirements for different Bt corn hybrids.

**Description:** There is a great diversity of IRM refuge requirements for Bt corn hybrids. This app helps growers understand the appropriate IRM plans for the hybrids they grow.

Based on your location, you are shown a menu of Bt corn products available from different seed companies. Choose a hybrid, then enter the field size and seeding rate. The IRM refuge calculator displays the appropriate refuge size, the number of standard seed bags to plant for both traited and refuge hybrids, and possible planting configurations for planting corn products in the United States.

This refuge calculator does not replace or supplement the applicable manufacturer’s IRM Grower Guide in any way. As a grower using this information, you are still obligated to understand and abide by the applicable IRM Grower Guide on planting and Insect Resistance Management. The desktop version allows printing reports summarizing the output.

**Fit for Nebraska:** This app is programmed to cover all major Bt corn seed companies and is updated as new products are labeled for use.

**To Download**

**iTunes**


**Android**

Spotted Wing Drosophila fruit fly now in Nebraska

The Spotted Wing Drosophila (SWD) is a newly introduced fruit fly from Asia that was first detected in California in 2008. It was first found in the north central region in Michigan in 2010 and is now broadly distributed across many states in the U.S. We have detected it for the first time in multiple counties in Nebraska in 2013 (Fig. 1). We have not sampled all Nebraska counties and it may be present in other counties not shown on this map. It has been detected by using adult traps, as well from samples collected of adults and larvae in the following sites: blackberries, raspberries, grapes, Aronia (chokeberry) and urban vegetable gardens. In other states it has primarily been a pest of small fruits such as raspberry, blackberry, and similar small fruits. It is less commonly a pest of grapes and orchard fruits.

Unlike native Drosophila fruit flies, which normally feed on damaged or rotting fruit, the Spotted Wing Drosophila adult female is capable of infesting undamaged small fruits, due to a sharp, serrated ovipositor, which allows it to penetrate the skin of small fruits and then insert its eggs. Spotted Wing Drosophila males have a noticeable black spot on the tip of each forewing, unlike other Drosophila species.

After initial detections in Nebraska this summer by UNL Extension faculty, the USDA-APHIS and UNL Extension continued conducting surveys. Additional information about Spotted Wing Drosophila is available at:

http://www.ncipmc.org/alerts/drosophila.pdf

http://www.ipm.msu.edu/invasive_species/spotted_wing_drosophila

Fig. 1. 2013 Spotted wing Drosophila fruit fly distribution in Nebraska
What’s New in Western Nebraska Entomology?

Jeff Bradshaw, Entomology Specialist

Pest Issues of 2013

Our chief issues with pest insects this year in the Nebraska panhandle were army cutworms, wheat stem sawflies, spider mites, sunflower head moth and a newly documented pest the spotted wing drosophila.

Army cutworm larvae (Fig. 1) are the offspring of noctuid moths that are commonly referred to as “miller moths”. The adults deposit eggs in the fall, preferring barren soil. This egg-laying often occurs prior to winter crop germination such that winter wheat or other winter crops can be susceptible to damage. The results of this damage often go unnoticed until spring. This spring, I received numerous phone calls and saw a number of fields that had large infestations of army cutworm larvae in winter wheat and alfalfa. There are economic thresholds for these insects in these crops and chemical controls are an option; however, scouting has to be timely.

Both two-spotted spider mites and Bank’s grass mites (Fig. 2) had high infestations in corn this year. As early as June, growers were treating corn for flares of mites. Unlike last year, we saw very few infestations of spider mites in sugar beet or dry beans. Also, I received no reports of brown wheat mites in wheat.

For sunflower growers who planted their fields early this year, they may have seen high numbers of sunflower head moths (Fig. 3). In our sunflower test plots at the Panhandle Research and Extension Center we have measured as much as 38% of seed damaged per head due to sunflower head moth in our 2013 plots. With current sunflower hybrids, planting early can mean heavy infestations of one or two generations of sunflowerhead moth in July and August.

Wheat stem sawflies (Fig. 4) have also continued to be a major problem in the Nebraska panhandle. I received many contacts over the 2013 growing season regarding various concerns about wheat stem sawfly. We are currently going through samples; however, it seems that lodging was more evident this year relatively to 2012. In 2012, most of the panhandle counties had measurable infestations of wheat stem sawflies in their fields. However, lodging was less noticeable. However, we had a few more storms and severe wind events in 2013 which aided in the lodging of sawfly-cut wheat. While it’s obvious that lodged wheat can have a tremendous impact on yield, yield loss (as much as 15%) can still occur as a result of sawfly larval feeding within tillers.
Finally, a newly documented pest has been identified throughout Nebraska, the spotted wing drosophila (Fig. 5). This insect attacks many species of thin-skinned fruit from tomato to raspberry to cherries and grape. This fruit fly is unique in that it will attack fresh fruit. The adult fly lays its eggs into the fruit and the larva will develop and feed within the fruit. The feeding damages the fruit and causes some fruits to exude their contents which creates secondary problems. There are various pesticides labeled for the control of this pest in various crops; however, thresholds for this invasive insect have yet to be determined in many crops. Some small fruit producers in Western Nebraska and Wyoming had serious issues with this insect in 2013.

Figure 5. A spotted wing drosophila maggot feeding within a raspberry cluster.

Pest Management Tool Development

For wheat insect management, we continue to develop iWheat.org to supply producers with management tools and technologies. We continue to develop the wheat variety selector, diagnostic keys, and pest sampling plans. Additionally, we have been developing a potato psyllid scouting mobile app. Similar to the soybean aphid scouting app, PsyllidScout uses a binomial sequential sampling plan to allow a scout to make a quick management decision without hassling with paperwork. A binomial sampling plans allows a scout to simply tally the number of infested plants and a threshold is calculated based on the frequency of infested plants. These sampling plans also have the advantage that after you tally a set number of plants, you may or may not need to continue sampling based on the infestation frequency calculated by app. These plans have been developed in many other crop systems save time in pest management. With moving these tool to mobile apps, these data can be stored on your hand-held device for every field you sample and the data can be easily accessed. With PsyllidScout we are taking our decisions a step further to map the threshold decisions across all participating users. This way all members of the user network can see, not just the populations but will be able to track whether or not individual fields or regions have exceeded economic thresholds based on the most recent sampling data. In this way a field manager might be able to plan not just for a treatment action in a field, but plan for the hire of field scouts in anticipation of an encroaching economic population of psyllids. My hope is that this design plan might be useful and adaptable across other commodities in Nebraska.

Figure 6. Example output report to illustrate the kind of output and information provided by PsyllidScout.
Corn Rootworm Management Update

L. Meinke, Professor of Entomology, D. Wangila, Entomology Graduate Research Assistant, R. Wright, T. Hunt, Extension Entomologists and G. Kruger, Extension Cropping Systems Specialist

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

To determine if shifts in rootworm susceptibility to Cry3Bb1 have occurred at some Nebraska locations, both lab and field research has been conducted at UNL during 2012-2013.

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

Lab Bioassays: Results

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

Field Trials

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

2013 Field Trials: Key Results:

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

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

Cry34/35
The relative root protection obtained with Cry34/35Ab1 was not significantly different across all
four sites (3 problem sites and the control site; relative rootworm control averaged 90.6% across sites). The greatest root protection was obtained with single trait Cry3/35 or a pyramid of Cry3/35 with either Cry3bb1 or Cry3/35.

The at-plant soil insecticide provided a significant root protection benefit only when applied to non-Bt near-isoline treatments or single traits exhibiting greater than expected relative injury (i.e., Relative root protection: Cry3Bb1 + insecticide: average of 3 problem fields = 81.3% control; Cry3Bb1 + insecticide: control site 95.3% control; mCry3A + insecticide: average of 3 problem fields = 80% control; mCry3A + insecticide: control site 92.4% control; Little root protection benefit was obtained by adding soil insecticide to single trait Cry3/35 (average across 4 sites = 95.6 % control) or pyramids containing Cry3/35 (Cry3/35 + Cry3B1 average control across four sites = 95.2 %, Cry3/35 + Cry3Bb1 + insecticide: average control across four sites = 95.7 %; Cry3/35 + mCry3A: average control across four sites = 94.3%; Cry3/35 + mCry3A + soil insecticide: average control across four sites = 96.5%

**Overall Conclusions:**

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

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

Data suggest that a possible cross-resistance relationship exists between Cry3Bb1 and mCry3A which reduced the effectiveness of mCry3A hybrids in Cry3Bb1 history/problem fields. However, there was no apparent cross resistance relationship between Cry3Bb1 or mCry3A and Cry3/35 expressing corn. An at-plant soil insecticide provided a significant root protection benefit only when applied to non-Bt near-isoline hybrids or single trait hybrids exhibiting greater than expected relative injury.

**General corn rootworm management recommendations**

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

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

2. If you must plant corn after corn:
   — Change to a hybrid containing a different Bt corn toxin active against rootworms, or one containing more than one Bt corn toxin active against corn rootworms. See the following for a list of available Bt corns and the toxins they express (C. DiFonzo and E. Cullen. 2013. Handy Bt Trait Table. http://labs.russell.wisc.edu/cullenlab/extension/extension-publications)
   — Follow all refuge requirements for any Bt hybrid.

3. It is important to use a diversity of control measures to manage rootworm populations, rather than relying on only one Bt corn. Crop rotation and use of different Bt corn hybrids that express different or multiple Bt proteins are important strategies for rootworm management. In addition, conventional insecticides may be used to provide some level of protection as part of a rootworm management program, including the following:
   — Liquid or granular insecticide applied at planting
   — Postemergence applications targeted for larval or adult control.
Table 1. Entries included in 2013 field trials.

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

Randomized complete block design, four replications

All seed were treated with a standard fungicide package and either Poncho 250 or Cruiser 250 Aztec 2.1G applied infurrow at planting; rate: 0.141 oz. ai / acre
<table>
<thead>
<tr>
<th>Bt Trait Table</th>
<th>Bt protein(s)</th>
<th>Insects controlled (bold) or suppressed (italics) Above-ground or in soil</th>
<th>Herbicide tolerance</th>
<th>Refuge %, location in the MIDWEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrilza CR151L</td>
<td>Cry1Ab, Cry1B</td>
<td>ECB, CEW, FAW, SB</td>
<td>--</td>
<td>LL 20% within ½ mile</td>
</tr>
<tr>
<td>Agrilza G175</td>
<td>Cry1Ab, Crys1A</td>
<td>ECB, CEW, FAW, SB</td>
<td>--</td>
<td>GT LL 20% within ½ mile</td>
</tr>
<tr>
<td>Agrilza Ref</td>
<td>mCry1A</td>
<td>--</td>
<td>CRW</td>
<td>-- 20% in field/adjacent</td>
</tr>
<tr>
<td>Agrilza Ref</td>
<td>mCry1A</td>
<td>--</td>
<td>CRW</td>
<td>GT 20% in field/adjacent</td>
</tr>
<tr>
<td>Agrilza CR151L/RW</td>
<td>Crys1A, mCry1A</td>
<td>ECB, CEW, FAW, SB</td>
<td>CRW</td>
<td>LL 20% in field/adjacent</td>
</tr>
<tr>
<td>Agrilza 3005G1</td>
<td>Crys1A, mCry1A</td>
<td>ECB, CEW, FAW, SB</td>
<td>CRW</td>
<td>G1 LL 20% in field/adjacent</td>
</tr>
<tr>
<td>Agrilza Antimare 3011A</td>
<td>Crys1A, mCry1A</td>
<td>ECB, CEW, FAW, SB</td>
<td>CRW</td>
<td>G1 LL 20% in field/adjacent</td>
</tr>
<tr>
<td>Agrilza Vipera 3110</td>
<td>Crys1A, Vip3A</td>
<td>BCW, CEW, ECB, FAW, WBG, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
</tr>
<tr>
<td>Agrilza Vipera 3111</td>
<td>Crys1A, Vip3A, mCry1A</td>
<td>BCW, CEW, ECB, FAW, WBG, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
</tr>
<tr>
<td>Agrilza 3122 L-2 Refuge</td>
<td>Crys1T, Crys1A, mCry1A, Cry3Aa, Cpa</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 3% in the bag</td>
</tr>
<tr>
<td>Agrilza Vipera 3222 L-2 Refuge</td>
<td>Crys1A, Vip3A</td>
<td>BCW, CEW, ECB, FAW, WBG, SB</td>
<td>CRW</td>
<td>G1 3% in the bag</td>
</tr>
<tr>
<td>Agrilza Duracade 5122 L-2 Refuge</td>
<td>Crys1T, Crys1A, mCry1A, Cpa, Cry3A</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 5% in the bag</td>
</tr>
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<td>Agrilza Duracade 522 T-2 Refuge</td>
<td>Crys1A, Crys1T, mCry1A, Cpa, Cry3Aa, Cry3Aa</td>
<td>BCW, CEW, ECB, FAW, WBG, SB</td>
<td>CRW</td>
<td>LL 20% in field/adjacent</td>
</tr>
<tr>
<td>Hercules</td>
<td>Crys1T, Crys1A</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
</tr>
<tr>
<td>Hercules XR (HXR)</td>
<td>Crys1T, Crys1A, Crys3Aa, Cpa, Cry3A</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
</tr>
<tr>
<td>Optimum</td>
<td>Crys1T, Crys1A</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
</tr>
<tr>
<td>Optimum</td>
<td>Crys1T, Crys1A, Crys3Aa, Cpa, Cry3A</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
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<tr>
<td>Optimum</td>
<td>Crys1T, Crys1A, mCry1A, Cpa, Cry3Aa, Cry3Aa</td>
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<td>Optimum</td>
<td>Crys1T, Crys1A, Cpa, Cry3Aa, Cry3Aa</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
<td>G1 LL 20% within ½ mile</td>
</tr>
<tr>
<td>Optimum</td>
<td>Crys1T, Crys1A, Cpa, Cry3Aa, Cry3Aa</td>
<td>BCW, ECB, FAW, WBG, CEW, SB</td>
<td>CRW</td>
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</tbody>
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Figure 1: A map of the state of Nebraska showing distribution of sites sampled in 2012. Sites beginning with P were Cry3Bb1 history/problem fields, sites beginning with C were control fields.
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 as it conserves the overwintering habitat for this insect. However, reduced tillage may not be the only contributing factor to the stem sawflies increasing abundance.

**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 50°F (10°C) 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.

**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**

Some forms of tillage have been shown to 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. In Nebraska, a spring tillage operation that buries stubble has been shown to reduce sawfly emergence. However, such tillage operations may have other negative consequences for dry land production, especially for soil and moisture conservation, and may not be effective when stem sawfly populations are large.
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 some winter wheat varieties that are solid-stemmed. Yield data indicates these varieties are almost competitive in yield with commonly used adapted varieties. However, none of these hard-stemed varieties have been tested for performance in Nebraska.

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.

## Chemical 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. Stem sawfly larvae are protected within the wheat stem and are largely protected from chemical exposure.

### 2013 Wheat Stem Sawfly Status

We continued a regional survey project in 2013 to document the management and environmental variables that are contributing to the spread of this sawfly. Twenty-eight fields, 21 growers, and various Extension Educators and crop consultants were involved in this year’s survey that extended geographically from eastern Wyoming throughout the western half of Nebraska. Large mailing 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. Currently there are 28 samples from 28 fields that have been returned. Stem count data are yet to be collected for 2013. However, reports of lodging were wide-spread in 2013.

For additional perspective on the 2013 sawfly emergence 15, soil-level emergence traps in wheat stubble (i.e., fallow) near McGrew, NE and sampled for adult wheat stem sawflies with four collections from 14 May to 26 June. We collected a total of 221 adults that emerged 13 days later than in 2012 (Table 1). The total capture was about 5 times greater than in this same general location in 2012 and the population demographics indicate a very abrupt emergence. This increased population appeared to be representative of the entirety of the panhandle of Nebraska as many, many producers reported serious infestations of wheat stem sawfly.

### Table 1. Emergence trap data compiled from previous sample years (1995-1997, 2012) to current sample year (2013). All traps were placed in wheat stubble using the same trap design.

<table>
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<td>20-May</td>
<td>15-May</td>
<td>28-May</td>
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<td>50% fly emergence</td>
<td>8-Jun</td>
<td>29-May</td>
<td>31-May</td>
<td>18-May</td>
<td>28-May</td>
</tr>
<tr>
<td>Peak fly emergence</td>
<td>7-Jun</td>
<td>31-May</td>
<td>30-May</td>
<td>22-May</td>
<td>28-May</td>
</tr>
<tr>
<td>Wheat stage at peak</td>
<td>Heads 25% emerged</td>
<td>Heads just fully emerged</td>
<td>Heads just fully emerged</td>
<td>Heads fully emerged</td>
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</table>
Soybean Stem Borers in Nebraska

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

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

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

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

Description and Life Cycle

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

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

Injury Symptoms

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

Larvae tunnel up and down the stem, and end up at the base of the plant at plant maturity. Mature larvae girdle the inside of the stem to make a cell for overwintering. This weakens the stem and may lead to stem breakage or lodging. Economic damage is caused primarily by lodging and
subsequent harvest difficulties. Girdling is most severe in earlier maturing varieties, and lodging is most severe in earlier planted soybean. In the absence of harvest losses from lodging, direct yield loss from larval feeding has been limited or absent.

Management

Cultural Controls

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

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

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

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

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

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

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

Chemical Controls

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

Recommendations for Harvest

Fields with a history of injury or with injury symptoms this year should be carefully watched during August and September. Fields with extensive stalk tunneling (greater than 50 percent of plants) by the soybean stem borer are most at risk for lodging and harvest losses, depending on weather conditions. Those fields should be targeted for harvest first to minimize harvest losses due to soybean stem borer injury. In the absence of lodging losses, this insect does not usually cause noticeable yield reductions.
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.
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 driven 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 hollow shaft 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>
<thead>
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<th>Potential Costs</th>
<th>Potential Benefits</th>
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<tbody>
<tr>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td>• sprinklers</td>
<td>Reduced Fuel Costs</td>
</tr>
<tr>
<td>• pressure regulators</td>
<td>• pump operates at lower pressure</td>
</tr>
<tr>
<td>• drop tubes</td>
<td>• more efficient system</td>
</tr>
<tr>
<td>• end-gun booster pump</td>
<td>• (fewer pumping hours)</td>
</tr>
<tr>
<td>• adding extra sprinkler fittings</td>
<td>• reduced demand charge</td>
</tr>
<tr>
<td>Acreage Reductions</td>
<td>Application Efficiency</td>
</tr>
<tr>
<td>• end gun inoperable</td>
<td>• higher if runoff is not a problem</td>
</tr>
<tr>
<td>• reduced wetted diameter of end sprinklers</td>
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</tr>
<tr>
<td>Pump Alterations</td>
<td>Increased Yields</td>
</tr>
<tr>
<td>• bowls and impellers</td>
<td>• if pump capacity is too low</td>
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<tr>
<td>• gear head or pulleys</td>
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</tr>
<tr>
<td>Motor Change</td>
<td></td>
</tr>
<tr>
<td>Artificially High Demand Charge</td>
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Table I. Potential economic costs and benefits associated with changing sprinkler packages.

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, which are multiplied 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:

\[
BHP = \frac{\text{total head (ft)} \times \text{gpm}}{3960 \times \text{pump efficiency (decimal)}}
\]
For the high pressure system, (pump efficiency from Figure 1 = 76%) this is:

\[
BHP = \frac{276 \times 800}{3960 \times 0.76} = 73.4 \text{ hp}
\]

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:

\[
Fuel \ Consumption = \frac{0.398 \ lb}{BHP\cdot hr} \times 73.4 \ BHP = 29.2 \ lb/\text{hr}
\]

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

\[
BHP = \frac{183.6 \times 800}{3960 \times 0.74} = 50.1 \text{ hp}
\]

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:

\[
Fuel \ Consumption = \frac{0.402 \ lb}{BHP\cdot hr} \times 50.1 \ BHP = 20.1 \ lb/\text{hr}
\]

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](http://extension.unl.edu/publications).
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 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,
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 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.

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.

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 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. The peak application rate is about 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.
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.

References

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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.

UNL Extension publications are available online at [http://extension.unl.edu/publications](http://extension.unl.edu/publications).
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 bubbler 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.

<table>
<thead>
<tr>
<th>Component</th>
<th>Low-Angle Impact Sprinkler Water Loss</th>
<th>Spray Head Water Loss</th>
<th>LEPA Water Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Evaporation and Drift</td>
<td>0.03 in.</td>
<td>0.01 in.</td>
<td>0.00 in.</td>
</tr>
<tr>
<td>Net Canopy Evaporation</td>
<td>0.08 in.</td>
<td>0.03 in.</td>
<td>0.00 in.</td>
</tr>
<tr>
<td>Plant Interception</td>
<td>0.04 in.</td>
<td>0.04 in.</td>
<td>0.00 in.</td>
</tr>
<tr>
<td>Evaporation From Soil</td>
<td>Negligible</td>
<td>Negligible</td>
<td>0.02 in.</td>
</tr>
<tr>
<td>Total Water Loss</td>
<td>0.15 in.</td>
<td>0.08 in.</td>
<td>0.02 in.</td>
</tr>
<tr>
<td>Application Efficiency</td>
<td>85%</td>
<td>92%</td>
<td>98%</td>
</tr>
</tbody>
</table>

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-canyon 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.

**References**


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**Index: Irrigation Engineering**

**Irrigation Operations & Management**

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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 (ETc) 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 crop 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:

\[
\text{Gross Capacity} = \frac{\text{PET} \times 453}{\text{HRS} \times \text{WAE}}
\]

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
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 \((0.32 \times 453)/(22 \times 0.85)\) 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.

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Plant Available Water Capacity (inch/ft)</th>
<th>Net Capacity* 9 of 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEAK ET**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loam, silt loam very fine sandy loam, w/silt loam subsoil</td>
<td>2.5</td>
<td>3.85</td>
</tr>
<tr>
<td>Sandy clay loam Loam, silt loam very fine sandy loam, w/silty clay subsoil</td>
<td>2.0</td>
<td>4.13</td>
</tr>
<tr>
<td>Silty clay loam Clay loam Fine sandy loam</td>
<td>2.0</td>
<td>4.24</td>
</tr>
<tr>
<td>Silty clay</td>
<td>1.6</td>
<td>4.36</td>
</tr>
<tr>
<td>Clay</td>
<td>1.4</td>
<td>4.48</td>
</tr>
<tr>
<td>Sandy loam Loamy sand</td>
<td>1.1</td>
<td>4.83</td>
</tr>
<tr>
<td>Fine sands</td>
<td>1.0</td>
<td>4.95</td>
</tr>
</tbody>
</table>


**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:

\[
\text{Multiplier} = \frac{168}{168 - \text{DT}}
\]

Where: \(\text{DT} = \text{hours of downtime}\)

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 \(\times 1.17 = 9.07\) 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.
   \[24 \text{ hours} + 3 \text{ hours} = 27 \text{ hours of downtime}\]
7. Calculate the multiplication factor for 27 hours \((168 \div (168 - 27)) = 1.19\)
8. Determine the total net system capacity by multiplying steps 3 and 7 together.
   \[
   \text{step 3} \times \text{step 7} = \text{total system capacity}
   \]
   \[
   4.24 \text{ net gpm/acre} \times 1.19 = 5.05 \text{ net gpm/acre}
   \]
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.
    \[
    \text{step 8} \times \text{step 9} = \text{total system capacity}
    \]
    \[
    5.05 \text{ net gpm/acre} \times 130 \text{ acres} = 656 \text{ gallon per minute}
    \]
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).
    \[
    \text{step 10} \div \text{Efficiency} = 772 \text{ gpm}
    \]
    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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**Index**: Irrigation Engineering

Irrigation Systems and Development

Issued May 2008
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
- Bee Aware: Protecting Pollinators from Pesticides EC301
- Rinsing Pesticide Containers G1736
- Cleaning Pesticide Application Equipment G1770
- Managing Pesticide Spills G2038
- Managing the Risk of Pesticide Poisoning & Understanding the Signs & Symptoms EC2505
- Safe Transport, Storage, and Disposal of Pesticides EC2507

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

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

Joe D. Luck, Assistant Professor and Precision Agriculture Engineer

Current pesticide application technologies provide producers with the opportunity to improve the efficiency of their operations. Potential benefits from adopting these technologies include a reduction in overall application by decreasing overlap and eliminating off-target application to environmentally sensitive areas including field buffers or grassed waterways. While adopting these technologies has several benefits, limitations still exist that must be considered during field application. The goal of this article is to provide an overview of how these systems function and highlight benefits in application efficiency based on data collected from case studies. In addition, current limitations will be discussed to provide operators with methods for avoiding unnecessary errors during field application of pesticides.

Automatic Section Control Systems

Automatic Section Control (ASC) technology has become a popular add-on for agricultural sprayers over the past five years. These systems combine global navigation satellite system (GNSS) with geographic information systems (GIS) to monitor field coverage in real-time and turn boom sections on or off automatically as they pass in or out of previously sprayed areas (Figure 1). ASC systems have become particularly useful on sprayers that have boom widths in excess of 100 ft that often are divided into sub-sections that would otherwise be controlled manually.

A case study conducted in Kentucky showed the potential for these systems to reduce field application using different sprayers and control systems. Data were collected from four sprayers during the 2008-2009 growing season. Three of the sprayers had 80 ft boom spans; the first sprayer utilized a manual 5-section control system, the second an ASC system with seven sections, and the third an ASC system with 9 sections. The fourth sprayer had a 100 ft boom and was equipped with a 30-section ASC system. Over-application as a percent of field area was calculated for a variety of fields covered by each sprayer. Table 1 contains a summary of the over-application determined for each of the systems studied. As expected, over-application was highest for the manually controlled system; over-application decreased as the number of control sections increased.

<table>
<thead>
<tr>
<th>Sprayer Control System</th>
<th>Boom Width (ft)</th>
<th>Over-Application (% of field area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual, 5-section</td>
<td>80</td>
<td>14.5</td>
</tr>
<tr>
<td>ASC, 7-section</td>
<td>80</td>
<td>5.7</td>
</tr>
<tr>
<td>ASC, 9-section</td>
<td>80</td>
<td>4.7</td>
</tr>
<tr>
<td>ASC, 30-section</td>
<td>100</td>
<td>2.3</td>
</tr>
</tbody>
</table>

While the number of boom control sections is an important factor in reducing over-application, other aspects will also influence any savings realized from using these systems. Control section width should be considered when setting up ASC on a sprayer. The focus should be on separating wide boom sections into smaller sections when feasible. Wide boom sections will contribute more to overlap especially in point-row situations. This is especially useful when an automated steering system is used and pass-to-pass overlap will be minimized.

Effects of Field Shape and Size on Over-Application

The size and shape of a field will also affect the potential savings from adopting ASC technology; two basic situations will contribute to higher savings. As field boundaries become more complex in nature, ASC systems will be of more benefit in reducing over-application. This is due to the fact that complex field boundaries typically create more point-rows compared to square or rectangular fields. In addition, smaller fields may often have higher amounts of over-application due to the potential size of the equipment operating in those fields. In many cases, operators cannot turn boom sections off quickly enough to guarantee that double coverage is minimized.

Figure 1. ASC systems combine GNSS and GIS to provide real-time mapping of field coverage areas and subsequent control of boom sections to eliminate application to previously treated areas.
Field shape and size may be classified by calculating the perimeter-to-area ratio (P/A). The measured field perimeter (including distances around interior obstacle boundaries) is divided by the field area (which excludes any interior obstacles). Essentially as the P/A factor increases, fields become either more complex in shape or smaller in size. The over-application data from the fields studied were further analyzed to determine how field shape and size may affect over-application; the results can be seen in Figure 2. Over-application increased for each of the four systems as P/A ratio increased (field boundaries became more complex); however, use of the ASC systems maintained less over-application compared to the manual system. Adding control sections also contributed to less over-application as P/A increased. As expected, when field boundaries became more simple in nature or larger in size (low P/A), there was little difference in over-application among the sprayer control systems studied. This was expected considering less over-application should occur in larger square-shaped fields.

### Boundary Mapping

An added benefit of ASC systems lies in the ability to map and store field boundaries and boundaries around environmentally sensitive areas. These locations may include field buffers, grassed waterways, or conservation reserve areas. In some cases, these boundaries may be recorded during field application or drawn using farm management software (FMS) and then uploaded into an in-cab computer console. For most ASC systems, these boundaries may be stored and classified as “no-spray” zones; the controller will then automatically shut off boom sections as they pass over these areas. This reduces the potential for accidental elimination of these conservation features which may provide numerous benefits one of which is reducing soil erosion (Figure 3).

![Figure 3. Soil erosion resulting from glyphosate application to a grassed waterway.](image)

### Limitations of Current Sprayer Control Systems

Operators today receive minimal feedback regarding the application accuracy during field operations. An example of an “as-applied” field application map is shown in Figure 4. The problem with these maps is that they contain vague information regarding actual application rates, in the example in Figure 4 only three ranges (Low, OK, and High) are provided. Portions of the field boundary were sprayed while turning; however there were no indications of application rate variation across the spray boom due to the turns.
While timeliness of field operations is important, application uniformity and accuracy will often suffer when field operations are carried out without considering the sprayer control system limitations. For example, spray rate controllers that compensate for ground speed changes manipulate control valves to maintain adequate flow to the boom. The time to operate the control valve results in a lag time when the sprayer accelerates or decelerates; the result is over- or under-application in those locations. Another example of control system limitations results from actuation of boom sections. Spray rate controllers compensate for turning boom sections on or off in the same way that they compensate for ground speed. As many producers adopt ASC systems, the demands on the rate controllers from boom section actuation also can result in increased boom flow through sections that remain on for a brief period. The result is over-application until the system balances actual flow rate with the desired rate. Conversely, as boom sections are turned on, the rate controllers must increase flow to meet the new flow rate. During this time, application rates are generally low as the system flow rate returns to the desired operating range.

To demonstrate these effects, pressure transducers were mounted on an agricultural sprayer with a 100 ft boom. GNSS coordinates were logged along with the status of each control section. Nozzle pressure data were used to estimate flow rates; GNSS data were used to calculate coverage areas and plot the coverage path of the boom control sections. Combining the coverage areas with nozzle flow rates provided the information necessary to estimate field application rates. Figure 5 illustrates the estimated application rate coverage map for one of the study fields along with the sprayer path. From this information it is clear that certain areas of the field received application rates well above or below the target rate of 10 gal/ac. Factors contributing to over-application included sprayer deceleration, boom sections turning off and boom velocity reduction at the boom interior during turns. Under-application was attributed to sprayer acceleration, boom sections turning on, and the outside boom velocity during turning movements. While the spray rate control system response time affected errors from acceleration, deceleration and boom section actuation, there was no turn compensation on the sprayer to minimize errors from turning.

Further analysis indicated that the majority of errors for this field (even with the excessive turning) was attributed to the sprayer rate control system. For the three study fields, only 35% of the field area received application rates between nine and 11 gal/ac.

**Summary**

The bottom line is that while sprayer control systems have improved pesticide application in some cases, operators must be aware of the limitations that exist in order to minimize application errors even with current technology. In many cases, errors could have been reduced had the operator accelerated or decelerated more slowly. In addition, reducing the amount of turning during field application would likely have greatly improved application uniformity.

Additional fine-tuning of the sprayer control system may also have resulted in reducing application errors. For instance, valve control numbers (VCN) may be adjusted to improve response time. The challenge is finding the optimum VCN setting so that the system responds quickly but doesn’t overshoot target rates. Currently only one commercial technology exists that attempts to provide turn compensation (from Capstan, Inc.); however it is generally
limited in availability. More testing of this system will provide better information regarding its ability to reduce errors from turning movements. For operators looking to improve the accuracy of their application; reducing in-field turning should be a goal. In some cases, this might not be possible due to field boundaries, but coupling ASC systems with automated steering will allow for improved application by traveling in straight passes across a field. Operators should also consider changing speed during application only when necessary. More information regarding the ability of these systems would definitely aid in evaluating current spraying operations for more than field efficiency. Ideally, a balance of high field efficiency with optimal application uniformity should be the goal.

**Proceedings Forward**

For more information, please contact Joe Luck, Precision Agriculture Engineer, 206 L.W. Chase Hall, Lincoln, NE 68583. 402-472-1488, jluck2@unl.edu.
This NebGuide provides general information on federal and state laws and regulations regarding pesticide applicator certification, licensing, and pesticide use in Nebraska.

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

**FIFRA**

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

**General Provisions**

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

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

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

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

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

**Nebraska Pesticide Act and Regulations**

The Nebraska Pesticide Act was enacted in 1993. It designates the Nebraska Department of Agriculture (NDA) as the lead state agency responsible for administering the Nebraska Pesticide Act under FIFRA and gives several other state agencies specific responsibilities. The Act requires registration of pesticides sold in Nebraska and state certification and licensing of those wishing to purchase and use any restricted use pesticide and, in certain situations, general use pesticides. It identifies the University of Nebraska Lincoln–Extension as responsible for providing training for private, commercial, and noncommercial applicators. People who attend these training sessions are considered competent to apply pesticides and are certified. Once certified, each must become licensed to purchase and use restricted use pesticides, and in some cases, general use pesticides.
Nebraska’s pesticide law and related regulations differ from that of FIFRA in several aspects. One difference is that in Nebraska, a pesticide license is required for applicators and mixer/loaders of all restricted use pesticides, although the NDA has allowed mixer/loaders to operate without licensing so long as they complete NDA-developed training every three years and document they took the training. The application of general use pesticides by a commercial applicator in the Ornamental and Turf, and the Structural categories requires a pesticide license, as does outdoor disease vector control in the Public Health Pest Control category. Under the Nebraska Pesticide Act, people wishing to be licensed as private applicators are not required to take an examination. It also stipulates that the minimum age for licensing is 16. Custom farmers are classified as commercial pesticide applicators.

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

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

Pesticide Applicator Licensing

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

To become certified as a private applicator, individuals can:

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

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

Commercial and Noncommercial Pesticide Applicator Categories

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

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

Direct Supervision

In general, a person must be licensed to use a restricted use pesticide. An individual required to be licensed may use such pesticides as an unlicensed applicator for a period of up to 60 consecutive days beginning on the first date of the pesticide application. The 60-day exemption is allowed once in that applicator’s lifetime. In order to use pesticides as an unlicensed applicator, the individual or his or her employer must apply to NDA for an applicator license within 10 days of making the first pesticide use. Both the licensed and unlicensed applicator are liable for any violations. The licensed applicator, as a supervisor, must possess the correct license category for the work being done and must do the following:
1. Determine the level of experience and knowledge of the unlicensed person in the use of a pesticide.
2. Provide verifiable (documented) detailed guidance on how to conduct each pesticide use performed under his/her direct supervision.
3. Accompany the unlicensed person to at least one site that typifies each different pesticide use the unlicensed individual performs.
4. Be in direct two-way communication with the unlicensed applicator during the application.
5. Be able to be physically on the pesticide use, storage, or mixing/loading site, if needed, within three hours.

**Recordkeeping Requirements — Commercial and Noncommercial Applicators**

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

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

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

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

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

**Recordkeeping Requirements — Private Applicators**

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

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

**Spot treatments — Recordkeeping**

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

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

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

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

Recordkeeping Requirements — Distributors/Dealers

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

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

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

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

Violations and Penalties

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

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

Resources

University of Nebraska–Lincoln Pesticide Safety Education Program, http://pested.unl.edu
Nebraska Department of Agriculture Pesticide Program, http://www.agr.ne.gov/pesticide/

This publication has been peer reviewed.

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

Index: Pesticides, General Regulations
1979, 2002-2007, Revised April 2013
Worker Protection Standard for Agricultural Pesticides

Clyde L. Ogg, Extension Educator
Larry D. Schulze, Pesticide Education Specialist

This NebGuide describes the Worker Protection Standard, helps you determine if you are covered or exempt from it, and provides information on how to comply.

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 (general and restricted use). Similar to OSHA, the standard strives to provide employees a safe workplace, with the obligation for safety falling on the employer. The standard requires employers to protect two types of agricultural employees: agricultural workers and pesticide handlers (see definitions below). The standard is considered to be part of the pesticide label and is enforceable when a pesticide with a label reference to 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 can be acquired in paperback or CD format from the Nebraska Department of Agriculture (NDA) at no cost, or 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, sodfarm, 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: food, feed, or fiber plants, trees, turf grass, 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 or clean or repair pesticide application equipment, etc., who 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. Includes 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 will inform users that they must comply with all WPS provisions. If you are using a pesticide product with WPS labeling to produce an agricultural commodity, the WPS requirements must be followed. WPS requirements are not in effect if an agricultural pesticide is used as labeled for a nonagricultural use.

**Who are theAffected Employers?**

- 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 Persons 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 compound 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. If in doubt, use the PPE recommended 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.
- 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)

The standard has established specific restricted re-entry intervals for all pesticides covered by the standard. The restricted entry interval (REI) is the time immediately following a pesticide application when entry into a treated area is restricted. 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 REIs are based on the active ingredient that requires 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 pesticides 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 (handlers and 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

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 a valid EPA-approved training validation card, 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 body. Accessible decontamination supplies are to be located within one-fourth mile of all workers and handlers and must include:

- **enough water for routine and emergency whole-body washing and for 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 eye wear. 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 is also 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 may not be in areas being treated or under an REI. Handler decontamination supplies may be in the treated area in which the handler is working, as long as the materials are stored in enclosed containers.

**Nurseries and greenhouses.** There are many special requirements for greenhouse and nursery owners or operators. These include special application restrictions, ventila tion criteria, early entry restrictions, and additional handler protection. Consult the EPA *How to Comply* manual and the pesticide label for specifics.

Additional Duties for Worker Employers

**Restrictions during application.** Employers must prohibit worker entry into treated areas and only allow entry by appropriately trained and equipped handlers. 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 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 in effect. Some pesticide labels may require both oral and posted sign warnings. All 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.
- 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 to not enter during the REI.

Additional Duties for employers of Handlers

Specific training for handlers. Before they perform any handling tasks, employers must inform handlers of all pesticide labeling instructions for 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. When commercial handlers will be on an agricultural establishment, inform them beforehand of areas on the establishment where pesticides will be applied or where an REI will be in effect and restrictions on 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, and changing into and out of personal protective equipment for each task. They 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 prevent heat illness while PPE is being worn. Train handlers to recognize, prevent, and treat heat illness. The 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.
- Supervisor 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 non-reusable or cannot be cleaned is disposed of properly.
- 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. Vapor-removing cartridges or canisters must be replaced when odor, taste, or irritation is noticed; when 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. Federal, state, and local laws must be adhered to 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 family, a commercial applicator must inform an agricultural owner/operator before a pesticide is applied on his or her 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 oral warnings and/or treated area posting are required
- Entry restrictions and other safety requirements for workers or other people

The owner/operator is responsible to pass the above information on to members of his immediate family.

If owners of agricultural establishments hire persons to perform worker or handler activities (like a commercial applicator) or hire contract employers (like a detasseling company), the agricultural owner/operator must inform those he hires of any treated areas under an REI if they will be present 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 (posted at a central location). Additionally, the employer must provide to the victim and medical personnel the following information:
- The product name, EPA number and active ingredients (on label and 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, range land, 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 (sod farms are covered by the WPS)
• on plants intended only for decorative or ornamental use (trees and shrubs in lawns)
• for mosquito abatement, or similar wide area public pest control
• for structural pest control, such as termite control
• for research uses of unregistered pesticides

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 or hired handlers or workers must stay out of a treated area during the restricted entry interval. This restriction has two exceptions:
• Early entry with no pesticide contact
• 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, or hired handlers or workers may enter a treated area during an REI, if you do not touch or are not touched by any pesticide residues, and if you are wearing the early entry personal protective equipment. Wearing PPE does not mean contact can be resumed.

Early entry with contact allows you, members of your family, or hired handlers or 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.
   • 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 a state-certified pesticide applicator or receive approved WPS pesticide handler training.

As pesticide handlers under the WPS, crop advisors or persons 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 end of pesticide application.

Persons under their direct supervision are exempt from WPS provisions except for the pesticide safety training requirements (see pesticide safety training). These persons must be trained as agricultural workers, under WPS provisions. The exemption applies only after the pesticide application ends and while performing crop advising tasks.

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

Resources


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

Index: Pesticides, General Regulations
1994, Revised October 2006
Nebraska Pesticide Container and Secondary Containment Rules

Erin C. Bauer, Extension Associate
Buzz D. Vance, Certification Specialist, Nebraska Department of Agriculture
Clyde L. Ogg, Extension Educator
Leah L. Sandall, Extension Assistant

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:

- 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.

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 refilers 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 refills 2) descriptions of acceptable containers that

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).
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


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


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Index: Pesticides, General Regulations

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Understanding the Pesticide Label

Leah L. Sandall, Extension Assistant
Clyde L. Ogg, Associate Extension Educator
Erin C. Bauer, Extension Assistant

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;

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.) 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>
<thead>
<tr>
<th>Table 1. Signal-level words.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal Word</strong></td>
</tr>
<tr>
<td>Danger or Danger-Poison</td>
</tr>
<tr>
<td>Warning</td>
</tr>
<tr>
<td>Caution</td>
</tr>
<tr>
<td>Caution or none</td>
</tr>
</tbody>
</table>

*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 1).

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
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.

<table>
<thead>
<tr>
<th>Agricultural Use Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
<tr>
<td>Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 4 hours.</td>
</tr>
<tr>
<td>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:</td>
</tr>
<tr>
<td>- Coveralls</td>
</tr>
<tr>
<td>- Chemical resistant gloves made of any waterproof material</td>
</tr>
<tr>
<td>- Shoes plus socks</td>
</tr>
</tbody>
</table>

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 Extension 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.

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
Issued July 2009
Spray Drift of Pesticides

Greg R. Kruger, Cropping Systems Specialist; Robert N. Klein, Extension Western Nebraska Crops Specialist; and Clyde L. Ogg, Extension Pesticide Educator

This NebGuide discusses conditions that cause particle drift, and methods private and commercial applicators can adopt to reduce drift potential from pesticide spray applications.

Spray drift of pesticides away from the target is an important and costly problem facing both commercial and private applicators. Drift causes many problems, including

1) damage to susceptible off-target sites;
2) a lower rate than intended on target, which can reduce the effectiveness of the pesticide and waste pesticide and money; and
3) environmental contamination, such as water pollution and illegal pesticide residues.

Drift occurs by two methods: vapor drift and particle drift. This NebGuide focuses on conditions that cause particle drift, and methods to reduce the drift potential when spraying pesticides. The potential for off-target movement needs to be a primary consideration for all pesticide applications.

**Drift Dynamics**

A solution sprayed through a nozzle atomizes into droplets that are spherical or nearly spherical in shape. Particle drift is the actual movement of spray particles away from the target area. Many factors affect this type of drift, but the most important is the initial droplet size. Small droplets fall through the air slowly and are carried farther by air movement.

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

*Table I* shows the effect of droplet size on the rate of fall. The longer the droplet is airborne, the greater the potential for drift.

When leaving the nozzle, the solution may have a velocity of 60 feet per second (41 mph) or more. Unless the spray particles are electrostatically charged, there are two forces acting upon the emerging droplets. These forces, gravity and air resistance, greatly influence the deceleration and movement of spray droplets. Droplet speed is reduced by air resistance, which can also break up the droplets. After their initial speed slows, the droplets are more influenced by gravitational pull.

With lower boom heights, the initial speed may be great enough that the droplet reaches the target before drift occurs. Large droplets maintain a downward velocity longer than smaller ones, and are more likely to be deposited on the intended target. Small droplets evaporate quicker than large droplets, leaving minute quantities of the pesticide in the air (Figure 1). In addition to realizing that spray droplet size is an important factor in reducing drift, an applicator should be aware that a nozzle will produce many different sizes of droplets.

**Droplet Size Categories**

A nozzle that produces only one size droplet is not available, despite many efforts to develop one. Volume median diameter (VMD) is a term used to describe the various droplet sizes

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*Table I. Effect of droplet size on drift potential (Grisso, et al., 2013).*

<table>
<thead>
<tr>
<th>Droplet Diameter (microns)</th>
<th>Droplet Size *</th>
<th>Time Required to Fall 10 Feet</th>
<th>Lateral Movement in a 3-mph Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Fog (VF)</td>
<td>66 minutes</td>
<td>3 miles</td>
</tr>
<tr>
<td>20</td>
<td>Very fine (VF)</td>
<td>4.2 minutes</td>
<td>1,100 feet</td>
</tr>
<tr>
<td>100</td>
<td>Very fine (VF)</td>
<td>10 seconds</td>
<td>44 feet</td>
</tr>
<tr>
<td>240</td>
<td>Medium (M)</td>
<td>6 seconds</td>
<td>28 feet</td>
</tr>
<tr>
<td>400</td>
<td>Coarse (C)</td>
<td>2 seconds</td>
<td>8.5 feet</td>
</tr>
<tr>
<td>1,000</td>
<td>Extremely coarse (XC)</td>
<td>1 second</td>
<td>4.7 feet</td>
</tr>
</tbody>
</table>

* *Droplet size categories in parentheses are based on the British Crop Protection Council (BCPC) and American Society of Agricultural and Biological Engineers (ASABE) droplet size classification now in use.*

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*Figure 1. Lateral movement of water droplets. (Hofman and Solseg, 2004)*
produced from a nozzle tip. VMD is the droplet size at which one-half the spray volume consists of droplets larger than the given value and one-half consists of droplets smaller than the given value. Since it takes many more small droplets to make up one-half the spray volume, there always will be more small droplets present in a typical spray pattern. Ideally, most of the volume should be contained in larger droplets, which is shown by a larger VMD.

The British Crop Protection Council (BCPC) and the American Society of Agricultural and Biological Engineers (ASABE) developed a droplet size classification system with categories ranging from extra fine to ultra coarse, based on VMD values measured in microns (Table II). Nozzle catalogs and guides often refer to these droplet size categories and color code descriptions to reduce confusion. An applicator can select the nozzle and pressure based on the droplet size category charts. In addition, the pesticide label may list the recommended droplet size category to use with a particular product. For example, the label statement might read: “Apply with 12 or more gallons per acre using a nozzle producing a coarse droplet.” The label includes these spray category recommendations to make sure that the droplet size is suitable for pesticide efficacy, yet as large as possible to reduce the potential for drift. Typically, low-drift nozzles produce spray droplets in the medium (M) to extremely coarse (XC) range, while reducing the amount of fine droplets that would be likely to drift.

### Table II. Droplet size classifications with color codes, based on BCPC specifications in accordance with ASABE Standards.

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Color Code</th>
<th>Approximate VMD Range (microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Fine</td>
<td>XF</td>
<td>Purple</td>
<td>~50</td>
</tr>
<tr>
<td>Very Fine</td>
<td>VF</td>
<td>Red</td>
<td>&lt;136</td>
</tr>
<tr>
<td>Fine</td>
<td>F</td>
<td>Orange</td>
<td>136-177</td>
</tr>
<tr>
<td>Medium</td>
<td>M</td>
<td>Yellow</td>
<td>177-218</td>
</tr>
<tr>
<td>Coarse</td>
<td>C</td>
<td>Blue</td>
<td>218-349</td>
</tr>
<tr>
<td>Very Coarse</td>
<td>VC</td>
<td>Green</td>
<td>349-428</td>
</tr>
<tr>
<td>Extremely Coarse</td>
<td>EC</td>
<td>White</td>
<td>428-622</td>
</tr>
<tr>
<td>Ultra Coarse</td>
<td>UC</td>
<td>Black</td>
<td>&gt;622</td>
</tr>
</tbody>
</table>

**Altering Droplet Size**

Some sprayer components can be adjusted to alter droplet size. Nozzle type selection is one of the most influential means (Table III). For more information on droplet sizes created under various conditions, download the University of Nebraska–Lincoln Extension smartphone app “Ground Spray” from the Apple App Store or the Google Play Store. The following section covers ways to alter droplet size.

### Nozzle Type

Spray droplets are produced from nozzles in different ways.

- A flat-fan nozzle forces the liquid under pressure through an elliptical orifice and the liquid spreads out into a thin sheet that breaks up into different-sized droplets. This type includes the venturi-type that relies on a pressure-against-orifice effect to atomize the spray.
- A flood nozzle deflects a liquid stream off a plate that causes droplets to form.
- A whirl chamber nozzle swirls the liquid out an orifice with a circular motion and aids the droplet formation with a spinning force.

- An air inclusion nozzle has one orifice to meter liquid flow and another larger orifice to form the pattern. Between these two orifices is a venturi or jet that draws air into the nozzle body. There, air mixes with the liquid and forms a spray pattern at a lower pressure. The coarse spray contains large, air-filled droplets and few drift-susceptible droplets.

Droplet sizes are influenced by various nozzle types and spray pressures. In Table III, of the three nozzles being compared, the Turbo TeeJet® produces the largest droplet, which results in the lowest drift potential. For many herbicide applications a large droplet gives good results, but for good plant coverage (i.e. postemergence application), large droplets may not give good pest control.

### Table III. Effect of nozzle type on droplet size at 40 PSI and 0.5 GPM (*adapted from Spraying Systems Co., 2007).

<table>
<thead>
<tr>
<th>Nozzle Type</th>
<th>Volume Median Diameter, microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow Cone</td>
<td>330 (Coarse)</td>
</tr>
<tr>
<td>Drift Guard</td>
<td>440 (Extremely Coarse)</td>
</tr>
<tr>
<td>Turbo TeeJet®</td>
<td>500 (Extremely Coarse)</td>
</tr>
</tbody>
</table>

* Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

**Spray Pressure**

Spray pressure influences the formation of the droplets as well as droplet size. When boom or nozzle pressure is increased, a higher percentage of droplets are small. With a greater proportion of the total spray volume in smaller droplets, the potential drift to off-target sites increases. The spray solution emerges from the nozzle in a thin sheet, and droplets form at the edge of the sheet. Higher pressures cause the sheet to be thinner and break up into smaller droplets. Small droplets are carried farther downwind than larger droplets formed at lower pressures (Figure 1). Table IV shows the mean droplet size for nozzles when spraying at three pressures. Higher pressures decrease the droplet size.

**Orifice Size and Carrier Volume**

Large orifice nozzles with higher carrier volumes produce larger drops. The relationship between flow rate (gallons per minute or GPM) and pressure (pounds per square inch or PSI) is not linear. For example, to double the flow rate would require the pressure to be increased by four times. This action would contribute to the drift potential and is not an acceptable method to increase carrier volume. If the carrier volume needs to be changed, select a different nozzle tip that meets the spraying requirements. Consult the pesticide label and NebGuide G955, Nozzles — Selection and Sizing, for proper selection.

**Nozzle Spray Angle**

The spray angle of a nozzle is the distance between the outer edges of the spray pattern, expressed as a number of arc degrees. (A full circle is 360°.) Wider angles cover a wider spray path and produce a thinner sheet of spray solution and smaller droplets at the same pressure (Table IV). However, wide angle nozzles can be placed closer to the target, and the benefits of lower nozzle placement may outweigh the disadvantage of slightly smaller droplets. Lower pressures can be used to reduce the amount of fine droplets. For lower pressures with flat-fan nozzles, low pressure or extended range nozzles must be used.
Spray Volume

The size or capacity of the nozzle also influences droplet size. A larger orifice increases the droplet size at a constant pressure. Since a larger orifice uses more spray volume, it also increases the number of refills; however, the increased volume of carrier solution improves coverage, and in some cases increases pesticide effectiveness. Table V shows the influence of increasing flow rate on droplet size at a constant pressure. With some pesticides, such as glyphosate, performance is better at lower carrier volumes.

Table IV. Effect of spray angle and pressure on droplet size (*adapted from Spraying Systems Co., 1990).

<table>
<thead>
<tr>
<th>Nozzle Spray Angle Degrees</th>
<th>Volume Median Diameter, microns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 PSI</td>
</tr>
<tr>
<td></td>
<td>40 PSI</td>
</tr>
<tr>
<td></td>
<td>60 PSI</td>
</tr>
<tr>
<td>40</td>
<td>900 (UC) 810 (UC) 780 (UC)</td>
</tr>
<tr>
<td>65</td>
<td>600 (EC) 550 (EC) 530 (EC)</td>
</tr>
<tr>
<td>80</td>
<td>540 (EC) 470 (EC) 450 (EC)</td>
</tr>
<tr>
<td>110</td>
<td>410 (VC) 380 (VC) 360 (VC)</td>
</tr>
</tbody>
</table>

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Other Drift Factors

Boom Height

Operating the boom as close to the sprayed surface as possible while staying within the manufacturer’s recommendation will reduce the potential for drift. A wider spray angle allows the boom to be placed closer to the target (Table VI). Booms that bounce cause uneven coverage and drift. Wheel-carried booms stabilize boom height, which reduces the drift hazard, provides more uniform coverage, and permits lower boom height. Boom height controllers are now optional on many sprayers.

Table V. Effect of flow rate on droplet size at 40 PSI (*adapted from Spraying Systems Co., 2007).

<table>
<thead>
<tr>
<th>Nozzle Type</th>
<th>Volume Median Diameter, microns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.3 GPM 0.4 GPM 0.5 GPM</td>
</tr>
<tr>
<td>Extended Range Flat Fan</td>
<td>270 (C) 300 (C) 330 (C)</td>
</tr>
<tr>
<td>Drift Guard</td>
<td>400 (VC) 425 (EC) 450 (EC)</td>
</tr>
<tr>
<td>Turbo TeeJet</td>
<td>450 (EC) 480 (EC) 510 (EC)</td>
</tr>
</tbody>
</table>

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Nozzle Spacing

This is the distance between nozzles on a spray boom. Nozzle spacing is critical to achieving adequate spray coverage. Spray angle and boom height also are key factors in coverage. Nozzle spacing for a given spray volume requires an increase in orifice size as the spacing increases. This typically means increasing the boom height to get the proper overlap. However, enlarging the droplet size is more important than increasing boom height.

Follow the equipment and nozzle manufacturer’s recommendations for appropriate nozzle configuration. As a general guideline, do not exceed a 30-inch nozzle spacing because the spray pattern will not be as uniform. A configuration of nozzle spacing, height, and direction that gives 100 percent overlap is preferred. The best nozzle spacing for most sprayers is 15 inches. Specifically, for high volumes use a 15-inch nozzle spacing and for low volumes, cap off every other nozzle and use a 30-inch nozzle spacing.

Wind Speed

Both the amount of pesticide lost from the target area and the distance it moves increase as wind velocity increases (Table VII). However, severe drift injury can occur with low wind velocities, especially under temperature inversion situations. Most recommendations are to stop spraying if wind speeds are less than 3 mph or exceed 10 mph. Some product labels have application restrictions when winds are higher than 8 mph. The wind effect can be minimized by using shielded booms and a lower boom height.

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

<table>
<thead>
<tr>
<th>Microns</th>
<th>1 mph Winds</th>
<th>5 mph Winds</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 (Mist) (VF)</td>
<td>15</td>
<td>77</td>
</tr>
<tr>
<td>400 (Coarse Spray) (VC)</td>
<td>3</td>
<td>15</td>
</tr>
</tbody>
</table>

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Air Stability

Air movement largely determines the distribution of spray droplets. Often wind is recognized as an important factor, but vertical air movement is overlooked. Temperature inversion occurs when cool air near the soil surface is trapped under a layer of warmer air. A strong inversion potential occurs when ground air is 2°F to 5°F cooler than the air above it and there is no wind.

Under inversion conditions there is little vertical mixing of air, even with a breeze. Spray drift can be severe. Small spray droplets may fall slowly or be suspended and move several miles to susceptible areas, carried by a gentle breeze. Do not apply pesticides near susceptible crops during temperature inversion conditions. Identify an inversion by observing smoke from a smoke bomb or a fire (Figure 2). Smoke moving horizontally close to the ground indicates a temperature inversion.

Relative Humidity and Temperature

Low relative humidity and/or high temperature conditions cause faster evaporation of spray droplets and a higher potential for drift. During evaporation, the spray solution loses more water than pesticide, creating smaller droplets with a greater concentration of pesticide. The quantity of spray that evaporates from the target surface is related to the quantity of spray deposited on that surface. Smaller droplets, being more prone to drift and evaporation, have less chance of actually being deposited on the target surface than do large droplets. Therefore, hot and dry weather conditions lead to less spray deposition and more drift, due to evaporation of the spray carrier solution.
Evaporation increases the potential for drift so spray during lower temperature and higher humidity conditions. Pesticides differ in their evaporation rate. Use formulations and adjuvants that reduce evaporation. Some pesticide labels specify relative humidity and temperature conditions for product use. Generally, if the relative humidity is above 70 percent, conditions are ideal for spraying. A relative humidity below 50 percent is critical if the relative humidity is above 70 percent, conditions are ideal for spraying. A relative humidity below 50 percent is critical enough to warrant special attention.

### Spray Thickeners

Some spray adjuvants act as spray thickeners or drift retardants when added to a spray tank. These materials increase the number of larger droplets and decrease the number of fine droplets. They tend to give water-based sprays a “stringy” quality and reduce drift potential. Droplets formed from an oil carrier tend to drift farther than those formed from a water carrier. Oil droplets are usually smaller, lighter, and remain airborne for longer periods, but don’t evaporate quickly.

### Best Management Practices to Avoid Pesticide Drift

All nozzles produce a range of droplet sizes. The small, drift-prone particles cannot be eliminated but can be reduced and kept within reasonable limits. Here are some tips:

1. Select low or nonvolatile pesticides.
2. Read and follow the pesticide label. Instructions on the pesticide label are given to ensure the safe and effective use of pesticides with minimal risk to the environment. Each pesticide is registered for use on specific sites or locations. Many drift complaints involve application procedures in violation of the label.
3. Use spray additives within label guidelines. This will result in better pesticide effectiveness and less potential for drift.
4. Use nozzles with larger orifice sizes. This will produce larger droplets and increase the number of tank refills, but may improve coverage and effectiveness while reducing the potential for drift.
5. Avoid high spray boom pressures; high spray pressure creates finer droplets. Consider 45 PSI the maximum for conventional broadcast ground spraying.

6. Use drift-reduction nozzles that produce larger droplets when operated at low pressures. When using venturi nozzles, higher pressures will be required to maintain an effective pattern. As the pressure is increased with these nozzles, the drift potential will increase, but not as much as with other types of nozzles.
7. Use wide-angle nozzles, low boom heights, and keep the boom stable. Drive perpendicular to terraces rather than parallel to avoid moving the boom ends high above the target surface or digging into the ground.
8. Drift is minimal when wind velocity is between 3 mph and 10 mph. Do not spray when temperature inversions are likely or when wind is high or blowing toward sensitive crops, gardens, dwellings, livestock, or water sources.
10. When possible, use lower application speeds. As application speed increases, there are often unintended effects on other application parameters that may increase drift.

### References


**This publication has been peer reviewed.**
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.
Protective Clothing and Equipment for Pesticide Applicators

Clyde L. Ogg, Extension Educator; Erin C. Bauer, Extension Associate; Jan R. Hygnstrom, Project Coordinator; and Pierce J. Hansen, Extension Assistant, all in the Pesticide Safety Education Program

This NebGuide explains how to choose and properly use personal protective equipment (PPE) when mixing, loading, and applying pesticides to help reduce exposure to pesticides and protect human health.

Pesticides are valuable pest management tools and, like any tool, must be used carefully and responsibly. Dressing appropriately and using personal protective equipment (PPE) can help minimize pesticide exposure and reduce the risk of pesticide poisoning. These steps also are important signals of appropriate and legal pesticide use.

Use all pesticides safely. Read the pesticide product label and comply with all directions. Failure to do so may subject you to state and/or federal penalties, and place you, your family, and the environment at a greater risk of pesticide exposure.

Manage Your Risk

Wearing protective clothing and equipment when handling or applying pesticides can reduce your risk of exposure, and thus your risk of pesticide poisoning. Understanding the toxicity of a product and the potential for personal exposure allows you to lower your risk. This idea is expressed by the Risk Formula: 

Risk = Toxicity x Exposure

No matter how toxic a substance is, if the amount of exposure is kept low, risk can be held to an acceptably low level. The toxicity of a substance can’t be changed, but risk can be managed, and the applicator is the manager.

What is Toxicity?

All pesticides are toxic, differing only in the degree of toxicity, and are potentially dangerous to people if exposure is high. Pesticide product labels have signal words that clearly indicate the degree of toxicity associated with a given product (Table I). The signal words — “Danger,” “Warning,” and “Caution” — indicate the degree of potential risk to a user, not the expected level of pest control.

Pesticides can enter the human body in three ways:

1) through the mouth (orally),
2) by breathing into the lungs (inhalation), and, most commonly,
3) by absorption through the skin or eyes (dermally).

Along with the signal words, pesticide product labels also include route of entry statements and specific actions a user must take to avoid exposure.

Table I. Pesticide product label signal words and relative toxicities.

<table>
<thead>
<tr>
<th>Group</th>
<th>Signal Word</th>
<th>Toxicity Rating</th>
<th>Lethal Dose for a 150 lb Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Danger a</td>
<td>Highly toxic</td>
<td>Few drops to 1 teaspoon</td>
</tr>
<tr>
<td>II</td>
<td>Warning</td>
<td>Moderately toxic</td>
<td>1 teaspoon to 1 tablespoon</td>
</tr>
<tr>
<td>III</td>
<td>Caution</td>
<td>Slightly toxic</td>
<td>1 tablespoon to 1 pint</td>
</tr>
<tr>
<td>IV</td>
<td>Caution (signal word not always required)</td>
<td>Relatively non-toxic</td>
<td>More than a pint</td>
</tr>
</tbody>
</table>

aThe lethal dose is less than those listed for a child, or a person under 150 lb and more for a person over 150 lb.

bThe skull and crossbones symbol and the word “Poison” are sometimes printed with the “Danger” signal word.

Read the Pesticide Product Label

Route of entry statements on the pesticide product label indicate the outcome that can be expected from different kinds of exposure. For example, a pesticide label might read, “Poisonous if swallowed, inhaled, or absorbed through the skin. Rapidly absorbed through the skin and eyes.” This tells the user that this pesticide is a potential hazard through all three routes of entry, and that skin and eye contact are particularly hazardous. The specific action statements normally follow the route of entry statements and indicate what must be done to prevent accidental poisoning. Using the previous example, the specific action statement might read, “Do not get in eyes, on skin, or on clothing. Do not breathe spray mist.”

Before handling, mixing, loading, or applying any pesticide, read the product label directions completely. If the label calls for the use of personal protective equipment, comply fully with those directions. The label will define the minimal protective equipment required for various tasks. Note that the PPE required for mixing and loading may be more extensive than the PPE required during application because of the potential for contact with a concentrated pesticide product.
Use Personal Protective Equipment

The type of PPE needed depends both on the toxicity of the pesticide being used and the formulation (liquid, granular, wettable powder, etc.). Some labels, especially for agricultural pesticides, are affected by the Worker Protection Standard and specifically state that certain items of clothing, equipment, eyewear, footgear, and gloves must be used. Others do not include such a statement. Some of the PPE required are specific to early entry while others are specific to handling and applying. In general, the more toxic the pesticide, the greater the need for PPE.

Choose the Right PPE

If a pesticide label does not have specific PPE requirements, always take reasonable precautions and use common sense. Use the route of entry and specific action statements from the product label to determine the type and degree of protection needed to handle the pesticide safely. For example, if you’ll be handling pesticides or pesticide equipment, consider wearing chemical-resistant gloves even if the label doesn’t specifically call for them.

Liquid pesticides often are more hazardous to use than dry formulations, and extra protection is warranted while mixing and/or loading pesticides. Recognize that in cases where there will be prolonged exposure to the spray or where the application is being made in an enclosed area, you must use extra protection.

Use Protective Clothing

Whenever you are using pesticides, at the very least you should wear a long-sleeved shirt, long pants, shoes, socks, and chemical resistant gloves (Figure 1). Many labels will require you to wear more than this, depending on the product’s toxicity and use. Select garments made of tightly woven fabrics to reduce pesticide penetration. Disposable coveralls, such as those made of Tyvek®, provide adequate protection to a pesticide applicator under most conditions. Protective suits made of or coated with butyl rubber, neoprene, PVC, or one of the newer coated and laminated polyethylene fabrics may be needed for certain applications.

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.

Protection for your head also is advisable and in some cases is specifically required. In general, a wide-brimmed, easily cleaned hat that will keep pesticides away from the neck, eyes, mouth, and face is adequate (Figure 2). Avoid hats with cloth or leather sweatbands as these will absorb pesticides. Baseball-style caps have headbands that readily absorb and retain pesticides. Labels that specify the use of headgear are generally found on highly toxic liquid concentrates. When working with these pesticides, wear a chemical-resistant hood or a plastic hard hat with a plastic sweatband and a rain-trough edge to keep drips off your neck and back.

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

Pesticides are readily absorbed through the eyes and can cause eye injury. When the labels for liquid pesticides include precautionary statements with the signal words “Warning” or “Danger,” it generally indicates the need for eye protection. Use goggles or safety glasses when the label requires it. (See Figure 3 for examples.) Some goggles have a wider bridge over the nose to be compatible with respirators. Goggles will provide adequate protection if they have the right type of venting. Safety goggles have three types of venting:

- 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.

Chemical-resistant gloves (Figure 4) 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 use and are available in reusable pairs that can be cleaned after each use.

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.

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.

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.

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.

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...
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 chemical spills after hours
(800) 525-5555; (402) 471-4545

Washing Up

Good personal hygiene is essential to keeping yourself pesticide-free. Soap and water are cheap insurance against pesticide contamination.

- Wash your hands and face often and keep soap and water nearby when working.
- If you’ve handled pesticides, always wash your hands with soap before smoking, eating, drinking, or using the toilet.
- Shower immediately after using pesticides and before changing into clean clothes.
- Remove and leave shoes at the door so you don’t track pesticides into the house.

Be Prepared for an Emergency

Take the pesticide label with you when seeking medical care. Have emergency telephone numbers handy (see above box) and keep them posted where pesticides are stored, mixed, or applied. If you experience any pesticide poisoning symptoms (nausea, skin rashes, headaches, coughing, diarrhea, chest pain, twitching, or seizures), see a physician immediately. For more information, see Extension Circular 2505, Signs and Symptoms of Pesticide Poisoning.

This publication has been peer reviewed.
Pesticide Safety: Choosing the Right Gloves

Erin C. Bauer, Extension Assistant
Clyde L. Ogg, Extension Pesticide Education Coordinator
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
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

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**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)

<table>
<thead>
<tr>
<th>Selection Category Listed on Pesticide Label</th>
<th>Types of Personal Protective Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (dry and water-based formulation)</td>
<td>Butyl Rubber ≥ 14 mils</td>
</tr>
<tr>
<td>NA</td>
<td>high</td>
</tr>
<tr>
<td>B (acetate)</td>
<td>high</td>
</tr>
<tr>
<td>C (alcohol)</td>
<td>high</td>
</tr>
<tr>
<td>D (halogenated hydrocarbons)</td>
<td>high</td>
</tr>
<tr>
<td>E (ketones, such as acetone)</td>
<td>high</td>
</tr>
<tr>
<td>F (ketone and aromatic petroleum distillates mixture)</td>
<td>high</td>
</tr>
<tr>
<td>G (aliphatic petroleum distillates, such as kerosene, petroleum oil, or mineral oil)</td>
<td>high</td>
</tr>
<tr>
<td>H (aromatic petroleum distillates, such as xylene)</td>
<td>high</td>
</tr>
</tbody>
</table>

*include 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.


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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:

<table>
<thead>
<tr>
<th>Glove size</th>
<th>Circumference of palm (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra small</td>
<td>6-7</td>
</tr>
<tr>
<td>Small</td>
<td>7-8</td>
</tr>
<tr>
<td>Medium</td>
<td>8-9</td>
</tr>
<tr>
<td>Large</td>
<td>9-10</td>
</tr>
<tr>
<td>Extra large</td>
<td>10-12</td>
</tr>
<tr>
<td>2XL</td>
<td>11-12</td>
</tr>
<tr>
<td>Jumbo</td>
<td>12-13</td>
</tr>
</tbody>
</table>

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.

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.

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

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.

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Index: Pesticides, General
Safety
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Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications

Erin C. Bauer, Extension Associate; Clyde L. Ogg, Extension Educator; Pierce J. Hansen, Extension Assistant; and Jan R. Hygnstrom, Project Coordinator

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

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

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

Your New Respirator

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

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

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

Fit Testing

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

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

Figure 3. Positive seal.

Figure 4. Negative seal.

Figure 5. Ampule test.
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.

Pay attention to when a cartridge’s life is spent and be sure to replace as necessary. Cartridge life may be reduced if exposure to organic vapors is extensive and occurs over a short time span. Always replace cartridges immediately if you can smell pesticide odors when using the respirator. If you are unsure of the last time a cartridge was used or if the total hours of use have not been recorded, replace it; when in doubt, replace.

Your new cartridges should be the same type as those you are replacing. Cartridges are color coded depending on what particulates they filter. For example, organic vapor cartridges are black and have “organic vapors” written on the label (Figure 8). A cartridge that filters organic vapors as well as pesticide dusts, mists, and fine particles (using a P100 filter) will be magenta and black.

To learn more about maintenance and fit testing of your respirator, refer to the user’s manual that came with your respirator, or view the University of Nebraska–Lincoln Extension video, “Cartridge Respirator Use” at http://www.youtube.com/user/UNLExtensionPSEP.

This publication has been peer reviewed.

Disclaimer

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Index: Pesticides, General Safety

Issued June 2011
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 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
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 praecaria*). The western prairie fringed orchid (threatened)

![Figure 2. Blowout penstemon (photo credit: James Stubbendieck, UNL).](image)

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

![Figure 4. Colorado butterfly plant (photo credit: Nebraska Game and Parks).](image)

![Figure 5. Interior least tern (photo credit: Nebraska Game and Parks).](image)
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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Index: Environmental & Natural Resources
Conservation
Issued September 2008
Protecting Pesticide Sensitive Crops

Clyde L. Ogg, Extension Pesticide Education Coordinator; Erin C. Bauer, Extension Associate; Greg R. Kruger, Extension Cropping Systems Specialist; Pierce J. Hansen, Extension Assistant; Janet R. Hygnstrom, Project Coordinator; and Craig L. Romary, Environmental Programs Specialist, Nebraska Department of Agriculture

This NebGuide examines how to protect sensitive crops, such as those found on organic and traditional commercial farms or in vineyards, from pesticide injury.

Pesticide sensitive crops, such as grapes in vineyards or fruit, vegetable, and ornamental crops grown on organic or traditional commercial farms, are becoming more common in the landscape. Consumer demand has created markets for these products, and sales of these crops have contributed to the state’s agricultural economic diversity. Even though any agricultural crop can be damaged by pesticide drift, these crops are especially sensitive to injury by pesticides; the potential for economic loss is significant. For example, grapes have an annual fruit value of $4,000 to $5,000 per acre and the processed value can be up to 10 times higher (Figure 1).

Use Pesticides Carefully

Pesticides include herbicides, insecticides, and fungicides. When applying pesticides, take extra precautions to avoid damaging sensitive crops. Many plants and animals are sensitive to pesticides and may be harmed by particle spray drift, vapor drift, or pesticides that run off the target area. This NebGuide focuses on herbicides that are especially prone to drift, and have high risk of causing damage when they move off-target. Reducing the potential for off-site movement onto sensitive sites is particularly important when applying these herbicides.

Since the introduction of Roundup Ready® crops in 1996, glyphosate has been used extensively for weed management in the Midwest. Glyphosate drift can damage many different crops. Plants including grapes, tomatoes, potatoes, soybeans, and fruit and nut trees, are very sensitive to spray drift from hormonal-type herbicides such as dicamba, picloram, MCPA, triclopyr, fluoroxypr, mecoprop, and 2,4-D. These herbicides can affect plants, especially sensitive crops, near the application site.

Be Proactive

The Nebraska Department of Agriculture (NDA) and Purdue University have arranged for a Web-based locater for sensitive commercial crops and bee hives called Driftwatch™ (Figure 2). Commercial growers of sensitive crops and bee keepers

Figure 1. Fruit crops such as grapes contribute to Nebraska’s agricultural economic diversity (Jeanne Fox, Kansas Department of Agriculture).

Figure 2. Nebraska Driftwatch encourages commercial producers to register locations of sensitive crops and bee hives.
are encouraged to register locations of their crops and hives. Pesticide applicators are encouraged to use this website to determine if any sensitive crops are near a planned pesticide application site. If a sensitive crop site is identified, applicators should adjust pesticide application procedures, including timing and/or application methods, accordingly.

Applicators are encouraged to use Driftwatch and document known locations in application records, or print a map from the website and incorporate it into application records. It is also good practice to scout the area before the planned pesticide application to become familiar with the landscape. Because listings on Driftwatch are voluntary, not all sensitive crop locations may be included. Pesticide applicators and dealers should visit with neighbors who may have sensitive crops or bee hives to let them know of intended pesticide applications, and assure them that all applications will be made so as to avoid injury.

Driftwatch allows applicators the ability to sign up for email notifications when new locations are entered in their “business area.” Simply register for this service then choose a business area by selecting statewide or individual counties, or use the online mapping tool to draw a geographic area.

Driftwatch is only as effective as the information provided by growers and the action taken by applicators. New or updated information should be submitted as soon as possible. In addition, those with sensitive crops should contact their neighbors and/or local pesticide dealers, co-ops, and other pesticide applicators in the area to alert them to the potential for pesticide damage. Good communication is the key to avoiding pesticide injury problems.

The Nebraska Driftwatch can be found at http://nebraska.agriculture.purdue.edu/.

**Strategies to Protect Sensitive Crops**

**Use Integrated Pest Management (IPM).** Before each application, review and consider using a variety of IPM methods, including pest prevention, scouting to monitor pest populations, economic threshold levels, and pesticide alternatives such as mechanical controls, sanitation, crop rotation, biological controls, and selection of resistant varieties.

**Select an appropriate pesticide product.** If using a chemical control, read product labels to find one suitable for the pest you want to control. Consider the toxicity and potential hazard of the product, and select one with the lowest risk of harming sensitive crops. Make sure the target site or crop is listed on the label.

**Read the label.** Follow all label directions. It is illegal to apply more than the label allows. For more details about the pesticide label see *Understanding the Pesticide Label* (NebGuide G1955).

- Remember that the pesticide label is the law. Read and follow all directions and precautions. Only apply pesticides on sites (crops, pastures, or other areas) that are listed on the label. Application of a pesticide to a site that is not listed on the label is illegal. Do not exceed the rate specified on the pesticide label; the use of a rate higher than that given on the label is illegal. The risk of off-target injury to people, livestock, pets, wildlife, and plants will be greatly reduced by following label instructions.
- Many labels, especially new ones, have instructions on avoiding drift. Some new labels include set-back zones to protect sensitive areas. Additionally, there could be information ranging from droplet size, nozzle selection, and maximum wind speeds in which applications can be made to avoid drift.

**Follow all precautions and plan your application.** The pesticide label will list environmental hazards and restrictions on the use of the product. Become familiar with the application site and ask yourself these questions:

- Are there any sensitive or desirable plants nearby?
- Is there a stream, pond, ditch, drainage area, or other open-water site close by?
- Does the weather forecast predict suitable conditions for application?
- Could the wind carry the pesticide to a neighboring property?
- Is my chosen pesticide product likely to volatilize due to high temperatures either on the day of application or the next day?
- Are there any children, pets, or other animals in the area?
- Do I know the amount of pesticide needed to complete the job so I don’t mix more than necessary?

**Watch for drift or runoff during the pesticide application.** It’s good practice to adjust pesticide applications for conditions that may increase drift or runoff. One factor to consider is wind speed and direction. Stop applying if the weather becomes too windy or if the product starts to run off the target area. You can also reduce injury by reducing your field speed when navigating difficult areas and if near sensitive crops. This will prevent uneven treatment patterns and wind eddies that can form behind a fast-moving tractor, and decrease unwanted movement of the boom.

Wind and boom height are two of the biggest problems when it comes to drift. By using a rate controller that changes output pressure, and lowering boom height, you can effectively decrease unwanted movement of the boom.

**Cleaning Pesticide Equipment**

Cleaning pesticide equipment can damage crops during future pesticide applications. Always clean tanks, nozzles, and other equipment thoroughly after applying herbicides by adding one-half tank of water, then flushing all parts of the tank for five minutes through both agitation and spraying. Always spray rinsate on an appropriate site.

If several pieces of spray application equipment are available, dedicate one to phenoxy herbicides or one to the specific crop to be treated. If not, extra careful cleaning following each application of a phenoxy herbicide is necessary to avoid subsequent crop damage. Mixing two quarts of ammonia and each application of a phenoxy herbicide is necessary to avoid injury. For more details about cleaning pesticide equipment see *Cleaning Pesticide Equipment* (NebGuide G1770).

**Follow directions for storing and disposing of unused pesticides and empty containers.** Off-site movement of rinse water or unused pesticides can harm sensitive sites, including sensitive crops. Plan your application carefully so that only the amount of pesticides needed will be mixed, and no extra mixed product will be left over. However, if extra product remains after an application is completed, dispose of the remainder by applying to a site mentioned on the label. Nebraska does not have a statewide pesticide disposal program. There are companies that can help you dispose of unused or outdated pesticides.
pesticide for a fee, but it is better to plan ahead and avoid having leftover pesticide.

Empty containers should be triple or pressure rinsed and either disposed of at a landfill according to label directions, or recycled. See the resources listed under “Additional Information” in this publication for more information about disposal and recycling programs.

Always store pesticides in a cool, dry, locked storage facility away from food, feed, and other supplies. Be sure the structure where you store pesticides is not located near water resources or sensitive sites. Store liquid pesticides on lower shelves in case of spills, and always have a spill kit available. Keep pesticides in their original containers, and when ready to do an application, use the oldest pesticides first.

For more details about storage and disposal of pesticides see Safe Transport, Storage, and Disposal of Pesticides (EC2507).

Pesticides Can Move Off the Application Site

Particle Drift. Small spray droplets are susceptible to drift during a pesticide application and may potentially travel long distances to damage nontarget plants or animals. To help prevent drift, use larger spray droplets and lower pressures; select nozzles designed to reduce drift, and apply the pesticides using the appropriate boom height. Make sure the wind speed is low and blowing away from sensitive areas.

Vapor Drift. After a pesticide is applied, the product may volatilize off the application site and move in an unpredictable manner, affecting off-site plants. The volatility of some pesticide products increases as the temperature rises into the upper 80s and 90s. The product label will warn you not to apply the product if a certain temperature is expected in the next few days. Ester formulations of phenoxy herbicides, for example, are more likely to volatilize and damage sensitive crops than amine formulations.

Spray drift can be reduced by doing the following:

- Spray when wind speeds are less than 10 mph.
- Avoid applying pesticides when there is a temperature inversion. An inversion occurs when there is cool, calm air near the surface with warmer air above. The inversion reduces air circulation and results in spray particles concentrating at the cool/warm air boundary and then moving off-site in an unpredictable manner.
- Select a nozzle that produces coarser (larger) spray droplets.
- Use the lower end of the suggested pressure range for a given spray nozzle.
- Adjust the height of the boom so it is at the appropriate application height.
- Use an additive to control drift on windy days.

Volatilization can be reduced by doing the following:

- Switch to a less volatile formulation. For example, switch from the ester form of 2,4-D to the less volatile amine form.
- The companies that manufacture growth regulator herbicides are currently working to design, manufacture and market low drift and low volatility compounds. These new formulations in combination with practices such as low drift nozzles, drift reducing adjuvants, and reduction in pressure will reduce both drift and volatility.
  - Dow AgroSciences has a low volatile 2,4-D choline salt
  - BASF has a low volatile dicamba BAPMA
- Spray only when temperatures will remain less than 90°F for several days.

Runoff. A pesticide product applied to a steep slope, bare ground, or even level ground immediately before a rain can run off and enter streams, rivers, and lakes, or severely damage other plants. Runoff can kill fish or aquatic invertebrates and/or make the water unsuitable for recreation or human consumption. Select a chemical weed control and application method that will not violate the label or cause damage. For more details about pesticide runoff and runoff prevention see Protecting Surface Water Quality (EC730).

Growth Regulator Herbicides

Growth regulator herbicides, despite being the oldest herbicide mode-of-action on the market, are not completely known. Growth regulator herbicides are known to mimic indole acetic acid in plants. The mimicry of auxin in the plant leads to malformed growth and epinasty (downward bending of plant parts such as leaves due to increased growth of upper leaf tissue) in broadleaf plants when exposed to growth regulator herbicides. While growth regulators are not any more prone to drift than other herbicides, they are often thought to be because injury from growth regulator herbicides are distinct and are caused by much lower doses than many of the other herbicides currently on the market.

Figure 3. A young grape shoot injured by 2,4-D (Bruce Bordelon, Purdue University).

Figure 4. Grape leaf injured by 2,4-D (Bruce Bordelon, Purdue University).
Symptoms of Phenoxy (2,4-D) Injury

Phenoxy (phenoxyacetic acid) herbicides, such as 2,4-D, are a subset of growth regulator herbicides that cause abnormal plant growth by disrupting the hormone balance within the plant. Broadleaf plants are more susceptible to this type of injury. Sensitive plants that receive small amounts of a phenoxy herbicide may develop abnormal leaves and multiple or enlarged lower plant parts (Figure 3). Higher concentrations of the herbicide can cause stunting and cupping of leaves, twisted growth of soft shoots, clearing and enlargement of major leaf veins (Figure 4), and severe distortion of flowering or fruiting plant parts.

When phenoxy injury is present, the youngest growth is most severely affected. Plant growth may stop after exposure to a phenoxy herbicide and may be restricted for several weeks. Vines (i.e. grapes) showing symptoms of 2,4-D injury usually do not produce new growth with normal features for the rest of the season. Severely injured vines may not recover for two or more years.

Other Growth Regulators

In addition to the phenoxy herbicides, other examples of growth regulators that can injure sensitive crops include dicamba (benzoic acid picloram) and triclopyr (pyridine carboxylic acid). Like phenoxy herbicides, these herbicides are prone to particle drift, but unlike phenoxy herbicides, they are less prone to vapor drift.

Other Herbicide Injury

While much of this publication is focused on growth regulator herbicides, it should be noted that any herbicide that moves into an unintended area through physical particle drift or volatility has the potential to cause injury. Because many of the compounds used in production agriculture have low risk of volatility, injury observed from physical particle drift is much more common. Products such as glyphosate, glufosinate, 4-HPPD inhibitors, and ALS inhibitors can all cause injury when they move away from the intended application area. The amount and type of injury will be dependent on the amount of drift that occurs as well as the type of species in the drift area.

Summary

Making pesticide applications having low drift potential and that are highly efficacious is a judicious task. It is absolutely necessary when it comes to protecting sensitive crops and bee hives. Reading pesticide labels, checking application equipment, and being cognizant of environmental conditions are critical to making sure the products go where they are intended, as well as maximizing the efficacy of the products.
Bee Aware: Protecting Pollinators from Pesticides

Erin C. Bauer, Extension Associate
Clyde L. Ogg, Extension Pesticide Educator
Frederick P. Baxendale, Extension Entomologist
Jan R. Hygnstrom, Project Coordinator
Pierce J. Hansen, Extension Assistant

Honey bees (Apis mellifera) and other bee species such as bumblebees, orchard mason bees, and leafcutter bees are very important to the pollination of flowers and crops, and can be found foraging on numerous plants in the spring through late summer and early fall. In addition, bees, butterflies, moths, flies, hummingbirds, and some bats can be important pollinators.

Approximately 3,500 species of bees live in North America. Bees are valuable pollinators of 95 crops grown in the United States. Crops pollinated by bees have a farm value of well over $10 billion annually in the U.S. Honey bee colonies also contribute to our agricultural economy by producing over $200 million of honey annually.

This Extension Circular focuses on the honey bee, the most important pollinator in the Midwest, because it can:

- be managed by beekeepers,
- be transported,
- be managed for income from both honey production and pollination,
- be maintained in large populations throughout the growing season, and
- visit and pollinate many plant species.

Honey bees (Figure 1) are hairy, yellow, and black or brown banded social insects that are about ½-inch long on average and live in hives. Each individual has distinct duties, either
as a worker (serving as a nursemaid, housekeeper, or forager) or a reproductive bee (drone or queen).

Maintenance of the hive relies on the distributed work within the colony. For example, foragers (usually older worker bees) search for food resources (pollen and nectar) and communicate this to the colony. Because the health of the hive and successful crop pollination relies on the foraging activities of worker honey bees, it is essential to protect these important insects from potentially harmful pesticide exposure.

Protecting pollinators is an important consideration when applying pesticides to control crop pests. Pesticides such as insecticides, fungicides, and miticides may be toxic to bees. Insecticides are formulated to kill insects, fungicides kill fungi that cause some plant diseases, and miticides kill mites. Pesticide labels may carry specific statements to protect bees and should be read carefully prior to pesticide application. The loss of native pollinators due to habitat reduction, and the decline in honey bee colonies due to parasitic bee mites and other factors, reinforces the need to protect these insects through good pesticide stewardship. While this Extension Circular focuses on protecting honey bees, many of the recommendations serve to protect other bee and pollinator species as well.

**Considerations for Pollinator Protection**

**Plant Growth Stage**

Most honey bee poisonings happen when pesticides are applied to flowering crops (e.g., apples, melons, soybeans) or are allowed to drift onto flowering plants (e.g., weeds and wildflowers) during periods when the bees are actively foraging. If applications are permitted by the label, growers and applicators need to communicate with beekeepers and exercise all reasonable measures to minimize the risks to bees.

**Relative Toxicity of the Chemical**

Pesticides vary in their toxicity to honey bees. Most fungicides and herbicides (pesticides that kill weeds) have relatively low toxicities to honey bees and can be used without endangering them. In addition, certain insecticides and miticides are not hazardous to bees and can be applied with little risk of bee injury. For example, *Bacillus thuringiensis* (*Bt*), a biological insecticide derived from a soil-dwelling bacterium, is not toxic to bees. However, insecticides such as pyrethroids that are more toxic to bees can only be applied when bees are not actively foraging because bees that are exposed during the application may be killed. Pesticides that are highly toxic to honey bees cannot be applied to flowering crops when bees are present without causing serious injury or death. Bee toxicity data for selected pesticides are listed in Table I. Lethal dose (LD$_{50}$) and relative toxicity ratings are provided for each active ingredient (AI) included. Use the table to compare toxicities within and between broad pesticide types (i.e. fungicides, insecticides, herbicides, miticides), but understand that these pesticide types can vary in their toxicity to bees. Also, recognize that toxicity does not indicate the exposure a bee is likely to receive, but rather how much of an AI it takes to kill a bee. Realize that toxicity is only one factor when considering hazards to bees. Exposure time and dosage, application rate, and formulation all contribute toward overall risk or hazard of using an active ingredient. A good way to think about risk is with the risk formula:

$$\text{RISK} = \text{TOXICITY} \times \text{EXPOSURE}$$

Always read and follow the label for the product you are using. It will provide guidance about toxicity to bees and how you can reduce the risk of exposure during application.

**Choice of Formulation**

Different formulations of the same pesticide often vary considerably in their toxicity to bees. Granular (G) pesticides are generally less hazardous to honey bees than other formulations. Dust (D) formulations, though uncommon, are usually more hazardous than emulsifiable concentrates (EC) because they adhere to the bee’s body hairs and are carried back to the beehive. Wettable powder (WP) and flowable (F) formulations dry after application to a dust-like material that can be transferred to foraging pollinators. Likewise, microencapsulated (M) formulations also can be transferred to bees along with pollen and brought back to the colony. Since bees are highly social and hives can be crowded, substances picked up in the field can be spread within a hive. Exposure to pesticide formulations can cause significant losses of both foraging bees and bees in the hive. In severe cases, pesticides may remain active in the hive for several months and prevent colonies from recovering.

**Using Treated Seed**

Pesticides added as a protective coating to seeds can become dislodged during handling and/or planting. Graphite and talc used to lubricate seeds during planting can carry these residues to non-target locations. Before handling or planting treated seed, take precautions to reduce the risk of pesticide residues or planter talcs drifting or moving offsite onto flowering plants where bees may be foraging. For example, if you intend to plant treated corn seed with a pneumatic planter, a burndown herbicide should be used to eliminate henbit from the site prior to planting. This will prevent planter talc from settling on the henbit, which is usually blooming at corn planting time and may be visited by bees.
Table I. Selected representative trade names, pesticide AIs, bee toxicities, toxicity ratings, and pesticide types.1

<table>
<thead>
<tr>
<th>Representative Trade Names</th>
<th>Pesticide Active Ingredient (AI)</th>
<th>Bee Toxicity (LD₅₀ as µg/bee)</th>
<th>Toxicity Rating</th>
<th>Pesticide type</th>
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<td>0.0039</td>
<td>Highly toxic</td>
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<td>Cyfluthrin</td>
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<td><strong>Methyl</strong></td>
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<tr>
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<td>Bifenazate</td>
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<td>Moderately toxic</td>
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<tr>
<td><strong>Captain</strong></td>
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<td>10</td>
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<td><strong>Javelin Dipel</strong></td>
<td>Bacillus thuringiensis²</td>
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</tr>
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<td>F</td>
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<td><strong>2,4-D Ester</strong></td>
<td>2,4-D 2-EHE</td>
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1The USDA Windows Pesticide Screening Tool (Win-PST) is an environmental risk screening tool that includes bee toxicity data available for each active ingredient in the database. The tool is available for download from [http://go.usa.gov/Kok](http://go.usa.gov/Kok).

2Bacillus thuringiensis (Bt) Reregistration Eligibility Decision (RED), U.S. EPA. Data can be found at [http://www.epa.gov/oppsrrd1/REDs/0247.pdf](http://www.epa.gov/oppsrrd1/REDs/0247.pdf)
Residual Action

Residual activity of a pesticide is an important factor in determining its safety to pollinators. Pesticides that degrade within a few hours usually can be applied with minimal risk during times when bees are not actively foraging. Applying pesticides with extended residual activity (more than eight hours), even when bees are not actively foraging, may still result in bee injury if bees visit the crop during the period of residual activity. Pesticides with extended residual activity require extra precaution to prevent bee exposure. Look for clues about the residual activity of an individual pesticide on the pesticide label. For example, restricted entry intervals greater than 12 hours indicate extended residual activity.

Drift

Bees may forage in areas adjacent to the target crop. Pesticides that drift from the target crop onto nearby flowering plants can cause significant bee poisoning. In general, sprays should not be applied if wind speed exceeds 10 mph or is blowing toward adjacent flowering plants. While pesticides should never be applied near beehives, drift alone rarely causes extensive bee poisoning. When evaluating potential drift hazards, focus on reducing the risk of drift moving to nearby flowering plants.

Temperature

Because temperature plays such an important role in the activity of cold-blooded animals, such as bees, as well as having an effect on pesticides, it can affect when or how bees are exposed to pesticides. Bees are most actively foraging during periods of high temperature and sunlight. Also realize that some pesticides vaporize during these times, thereby increasing potential for bee injury. Making pesticide applications during periods of cooler temperatures and low light or overcast conditions will minimize exposure to bees. Always be aware of temperature fluctuations and use common sense before applying pesticides that are toxic to bees.

Distance from Treated Areas

Honey bee mortality due to pesticides usually decreases the farther away colonies are from treated areas (i.e., crops, turf, etc.). Most foraging activity occurs within one to two miles of the hive. However, during periods of nectar or pollen shortage, honey bees forage at greater distances, and colonies up to five miles from the treated area can be injured.

Time of Application

Application timing is related to all the previously mentioned factors, but the most critical one is to control pests either prior to crop flowering or after flowering is complete. This will greatly reduce the risk of pollinators being exposed to pesticides. If pesticides must be applied to flowering plants, use pesticides with short residuals in the evening when the temperatures are below 60 degrees. This can greatly reduce the potential for honey bee injury.

Communication and Cooperation

Reducing pesticide injury to honey bees requires communication and cooperation among beekeepers, growers, and pesticide applicators. Beekeepers should understand the cropping and pest management practices used by growers near their apiaries. Likewise, pesticide applicators should be aware of apiary locations, have a basic understanding of honey bee behavior, and know which materials and application practices are the most hazardous to bees. It is unlikely that all bee poisonings can be avoided, but in most cases, bee losses can be reduced by understanding the hazards and maintaining effective communication.

How Growers and Applicators Can Reduce Risks of Honey Bee Injury

Understand the risks. Many crop pests can be controlled without endangering bees. Attend crop pest management training sessions to learn the latest about crop pests and control measures used by growers and applicators.

Do not treat flowering plants. Be especially careful when treating crops such as alfalfa, sunflowers, and canola, which are highly attractive to bees. Pesticide labels carry warning statements and sometimes prohibit application during bloom. Always read and follow the label.

Examine fields before spraying to determine if bees are foraging on flowering weeds. Milkweed, smartweed, henbit, and dandelion are examples of weeds that are highly attractive to honey bees. Where feasible, eliminate these flowering weeds in fields by mowing or cultivating prior to pesticide application or planting. While bright and colorful flowers are highly attractive to bees, some plants with inconspicuous blossoms such as dock, lambsquarter, and ragweed are also visited. Therefore, when you examine areas for flowering plants, consider all plants that have flowers. Be aware that many plants only produce pollen and nectar for a few hours each day. Fields should be scouted for honey bees at the same time of day as the anticipated pesticide application.

Maintain forage areas for bees. Intensive agriculture often increases bee dependence on cultivated crops for forage. Establishing plants in wild or uncultivated areas for honey bees to forage will reduce bee dependence on crop plants that may require pesticide treatments. Plants recommended for uncultivated areas include sweet clover, white Dutch clover, alfalfa, purple vetch, birdsfoot trefoil, and partridge.
pea (Figure 2). Many trees and shrubs are beneficial to bees as well. The most attractive species include linden, black locust, honey locust, Russian olive, wild plums, elderberries, red maples, willows, and honeysuckle. However, when establishing foraging areas with trees and shrubs, avoid planting honey locust, Russian olive, or honeysuckle. Although attractive to honey bees, these species can become invasive and outcompete native plant species. Soil conservation, natural resource, and game managers usually are eager to help establish plantings that benefit honey bees because these areas also conserve soil and provide valuable habitat for plant and wildlife conservation programs. These individuals can be a good resource for selecting trees that are both attractive to bees and healthy for the environment.

**Avoid spray drift.** Give careful attention to the location of flowering crops and weeds relative to wind speed and direction. Changing spray nozzles or reducing pressure as allowed by the label can increase droplet size and reduce spray drift.

**Apply pesticides when bees are not foraging.** In general, bees are foraging more actively during the sunniest and warmest times of the day. Therefore, some pesticides can be applied in late evening or early morning (i.e. from 8 p.m. to 6 a.m.) with relative safety. For example, with the partridge pea plant, bees work heavily on it in the morning, but by early afternoon the field will go quiet because the nectar stops flowing about that time of day.

Although bees don’t prefer corn pollen and it has limited nutritive value, they may collect pollen from tassels in the early morning but are not present in the afternoon or evening. Short-residual materials applied from late afternoon until midnight pose less bee hazard in corn fields if flowering weeds are not present.

**Adjust spray programs in relation to weather conditions.** Reconsider the timing of a pesticide application if unusually low temperatures are expected. Cool temperatures can delay pesticide degradation and cause residues to remain toxic to bees the following day. Stop applications when temperatures rise and when bees re-enter the area in early morning. Similarly, do not apply during evening hours if temperatures are unusually high and bees are still foraging.

**Contact local beekeepers and obtain locations of beehives.** If colonies are present in an area where you will be applying a product that is toxic to bees, you should contact beekeepers (Figure 3) within 48 hours so they have time to protect or move the colonies. Many pesticide applications pose minimal risk to bees, and beekeepers may choose to accept some risk rather than move colonies. Notify beekeepers as far in advance as possible.

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*Figure 2. Partridge pea planted in an uncultivated area serves as bee forage.*
Figure 3. Notify beekeepers when you will be applying a product that is toxic to bees.

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

Use DriftWatch. The Nebraska Department of Agriculture (NDA) and Purdue University have developed a Web-based locator for sensitive commercial crops and beehives called DriftWatch™ (Figure 4). This site can be accessed at http://www.driftwatch.org. Beekeepers are encouraged to register the locations of their hives, and pesticide applicators are encouraged to use this website to determine if any beehives are located near a planned pesticide application site. Many beekeepers have provided their contact information on DriftWatch, making personal communication much easier. If beehives are present, pesticide application procedures, including timing and/or application methods, should be adjusted accordingly.

Beekeepers, crop producers, and applicators are encouraged to access DriftWatch and document known beehive locations in application records, or print a map from the website and incorporate it into application records. It is also good practice to scout the area prior to a planned pesticide application to become familiar with the landscape. Because listings on DriftWatch are voluntary, not all apiary locations may be included. DriftWatch is only as effective as the information provided by beekeepers and the action taken by applicators. New or updated information should be submitted as soon as possible. Good communication is the key to avoiding pesticide injury to honey bees. To view video segments about DriftWatch and bees/pollinators, visit the UNL Extension PSEP YouTube channel, listed in the Resources section of this Extension Circular.

Read the pesticide label. Carefully follow listed restrictions and/or precautions with regard to bee safety.

Steps Beekeepers Can Take to Protect Their Colonies

Choose low hazard apiary locations. Do not place beehives adjacent to crops likely to be sprayed with a pesticide (Figure 5).

Know the risks. Many crop pests can be controlled without endangering bees. Attend crop pest management training sessions to learn the latest about crop pests and control measures used by growers and applicators. These sessions also provide an opportunity to establish communication links with growers and pesticide applicators.
Maintain positive working relationships with applicators. Risk management decisions can best be made when both parties understand each other’s needs. Establish a communication link prior to the spray season rather than during peak activity periods when all parties are busy.

Use DriftWatch. As mentioned earlier, register the location of your hives on DriftWatch.

Applicators will be able to search for such locations and communicate with you before applying pesticides near your beehives.

Be prepared to protect colonies if necessary. If pest control measures that carry unacceptable risks are necessary, know the options for protecting your colonies and be prepared to implement them. Options for protecting bees include:

1. When products with short residual activity are to be applied, briefly confine bees to their hive with wet burlap. This measure is only feasible if a small number of colonies are involved and if the confinement period is brief and early in the morning. **Caution! This measure can result in the colony overheating and should be used with care.** Fine mesh moving nets are also available and can be purchased by beekeepers if the need arises.

2. Temporarily disrupt foraging activity by removing colony covers and offsetting boxes. This will result in a temporary reduction in foraging. Most honey bees will remain in the hive to protect their stores and to maintain temperature and humidity in the exposed hive. After a few hours to one day, colonies will adjust to the change and resume foraging. This approach is safer than confining colonies but is not recommended if bees are located in or adjacent to areas that will be treated.

3. When highly toxic products with extended residual activity are applied to flowering crops, move honey bees to another location at least four miles from the treated area. Moving populous colonies during hot weather can result in considerable bee mortality and should be avoided if possible. Moves should be made early in the morning or evening when temperatures are cool and the bees are the least active. In general, moving colonies isn’t practical for most beekeepers. It requires that hives be kept on pallets and moved using a forklift. Migratory beekeepers may be some of the few with such equipment.

Report colony injury. Beekeepers are often reluctant to report bee injury incidents for a number of reasons, one of which is because they may be relying on the landowner/applicator to provide a place to put their hives. However, EPA is unable to adequately evaluate product use and risk.
With good environmental stewardship, you can help protect the bees that are essential pollinators for Nebraska crops. Applicators and beekeepers should work together to ensure successful pest control while reducing the risks to honey bees. This includes registering beehives on DriftWatch, having a good communication network, using pesticides that are least toxic to bees, and timing applications when bees are not actively foraging. Bees are a valuable agricultural resource that are worthy of our respect and protection.

Final Thoughts

There are many ways to reduce bee poisoning. Often, severe losses can be avoided by relatively simple modifications of pest control programs. Talk with other growers and applicators about how to reduce bee injury and consult reference materials, such as this Extension Circular, on protecting honey bees.

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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Rinsing Pesticide Containers

Clyde L. Ogg, Extension Pesticide Education Educator; Erin C. Bauer, Extension Associate; Pierce J. Hansen, Extension Assistant; and Jan R. Hygnstrom, Project Coordinator, all in the Pesticide Safety Education Program

It is estimated that every year 1 million plastic agricultural pesticide containers are used in Nebraska. Effective rinsing of these containers saves money, protects the environment, and meets federal and state regulations for pesticide use.

Proper rinsing of pesticide containers is easy to do, saves money, and contributes to good environmental stewardship. Rinsing containers when preparing spray solutions prevents potential problems with un-rinsed containers, storing rinse solution (rinsate), and generating hazardous waste. Even during a busy season, the few extra minutes it takes to properly rinse empty pesticide containers is time well spent.

For example:

• Rinsing pesticide containers efficiently and economically uses all the pesticide that you purchased. When the rinsate is added immediately to the load and sprayed on a labeled site, the need to store and later dispose of it is eliminated.
• Rinsing pesticide containers immediately after emptying easily removes leftover concentrate. If the container is not rinsed immediately, remaining pesticide mixtures may dry inside the container and be difficult to remove.
• Rinsing containers removes potential pesticide exposures to people, wildlife, and the environment.
• Proper rinsing is required by federal regulations and is a sound management and environmental practice.

Rinsing Helps Protect the Environment

Proper rinsing of pesticide containers reduces a potential source of contamination of soil, surface water, and groundwater. Contamination harms plants and animals and affects water supplies. Preventing environmental contamination is always better and less expensive than cleanup.

Federal laws require the rinsing of liquid pesticide containers. Violation of these laws is punishable by criminal and/or civil penalties. When an empty container is recycled, returned to the supplier, or disposed of according to label directions, it must be properly rinsed. Approved pesticide container recyclers and those receiving returned minibulk containers can accept only properly rinsed containers. Some landfill operations may not accept rinsed pesticide containers.

Types of Pesticide Containers

The most common agricultural pesticide containers are the minibulks (from 85 to 300 gallons), plastic drums in 15-, 30- and 55-gallon sizes, and returnable shuttle containers. The 2.5-gallon plastic containers also remain popular. The minibulk containers and shuttles are intended to be returned and reused by the supplier. Granular and dust insecticides are sold in waxed-paper bags or other water-resistant containers. Nearly all pesticide products used on animals and in households are sold in plastic containers.

Plastic drums and 2.5-gallon containers may be recycled after the pesticide materials have been removed by rinsing. Proper rinsing of plastic pesticide drums and containers will remove more than 99 percent of any pesticide residue after they have been emptied. Two commonly used procedures are effective for rinsing pesticide containers: triple-rinsing and pressure-rinsing.

Triple-Rinsing

Triple-rinsing means rinsing the container three times. This method can be used with all plastic containers.
How to triple-rinse (Figure 1):

1. Wear the same personal protective equipment while rinsing containers as the pesticide label requires for handling and mixing.

2. Remove the cap from the pesticide container. Empty all pesticide into the spray tank, allowing the container to drain for 30 seconds. Begin rinsing immediately or the product may be difficult to remove. If you are unable to rinse the container immediately, replace the cap until you can.

3. Fill the container 10 percent to 20 percent full of water or rinse solution (i.e., fertilizer solution).

4. Replace the cap on the container.

5. Swirl the liquid within the container to rinse all inside surfaces.

6. Remove the cap from the container. Pour the rinsate from the pesticide container to the spray tank and allow it to drain for 30 seconds or more.

7. Repeat steps 3 through 6 two more times.

8. Puncture or crush the container so it cannot be reused.
9. Replace the cap and dispose of pesticide container according to label directions.

10. If recycling, remember that caps and containers are made from different materials; therefore, caps cannot be recycled.

**How to triple-rinse drums:**

First, reread the procedures for triple-rinsing containers because they contain important information not listed here. Using the following procedures for triple-rinsing drums may require two people.

1. Empty the drum as much as possible.
2. Fill the drum with water to 25 percent of capacity. Replace and tighten bungs.
3. Tip the drum on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds.
4. Stand the drum on end and tip it back and forth several times to rinse the corners.
5. Turn the drum over, onto its other end, and repeat this procedure.
6. Carefully empty the rinsate into the spray tank.
7. Repeat steps 2 through 6 **two more times**.
8. Carefully rinse the cap over the spray tank opening and then dispose of as regular solid waste.
9. Puncture the base of the drum with a drill so that it cannot be reused.
10. Store rinsed drums under cover where they will be protected from rain.

**Pressure-Rinsing**

Use a pressure rinser with an anti-siphon device to flush the remaining pesticide from the container. Attach a special nozzle with a spear-point, which is generally available from your pesticide supplier and other sources, to the end of a water hose and force water under pressure into the pesticide container. Pressure-rinsing is faster and easier than triple-rinsing and can be used most effectively with plastic 2.5 gallon pesticide containers.

**How to pressure-rinse 2.5-gallon containers** *(Figure 2)*:

1. Wear the same personal protective equipment while rinsing containers as required on the pesticide label for handling and mixing.
2. Remove the cap from the pesticide container. Empty all pesticide into the spray tank. Turn the container so that any product in the handle flows out. Allow the container...

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Figure 2. Pressure-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.
to drain for 30 seconds. Begin the rinsing procedure immediately or the product may be difficult to remove. If you are not able to rinse the container immediately, replace the cap until you are able to rinse the container.

3. Insert the pressure-rinsing nozzle, which should be equipped with a flow control, by puncturing a hole through the lower side of the pesticide container.

4. Hold the pesticide container upside down over the spray tank opening, turn on the flow of water, and allow the rinsate to run into the spray tank.

5. Rinse for the length of time recommended by the manufacturer (usually 30 seconds or more). Rotate or rock the nozzle to rinse all inside surfaces.

6. Rinse the cap separately in a bucket of water and pour this rinse water into the spray tank.

7. Replace the cap and dispose of pesticide container according to label directions.

8. If recycling, remember that caps and containers are made from different materials; therefore, caps cannot be recycled.

Storing Empty Pesticide Containers

- Un-rinsed empty pesticide containers should be stored in the same way you store containers with pesticide. Replace the cap and store un-rinsed containers upright in a roofed or covered and secure (locked) structure over an impervious surface.
- Pressure-rinsing creates a hole in the container. Store pressure-rinsed containers indoors to prevent water, rain, or snow from entering the containers. Remove the caps to allow the containers to completely dry out during storage.
- Triple-rinsed containers should be stored outside only if you replace the cap. Triple-rinsed and capped containers do not need to be stored on impervious surfaces.
- When you are ready to offer rinsed, empty pesticide containers for recycling, remove the caps (they cannot be recycled) and any labels, plastic sleeves, or wrappers attached to the container. Dispose of these materials in an approved landfill.

Container Recycling

Recycling clean agricultural pesticide containers protects Nebraska’s environment. Several locations in Nebraska accept rinsed plastic agricultural pesticide containers for recycling. All containers are thoroughly inspected before acceptance.

Any pesticide container with pesticide residue that can be rubbed off with a neoprene- or nitrile-gloved hand will be rejected. Properly rinsed containers that are stained will be accepted. Do not include pesticide containers in household or curbside recycling programs. Check with your University of Nebraska–Lincoln extension educator, other local officials, or the website (http://pested.unl.edu/recycling) to determine the locations of plastic pesticide container recycling sites in Nebraska.

Remember

✓ Read and follow all pesticide label directions. Federal law requires rinsing of liquid pesticide containers.
✓ NEVER dispose of rinsate on a site the pesticide product label doesn’t allow. Instead, use the rinsate generated by triple- or pressure-rinsing pesticide containers as part of your spray mixture.
✓ Store pesticides only in the original, labeled containers. Never reuse a pesticide container for any purpose.
✓ Wear appropriate personal protective equipment as required by the label.
✓ Always use an anti-siphon or backflow prevention device when filling spray tanks or rinsing pesticide containers.
✓ Mixing and loading sites should be at least 150 feet away from all wells. Review pesticide labels. Be aware of requirements for specific setbacks from wells regardless if the well is active or not.

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Index: Pesticides, General Safety
2007, Revised April 2013
Cleaning Pesticide Application Equipment

Clyde L. Ogg, Extension Educator
Charles A. Burr, Extension Educator
Robert N. Klein, Extension Specialist
Pierce J. Hansen, Extension Assistant
Erin C. Bauer, Extension Associate
Jan R. Hygnstrom, Extension Project Manager

Important steps in completely and carefully cleaning and rinsing pesticide application equipment are covered in this NebGuide.

Mixing, loading, and application equipment should be cleaned and rinsed as soon as you finish a pesticide application. Do not leave equipment containing pesticides at the mixing/loading or application site, or wash application equipment repeatedly in the same location, unless you use a containment pad or tray.

Anyone cleaning pesticide-contaminated equipment must have instruction on proper safety procedures. Equipment cleaning can present as great a risk of exposure to pesticides as many other pesticide handling tasks. When cleaning pesticide-contaminated equipment, wear the same personal protective equipment (PPE) that the labeling requires for making applications, plus a chemical-resistant apron or other appropriate protective equipment. Also wear eye protection, even if not required by the label directions.

Cleaning Procedures

After the equipment is empty, clean both the inside and the outside thoroughly, including nozzles or hopper openings (Figure 1). Certain pesticides use a carrier (e.g., petroleum-based products) that may require special cleaning agents or high water pressure to remove.

Select a location to clean the sprayer where any spilled rinsate will not contaminate water supplies, streams, crops, or other plants and where puddles will not be accessible to children, pets, livestock, or wildlife.
attention to the following areas as they may be missed or difficult to clean:

- spray surfaces or components where buildup of dried pesticides might occur
- sprayer sumps and pumps
- inside the top of the spray tank and around baffles
- irregular surfaces inside tanks caused by baffles, plumbing fixtures, agitation units, etc.
- collection points where the hoses connect to the nozzle fittings in dry boom sprayers. Wet booms eliminate this problem.

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

Some cleanups require special cleaning agents. Choose sprayer cleaning agents according to the pesticide and formulation to be removed (for herbicide-specific information see the “Recommended Cleaning Agents for Selected Herbicides” table in the Guide for Weed Management, EC130). These agents penetrate and dissolve residues and then are removed in the rinsate. Commercial tank cleaning agents are generally preferred because they do a better job than household detergents and can deactivate some herbicides.

Rinsates

Rinsates from cleaned equipment contain pesticides and can be harmful to people and the environment. Do not allow rinsates to flow into water systems, including sink or floor drains, storm sewers, wells, streams, lakes, or rivers. Collect rinsates and apply them to labeled sites at or below labeled rates. If possible, consider rinsing your equipment at the application site and applying the rinsate to the labeled site.

Equipment rinsate may be also used as a diluent for future mixtures of pesticides if:

- the pesticide in the rinsate is labeled for use on the target site where the new mixture is to be applied.
- the amount of pesticide in the rinsate plus the amount of pesticide product in the new mixture does not exceed the label rate for the target site.
- the rinsate is used to dilute a mixture containing the same or a compatible pesticide.

The rinsate cannot be added to a pesticide mixture if:

- the rinsate contains strong cleaning agents, such as bleach or ammonia, which might harm the plant, animal, or surface to which the pesticide will be applied.
- the rinsate would alter the pesticide mixture and make it unusable; for example, if the pesticides are physically or chemically incompatible.

If rinsates cannot be subsequently applied to labeled sites, dispose of them as you would waste pesticides.

Equipment Cleanup

Clean your equipment thoroughly after each use or when changing chemicals. Pesticide residues in a spray tank may corrode metal, plug hoses, or damage pumps and valves unless they are removed immediately after use. Some residues left in the sprayer tank and components can react with pesticides used later, reducing the effectiveness of the pesticides.

Special tank-cleaning nozzles are available for cleaning the interior walls of spray tanks.

Thoroughly rinse equipment with the recommended cleaning agent and carrier, allowing the cleaning solution to circulate through the system for several minutes. Remove the nozzles and screens, and flush the sprayer system twice with clean water.

Sloppy cleanup practices are a main cause of equipment failure or malfunction. Always clean application equipment immediately after each use. Pesticides allowed to dry in the application equipment are more difficult to remove.

Several commercial compounds are available to aid in tank cleaning. These can neutralize and remove pesticide residues, remove mineral deposits and rust, and leave a protective film on tank walls to help prevent corrosion.

As with any procedure involving exposure to pesticides, remove contaminated clothes and take a shower immediately after cleaning equipment. Waiting until the end of the day to clean up can allow additional absorption of the pesticide through the skin. Keep contaminated clothing separate from other laundry and tell whoever washes the clothes of the possible hazards. Encourage him/her to wear protective gloves while handling contaminated laundry and, if the same washer is used for family clothing, run the washer through one or more cycles with hot water and detergent but no clothing before doing regular laundry.

Equipment Storage

When preparing to store your sprayer, add one to five gallons of lightweight oil such as diesel fuel or kerosene (how much depends on the size of the tank) before the final flushing. As water is pumped from the sprayer, the oil leaves a protective coating on the inside of the tank, pump, and plumbing. To prevent corrosion, remove nozzle tips and screens and store them in a can of light oil. In addition, add a small amount of oil and rotate the sprayer pump four or five revolutions by hand to coat interior surfaces completely. Sprayer engines, whether air- or water-cooled, require additional servicing following a pesticide application. Follow the directions in the engine’s owner’s manual.

After thoroughly cleaning and draining the application equipment, store it in a dry, clean building, if possible. Replace worn-out, deteriorated, or broken parts. If you must store the sprayer outside, remove the hoses, wipe oil off exterior surfaces, and store them inside where they will not become damaged by ultraviolet light. When using trailer sprayers, you may want to put blocks under the frame or axle to prevent flat spots on the tires during storage.
Removing Herbicide Residues from the Sprayer

The following is the sprayer cleanout procedure listed in University of Missouri publication G4852, *Cleaning Field Sprayers to Avoid Crop Injury*, available on the website: [muextension.missouri.edu/xplor/agguides/crops/g04852.htm](http://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.
Managing Pesticide Spills

Leah L. Sandall, Extension Assistant
Clyde L. Ogg, Associate Extension Educator
Erin C. Bauer, Extension Associate

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.](image)

**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**


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

Clyde L. Ogg, Extension Educator
Jan R. Hygnstrom, Project Manager
Erin C. Bauer, Extension Associate
Pierce J. Hansen, Extension Assistant
Managing Pesticide Poisoning Risk and Understanding the Signs and Symptoms

Clyde L. Ogg, Extension Educator
Jan R. Hygnstrom, Project Manager
Erin C. Bauer, Extension Associate
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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 (1.3) to a sweaty forehead (4.2) or to the genital area (11.8). When this occurs, the applicator increases the potential for pesticide poisoning.

Oral exposure may result in serious illness, severe injury, or even death. Pesticides can be ingested by accident, through carelessness, or intentionally. The most common accidental oral exposure occurs when a pesticide is taken from its original container and put into an unlabeled bottle, jar, or food container. A pesticide stored in a food container can be especially inviting to a child. When pesticides are managed and stored properly, children should not be able to touch them.

Inhalation or respiratory exposure is particularly hazardous because the lungs can rapidly absorb pesticides into the bloodstream. Some pesticides can cause serious damage to the nose, throat, and lung tissue if inhaled in sufficient amounts. Vapors and very small particles pose the most serious risks.

Lungs can be exposed to pesticides by inhalation of powders, airborne droplets, or vapors. Concentrated wettable powders can pose a hazard if inhaled during mixing. The hazard from inhaling pesticide spray droplets usually is fairly low when dilute sprays are applied with low-pressure application equipment, because most
Droplets are too large to remain airborne long enough to be inhaled. The potential for respiratory exposure increases, however, when high pressure, ultra low volume (ULV), or fogging equipment is used. Droplets produced during these operations are fog-sized (less than 10 microns) or mist-sized (10 to 100 microns) and can be carried on air currents for a considerable distance.

Follow these guidelines to reduce the risk of pesticide exposure:

• Always store pesticides in their original labeled containers.
• Never use your mouth to clear a spray hose or nozzle, or to begin siphoning a pesticide.
• Always leave the work area and wash thoroughly before eating, drinking, using tobacco, or using the toilet.
• Read the pesticide label and wear appropriate clothing and personal protective equipment (PPE). The label has precautionary statements listing hazards to humans, indicating whether risks are due to oral, dermal, and/or respiratory exposure.

Pesticide Toxicity

The toxicity of a pesticide can be measured several ways. Determining the toxicity of a pesticide to humans is not easy, since humans cannot be used as test subjects. Because of this, other animals, such as rats, are used. If a pesticide is poisonous to rats, however, it is not necessarily poisonous to dogs, cows, wildlife, or people. Toxicity studies are only guidelines: they are used to estimate how poisonous one pesticide is compared with another. Some pesticides are dangerous in one large dose or exposure, which is known as acute toxicity. Others can be dangerous after small, repeated doses, called chronic toxicity.

Measuring toxicity. The LD$_{50}$ (lethal dose, 50 percent) describes the dose of a pesticide that will kill half of a group of test animals (rats, mice, or rabbits) from a single exposure or dose by a dermal, oral, or inhalation route. The LD$_{50}$ is the dose per unit of body weight, such as milligrams per kilogram (mg/kg). A pesticide with a lower LD$_{50}$ is more toxic than a pesticide with a higher

number because it takes less of the pesticide to kill half of the test animals. For example, a pesticide with an LD$_{50}$ of 10 mg/kg is much more toxic than a pesticide with an LD$_{50}$ of 1,000 mg/kg.

The toxicity of fumigant pesticides is described in terms of the concentration of the pesticide in the air, LC$_{50}$ (lethal concentration, 50 percent). Researchers use a similar system to test the potential effects of pesticides on aquatic organisms in water.

Acute toxicity of a pesticide refers to the effects from a single exposure or repeated exposures over a short time, such as an accident when mixing or applying pesticides. Various signs and symptoms are associated with acute poisonings. A pesticide with a high acute toxicity can be deadly even if a small amount is absorbed. Acute toxicity can be measured in terms of acute oral, dermal, or inhalation toxicity.

Chronic toxicity refers to the effects of long-term or repeated low-level exposures to a toxic substance. The effects of chronic exposure do not appear immediately after first exposure: years may pass before signs and symptoms develop. Possible effects of long-term exposure to some pesticides include:

• cancer, either alone or by assisting other chemicals;
• genetic changes;
• birth defects in offspring following exposure of the pregnant female;
• tumors, not necessarily cancerous;
• liver damage;
• reproductive disorders;
• nerve damage;
• interfering with the endocrine system (hormones and glands that regulate many body functions); and
• sensitivity or allergic reactions such as irritation of the skin and/or respiratory tract.

The effects of chronic toxicity, as with acute toxicity, are dose-related. Low-level exposure to chemicals that have the potential to cause long-term effects may not cause immediate injury, but repeated exposures through careless handling or misuse can greatly increase the risk of chronic adverse effects.

Table 1. Signal words and relative toxicities used on labels of pesticide products.

| GROUP | SIGNAL WORD | TOXICITY RATING | ORAL LETHAL DOSE for a 150-pound Human$^a$
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>Danger$^b$</td>
<td>Highly toxic</td>
<td>Few drops to 1 tsp</td>
</tr>
<tr>
<td>II</td>
<td>Warning</td>
<td>Moderately toxic</td>
<td>1 tsp to 1 Tbsp</td>
</tr>
<tr>
<td>III</td>
<td>Caution</td>
<td>Slightly toxic</td>
<td>1 Tbsp to a pint</td>
</tr>
<tr>
<td>IV</td>
<td>Caution (signal word not always required)</td>
<td>Relatively nontoxic</td>
<td>More than a pint</td>
</tr>
</tbody>
</table>

$^a$The lethal dose is less than those listed for a child or for a person under 150 lb, and more for a person over 150 lb.

$^b$The skull and crossbones symbol and the word “Poison” sometimes are printed with the signal word “Danger.”
Signal Words

Nearly all pesticides are toxic at some dose. They differ only in the degree of toxicity. All pesticides are potentially dangerous to people who have had excessive exposure. Every label of a pesticide product will have one of three signal words that clearly indicates the degree of toxicity associated with that product (Table I). The signal word indicates the degree of risk to a user, not the effectiveness of the product in controlling the target pest.

Read the Pesticide Label

Pesticide labels also include statements about route of entry and specific actions that must be taken to avoid exposure. Route of entry statements indicate the outcome that can be expected from exposure. For example, a pesticide label might read, “Poisonous if swallowed, inhaled, or absorbed through the skin. Rapidly absorbed through skin and eyes.” This indicates that the pesticide is a potential hazard through all three routes of entry, and that skin and eye contact are particularly hazardous. Specific action statements normally follow the route of entry statement and indicate what must be done to prevent poisoning accidents. In the case of the pesticide discussed above, the statement might read, “Do not get in eyes, on skin, or on clothing. Do not breathe spray mist.”

The route of entry and specific action statements usually are followed by first aid instructions (see Table II). Read this section of the label carefully prior to using the pesticide so you know what to do if an accidental exposure occurs. By following the instructions carefully, you will help limit the amount of exposure you or the victim will receive, even after initial contact with the pesticide.

Table II. Example of a first aid section from a pesticide label.

| FIRST AID: | Call a poison control center or doctor for treatment advice. |
| IF IN EYES: | Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. |
| IF INHALED: | Move the victim to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. Get medical attention. |
| IF SWALLOWED: | This product will cause gastrointestinal tract irritation. Immediately dilute by having the victim swallow water or milk. Get medical attention. Never give anything by mouth to an unconscious person. |

Another important section on a pesticide label provides instructions for pesticide applicators and other handlers on the use of personal protective equipment (PPE) to help them limit pesticide exposure. It lists specific protective clothing and equipment requirements. For example, the label for a moderately toxic pesticide might read, “Applicators and other handlers must wear long-sleeved shirts and long pants, shoes plus socks, protective eyewear, and chemical-resistant gloves.”

Manage Your Risk

Wear PPE required by the label when handling or applying pesticides to reduce the risk of exposure to pesticides. If none are listed, wear appropriate clothing, including a long-sleeved shirt, long pants, shoes, socks, and chemical-resistant gloves. Risk of pesticide poisoning is directly related to the toxicity of a pesticide and the level of exposure, which is reflected in the Risk Formula:

\[ \text{Risk} = \text{Toxicity} \times \text{Exposure}. \]

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

Recognizing Signs and Symptoms of Poisoning

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

1. Recognize the signs and symptoms of pesticide poisoning for those pesticides commonly used or to which people may be exposed. Often, pesticide poisoning resembles flu symptoms.

2. If you suspect poisoning due to a pesticide, get immediate help from a local hospital, physician, or the nearest Poison Control Center (800-222-1222).
3. Identify the pesticide to which the victim was exposed, giving the chemical name and the EPA registration number found on the label, if possible. Provide this information to medical authorities.

4. Have a copy of the pesticide label available when medical attention begins. The label provides information that will be useful to those assisting a victim of pesticide poisoning.

5. Know emergency measures you can undertake until help arrives or the victim can be taken to the hospital. Both first aid and medical treatment procedures are listed on the product label.

Recognizing Common Pesticide Poisonings

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

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

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

Insecticides

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

Organophosphate and Carbamate Insecticides

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

| Table III. Organophosphate and carbamate insecticides that have been or currently are used in Nebraska. Examples of trade names are in parentheses. |
|---|---|---|
| **Organophosphates** | **Carbamates** |
| Acephate (Orthene®) | Dimethoate (Cygon) (Defend) | Phorate (Thimet®) | *Aldicarb (Temik®)* |
| Azinphos-methyl (Guthion®) | Disulfoton (Di-Syston®) | Phosmet (Imidan®) | Carbaryl (Sevin®) |
| Chlorpyrifos (Lorsban®) | Ethoprop (Mocap®) | Pirimiphos-methyl (Actellic) | **Carbofuran (Furadan®)** |
| Coumaphos (Co-Ral®) | Malathion | Terbufos (Counter®) | Methomyl (Lannate®) |
| Diazinon | Methyl Parathion (Penncap-M®) | Trichlorfon (Dylox®) | Propoxur (Baygon®) |
| Dichlorvos (Vapona®, DDVP®) | Naled (Dibrom®, Trumpet®) |

*Registrations for italicized products have been discontinued or will be soon after this publication is printed. The product still may be in an applicator’s storage, so names are listed in the tables.

**Registration of this product has been discontinued, and it must not be used after December 31, 2013.
The effects of these materials, particularly organophosphate insecticides, are rapid. Signs and symptoms begin shortly after exposure, and in cases of acute poisonings, during exposure. Exposure to either of these insecticide classes may pose special risks to people with reduced lung function, seizures, or other conditions. In some cases, consumption of alcoholic beverages may worsen the effects of the pesticide.

The onset of symptoms in milder exposures usually occurs within 4 hours, but can occur up to 12 hours after exposure. Diagnosis of a suspected poisoning must be rapid. Signs and symptoms associated with mild exposures to organophosphate and carbamate insecticides include headache; fatigue; dizziness; loss of appetite; 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 prickling 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.
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.

Ingestion of pyrethroids may cause slight to moderate eye irritation and mild skin irritation due to the solvent carriers. Antibiotic pesticides 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.

**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).

**Pyroles.** 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. Protracted 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>
<thead>
<tr>
<th>Table V. Common insect growth regulators. Examples of trade names are in parenthesis.</th>
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<tbody>
<tr>
<td>Diflubenzuron (Adept®, Clarify®)</td>
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<tr>
<td>Hexaflumuron (Shatter™)</td>
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<tr>
<td>Hydroprene (Gentrol®)</td>
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**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®, Fumitoxicin®, 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 build up of fluids in and narrowing of the air passages. If ingested, it attacks the stomach lining, resulting in open sores and cell death. Contact with skin may cause blistering.

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

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

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

**Rodenticides**

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

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

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

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

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

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

**Wood Preservatives**

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

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

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

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

**Herbicides**

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

**Bipyridyl Herbicides**

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

Ingesting diquat or paraquat causes severe irritation to the mucous membranes of the mouth, esophagus, and stomach. Repeated vomiting generally follows. Large doses of diquat also produce restlessness and reduced sensitivity to stimulation. Large doses, and sometimes even small doses, of paraquat initially can affect the kidneys, liver, adrenal glands, and lungs: potentially fatal fluid accumulation in the lungs can occur in 24 to 72 hours. Lesser amounts of paraquat will cause decreased urine output because of kidney failure. Yellowing of the skin due to liver damage is sometimes observed. This initial phase is followed by an inactive period lasting up to two weeks, during which the victim appears to improve. The victim, however, may have permanent and gradually advancing lung damage caused by rapid growth of connective tissue. This prevents proper lung function and eventually leads to death through respiratory failure. Paraquat selectively concentrates in cells in the lungs.

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

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

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

**Chlorophenoxy Herbicides**

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

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

**Arsenical Herbicides**

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

Arsenic may affect the central nervous system as well. Effects include headache, dizziness, muscle weakness and spasms, low body temperature, sluggishness, delirium, seizures, and coma. Liver damage may lead to yellowness of the skin. Injury to tissues that form blood vessels 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.

**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.

**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.

**Other Herbicides**

Endothall (Aquathol®) is commonly used as an aquatic herbicide or algaeicide. 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.
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: Inhalng vomit can be life-threatening. Timely emergency treatment is vital to survival.

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

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

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

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


Pesticide Safety Telephone Numbers

Emergency Telephone Numbers

Poison Control Center 800-222-1222
For aid in human poisoning cases

Nebraska Department of Environmental Quality 402-471-2186 or 877-253-2603
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.

Nebraska State Patrol Dispatch 402-471-4545 or 800-525-5555

Nonemergency Telephone Number

National Pesticide Information Center 800-858-7378
8:30 – 4:30 Mountain time, 9:30 – 5:30 Central time,
Monday through Friday

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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SAFE Transport, Storage, and Disposal of Pesticides

Clyde L. Ogg, Extension Educator
Shripat T. Kamble, Extension Urban Entomologist
Jan R. Hygnstrom, Project Coordinator
Erin C. Bauer, Extension Associate
Pierce J. Hansen, Extension Assistant

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Most accidental pesticide poisonings occur when pesticides are mishandled. Young children are often the victims.

Pesticide accidents can be prevented by careful planning, using a secure storage location, adopting safe handling methods during transport, and following proper disposal guidelines for both products and containers.

The first step in preventing accidental poisonings and environmental contamination is to use good judgment when buying pesticides.

• Buy only the amount that can be used in a reasonable length of time.
• Don’t be tempted by “sale prices.”
• Buy pesticides in quantities that you will use in the near future. Some pesticides should not be stored for long periods of time, allowed to freeze, or be stored in direct sunlight because they may become less effective.

Always keep pesticides in their original containers. Using any other container is illegal and could cause an accidental pesticide poisoning. Also, using another container could make it very difficult to retrieve the pesticide label information in the case of pesticide poisoning or environmental contamination.
Certain precautions should be taken when transporting pesticides. Traffic accidents can happen even when you travel only a short distance, and improperly loaded pesticide containers can fall off your vehicle or become punctured or torn. Because pesticides are transported on public roads, the potential damage from such accidents is great.

Never transport pesticides with food, livestock/poultry feed, or minerals. Also, transport pesticides separately from seed, grain, or consumer goods.

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

In case of a pesticide spill follow the three “C’s”: control, contain, and cleanup. Control the spill immediately to prevent further spillage. Turn off or close the valve on a leaky hose or upright a container that has tipped over. Contain the spill. Dike the spill with absorbent material or sorbent pads to keep it out of water and prevent environmental contamination. Clean up the spill. Use absorbent material to soak up the spill, then shovel contaminated material into a plastic storage container for disposal. Additional information may be found in the shipping papers or the label.

What Vehicle to Use

The safest way to transport pesticides is in the back of a truck or pickup. Never carry pesticides in the passenger compartment of a vehicle. If you use a flatbed truck, it should have side and tail racks. If the truck has a wooden bed, insert an impervious liner such as plastic or a truck bed liner before loading pesticides. Nonporous beds are preferred because they can be easily decontaminated in case of an accidental spill. Make sure your truck is in good operating condition to help reduce the chance of an accident (see Vehicle Maintenance Checklist, page 12).

Loading Pesticides

Wear work clothing and chemical-resistant gloves even when handling unopened pesticide containers, in case the container should leak. Also, carry protective clothing and equipment in the passenger compartment of the vehicle. You will need protective equipment if a spill or other pesticide-related accident should occur.

Thoroughly inspect all containers at the time of purchase, before loading. Accept them only if the labels are legible and firmly attached. Check all caps, plugs, or bungs and tighten them if necessary. If leakage has occurred, do not accept the container. Request another container.

When loading containers, handle them carefully; don’t toss or drop them. Avoid sliding containers over rough surfaces that could rip bags or puncture rigid containers. Know safe handling procedures when using forklifts. Secure all containers to the truck to prevent load shifts and potential container damage. Protect containers made of paper, cardboard, or similar materials from rain or moisture.

Unloading Pesticides

Never leave pesticides unattended. You are legally responsible if people are accidentally poisoned from pesticides left unattended in your vehicle. Move the pesticides into your storage facility as soon as possible. Inspect the vehicle thoroughly after unloading to determine if any containers were damaged or any pesticide leaked or spilled.
Transporting Hazardous Pesticides

The U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration has designated many chemical compounds, including some pesticides, as hazardous materials (hazmat). If you transport any of these materials on public roads in commerce, you are required to comply with DOT Hazmat Regulation 49 Code of Federal Regulations (CFR) parts 100-185. To determine which pesticides are classified as hazardous, refer to Hazmat Tables (HMT) I and II (49 CFR part 172.101). To be in compliance, you may be required to:

- Carry shipping papers in your vehicle including an emergency response phone number and Material Safety Data Sheets (MSDS) for the pesticides in transport,
- Receive training concerning DOT Hazmat regulatory requirements,
- Be sure that packages are properly labeled and/or marked,
- Placard your vehicle if transporting a bulk container or 1,000 pounds or more of a pesticide from HMT II or any amount of a pesticide from HMT I, and
- Obtain a Commercial Driver’s License (CDL) when required.

Shipping Papers. When you transport any hazardous pesticide, carry the proper shipping papers in the passenger compartment of the vehicle. While you are driving (belted and operating the vehicle), the papers must be within your reach or placed in a door pouch and readily recognizable by emergency personnel. These papers provide information about the chemical that can be used to prevent further damage or injury in case of an accident. Your pesticide dealer will help you obtain the proper papers. Also, carry the Material Safety Data Sheet (MSDS) for each hazardous pesticide or an emergency response guidance manual that cross-references a chemical’s shipping name with emergency response information.

Hazardous Materials (Hazmat) Training. The DOT Hazmat training increases your awareness of safety considerations involved in loading, unloading, handling, storing, shipping-paper preparation, marking, labeling, placarding, and transporting of hazardous pesticides. It also improves emergency preparedness for responding to transportation accidents. Hazmat training includes general awareness training, function-specific training, and safety training.

DOT Training Is Available. The DOT Office of Hazardous Materials Safety has prepared training modules that meet the requirements for general awareness Hazmat training. These modules are available online (http://phmsa.dot.gov/hazmat/training/publications/modules) or on an interactive CD-ROM. (For more information, phone: 202-366-4900 or email: phmsa.hm-training@dot.gov.) A list of training opportunities for the function-specific and safety training sections is available online (http://www.phmsa.dot.gov/hazmat/training-outreach) or can be obtained by contacting the DOT Office of Hazardous Materials Initiatives and Training (Phone: 202-366-4900 or email: phmsa.hm-training@dot.gov). Specialized training is available from the DOT Transportation Safety Institute as well (405-954-5000).

Labeling and Marking. Always check each package (e.g., cardboard box, plastic or metal drum) to be sure it is properly labeled and/or marked. Labeling means a prescribed hazard warning notice (usually diamond-shaped) on the outer package. Marking means the required words are written on the side of the outer package, including shipping name, identification number, specifications or UN marks, plus other required information, instructions, or cautions.

Accessing the Regulations

Hazardous materials regulations are available online and in print versions.


The print version can be ordered through: http://bookstore.gpo.gov/catalog/laws-regulations

It is published by the Office of the Federal Register National Archives and Records Administration as a Special Edition of the Federal Register.
Placarding. For most hazardous pesticides (HMT II) in non-bulk, you will need to placard your vehicle when you transport as little as 1,000 pounds of the chemical. When transporting hazardous pesticides (HMT II) in bulk (over 119 gallons) or any amount from HMT I, placarding is required at all times. Place placards, which are available from your pesticide dealer, on all four sides of your vehicle.

Commercial Driver’s License. Contact the hazardous materials coordinator at the Nebraska State Patrol (402-471-0105) for more information on training, shipping papers, labeling, marking, and placarding. For more information on the CDL, contact the Nebraska Department of Motor Vehicles office (402-471-2281) or your local driver’s license examiner.

Farmer Exception

Farmers have been granted exceptions from the DOT Hazmat regulations if they are private motor carriers transporting pesticides within the state of Nebraska. Farmers can transport DOT-defined hazardous pesticides (other than compressed gases) between fields of the same farm over any roadway EXCEPT the interstate highway system. Farmers also have had emergency response information and Hazmat employee training requirements waived when they were transporting agricultural pesticides to or from their farm (within 150 miles of the farm).

Transporting Hazardous Pesticide Waste

Certain pesticide wastes are listed as hazardous under the Resource Conservation and Recovery Act (RCRA). RCRA defines “hazardous wastes” (40 CFR parts 240-299) as either:

- “Characteristic” wastes. These are waste materials with one or more of these characteristics: ignitable, corrosive, reactive, TCLP toxic. These are considered “hazardous wastes” even though they may not be “listed,” or,
- “Listed” substances. See the Code of Federal Regulations 40, parts 261.3 and 261.32 for those pesticides that have been declared to be “hazardous waste.”

Except for those taking their own pesticides to an approved excess pesticide waste collection/disposal site, only a permitted hazardous waste hauler can transport such waste. For more information, contact the hazardous waste specialist at the Nebraska Department of Environmental Quality at 402-471-2186.
Storing Pesticides

As soon as pesticides arrive at their destination, they should be properly stored and the area immediately secured. This not only helps discourage theft, but also prevents access to the materials by pets, children, and others not trained to use pesticides. Always keep personal protective equipment (PPE) and a pesticide spill kit (chemical-resistant gloves, coveralls, and goggles; sorbent pads and absorbent material such as kitty litter; and a plastic temporary storage bag or container) readily available in or near the pesticide storage area.

When storing pesticides on shelving, place liquid formulations on lower shelves and dry formulations above them. If a liquid formulation container leaks, the dry formulations will not be contaminated. Keeping the liquid containers on lower shelving also helps reduce the risk of accidental spills if the container is knocked off the shelf.

To prevent contamination or accidental use of the wrong chemical, store herbicides, insecticides, and fungicides in separate areas within the storage unit. Dry formulations of insecticides or fungicides can become contaminated if stored with certain volatile herbicides and may cause plant injury when used. Treated baits (for rodents, insects, and birds) should not be stored near other chemicals because they can absorb odors and may repel the pest.

Always store a pesticide in the original container with the label intact. Once a container is opened, the shelf life is considerably reduced. Never store a pesticide, for even a short time, in any container other than the original. Doing so is a violation of the law. Pesticides in soft drink bottles, fruit jars, milk cartons, margarine tubs, or glassware are a common cause of accidental poisonings. Store pesticides away from food, pet food, animal feed, seed, fertilizers, veterinary supplies, and plants.

Check all stored pesticide containers (see Pesticide Storage Checklist, page 13) for any existing or potential problems, including leaks or spills. Transfer the contents of any leaking container into a container with exactly the same original formulation and label. When this is not possible, put the leaking container with the pesticide into a liquid-proof container and dispose of it as discussed under Disposal of Excess Pesticide Waste. If necessary, contact the pesticide manufacturer for specific directions.

The pesticide storage location should be a cool, dry, well-ventilated area away from sources of heat or flame. See the pesticide label for specific storage recommendations. Some pesticides may not be as effective if they are or have been frozen or overheated. Expansion of pesticides caused by freezing or heating can cause containers to crack or break, resulting in potentially dangerous leaks or spills. Heat expansion of a liquid pesticide also may result in contents that are under pressure. When the container is opened, the pressure may cause an overflow and/or contamination of the user or storage site. Excessively high temperatures (120°F or higher) also can change the effectiveness of a pesticide and may produce dangerous fumes, making the storage area unsafe.

To prepare for pesticide applications, remove the pesticide containers from storage and take them to an open area. Always measure and mix pesticides in a well-lit, well-ventilated location. Regardless of whether they are partially or completely emptied, never leave pesticide containers open or unattended while the pesticide is being applied. Return all containers to storage prior to application to prevent accidental spills, ingestion, or exposure to people, pets, livestock, or wildlife.

Mixing and applying pesticides requires detailed attention to label instructions, along with common sense and good judgment. So, too, does pesticide storage. Being careless or using improper storage procedures is an open invitation to disaster. While all pesticide labels have a section on storage and disposal, the guidelines do not answer every question. If you have questions about pesticide storage, contact the Nebraska Department of Agriculture (402-471-2394).

Be Prepared for Pesticide Spills

Despite all safety precautions, accidents can happen. If a pesticide spills in a storage area, quick action is imperative. Have a pesticide spill kit on hand. If a pesticide spill occurs on a public right-of-way, contact the Nebraska State Patrol at 800-525-5555 for assistance.

If a pesticide is spilled on a person’s body or clothing, the person should leave the area immediately. All contaminated clothing should be removed as quickly as possible — this is no time for modesty! Wash affected areas of the body thoroughly with detergent or soap and water. In any pesticide
contamination incident, follow the instructions given in the label’s first aid treatment guidelines. If the label is not available or if there are further questions, seek medical attention. If necessary, contact The Poison Center in Omaha (800-222-1222).

If toxic fumes are present at the spill site, evacuate people and animals from the immediate area. In addition, secure the area until qualified rescue personnel, with proper protective equipment, arrive at the scene. Except for a small, properly equipped cleanup crew, don’t allow anyone to enter the area until it is thoroughly decontaminated.

Spilled pesticides must be contained. If the pesticide starts to spread, contain it by diking with soil or sorbent materials, if this can be done safely without contacting the pesticide or breathing the fumes. Never hose down a contaminated area. This will cause the pesticide to spread and infiltrate into the soil, possibly reaching groundwater. If the spill is liquid, use activated charcoal, absorptive clay, vermiculite, pet litter, or sawdust to cover the entire spill area. Use enough absorbing materials to completely soak up the liquid. Then sweep or shovel the material into a leak-proof drum. Dispose of this material according to the label of the pesticide involved.

Always refer to the product label and, if necessary, contact the chemical manufacturer for information about the appropriate neutralizing materials to be used following a pesticide spill. As a precaution, it is wise to read all product labels thoroughly at the time of purchase and/or delivery to be able to deal quickly and safely with any pesticide emergency.

Pesticide Storage and Spill Reporting Requirements

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) requires that spills or releases of reportable quantities (RQ) of hazardous substances must be reported immediately to the National Response Center (800-424-8802). The reportable quantity for some chemicals can be as low as 1 pound; however, the majority are 100-5,000 pounds. Definitions of hazardous substances and specific reportable quantities can be found in 40 CFR 302. General information is available by calling 800-424-9346.

The Superfund Amendments and Reauthorization Act (SARA) amended CERCLA. One part of the provisions, the Community Right-to-Know Act (Title III), established new lists of “Extremely Hazardous Substances” (EHS) and “Toxic Chemicals” for additional notification and reporting requirements. It also added new reporting requirements for the CERCLA list of “hazardous substances.”

SARA Title III established threshold planning quantities (TPQ). Any facility that produces, uses, or stores these Extremely Hazardous Substances (EHS), in amounts equal to or in excess of the threshold planning quantities, has reporting and notification obligations under section 302 of SARA Title III (40 CFR Part 355). If the facility produces, uses, or stores hazardous chemicals or Extremely Hazardous Substances exceeding the designated amounts (10,000 pounds for hazardous chemicals and either 500 pounds or the threshold planning quantities, whichever is lower, for Extremely Hazardous Substances), specific information must be submitted to state and local officials as defined in sections 311 and 312 of the Act (40 CFR 370).

In addition, owners and operators of most business facilities must report spills or releases of CERCLA hazardous substances and Extremely Hazardous Substances to state and local authorities (section 304, 40 CFR 355). If the spill occurs while in transport, the notification can be made either by the owner or the operator of the motor vehicle. Report spills and releases to the Nebraska State Patrol (800-525-5555) or to the 911 emergency operator.

Selecting a Site for Pesticide Storage

Several points must be considered when selecting the site for pesticide storage. One of these factors is prevailing wind direction. The best site is downwind and downhill from sensitive areas, such as houses, play areas, feedlots or animal shelters, gardens, and ponds. Locating storage facilities away from dwellings and livestock facilities will minimize possible contamination.

The site also should be in an area where flooding is unlikely. It should be located where runoff can be diverted and drainage from the site cannot contaminate surface or groundwater.
Ideally, a drainage system should be built to collect any runoff water from the storage area. Pesticides that may be present in tank rinsate, spills, seepage from storage, and heavy runoff in the event of fire or flooding must be controlled. Dikes, collecting pools, and washing slabs with sumps provide a proper drainage system. All of the collected runoff water should be treated as a surplus pesticide and disposed of properly.

**Storage Area**

Depending on inventory size, a separate building, room, or enclosure may be best for pesticide storage. If the inventory is not large enough to warrant a separate facility, enclose the storage area on the first floor of an existing building. In either case, store pesticides and pesticide containers in a fire-resistant structure having good ventilation and a sealed, concrete floor that slopes toward drainage and secondary containment.

Post weatherproof signs, stating “Danger – Pesticides – Keep Out!” or a similar warning on each door and in any windows of the facility. In some cases, it may be advisable to post the warning signs in one or more languages in addition to English. Post the name, address, and phone number of a contact person at the primary entrance to the storage area.

Regardless of whether it is a cabinet, room, or an entire building, the pesticide storage area should be lockable to prevent unauthorized entry and should be used only for pesticides and pesticide equipment.

An electrically shielded exhaust fan may be needed in a confined storage area to reduce the temperature and/or concentrations of toxic fumes. The fan should be installed so that fumes can be vented outdoors without endangering people, animals, or plants in the area.

Whenever large quantities of pesticides must be stored, it is strongly recommended that fire detection sensors and fire-fighting equipment be provided. A floor plan, records related to the storage location, and an annual inventory of the pesticides and containers in storage must be provided to the local emergency response coordinator as well.

Wooden pallets or metal shelves must be provided for storing granular and dry formulations packaged in sacks, fiber drums, boxes, or other water-permeable containers. If metal pesticide containers are stored for a prolonged period, they should be placed on pallets, rather than directly on the floor, to help reduce potential corrosion and leakage.
Disposing of Excess Pesticides and Pesticide Containers

Despite one’s best efforts to avoid accumulating excess pesticides, it is sometimes necessary to dispose of leftover chemicals. And, occasionally it may be necessary to dispose of pesticide wastes, such as materials collected while cleaning up a spill. Pesticide wastes are as hazardous as the pesticide itself. These guidelines should be followed in handling both excess pesticides and pesticide wastes.

In addition, empty pesticide containers must be disposed of properly. Empty containers that have been properly rinsed may be disposed of in a sanitary landfill if allowed by state and local laws/regulations. Some plastic containers may be recycled after they have been rinsed properly. Refillable containers, described later, may be returned to the supplier unrinsed.

Types of Pesticide Containers

There are several types of pesticide containers. A common agricultural pesticide container is the 2.5-gallon plastic jug. Many liquid agricultural pesticides also are sold in bulk containers (mini-bulks, shuttles, shuttle juniors, etc.), which are intended to be returned and reused by the supplier. Liquid, dry, and granular pesticides often are sold in various sizes of plastic containers and some granular pesticides are sold in bags. Another type of pesticide container is the pressurized can, which is commonly used for indoor pesticides.

Some containers are designed to be returned to the supplier upon emptying without rinsing. These containers commonly are referred to as “refillables.” Refillable containers must not have the seal broken or the container opened. They should never be rinsed. NebGuide G2033, Nebraska Pesticide Container and Secondary Containment Rules, has information about rules for refillable and nonrefillable containers.

Removing Pesticide Residues from Nonrefillable Liquid Containers

Proper rinsing of nonrefillable liquid pesticide containers is easy to do, saves money, is required by state and federal regulations, and is a good, sound management practice that helps protect the environment. Even during a busy season, the few extra minutes it takes to properly rinse empty pesticide containers is time well spent. Here are some rinsing guidelines:

- Rinse the container immediately, as otherwise the remaining residue may dry and become difficult to remove. Typically, an unrinsed pesticide container is considered hazardous waste, but once rinsed, the same container usually is considered solid waste. Rinsing containers also removes a potential source of pesticide exposure to people, pets, livestock, wildlife, and the environment.
- The rinse solution (rinsate) should be added directly into the sprayer tank. This action eliminates the need to store and later dispose of the rinsate.

Proper Rinsing

Two commonly used procedures are effective for properly rinsing nonrefillable liquid pesticide containers: pressure-rinsing and triple-rinsing.
Pressure-rinsing

Usually, pressure-rinsing is faster and easier than triple-rinsing. A special nozzle, generally available from your pesticide supplier, is attached to the end of a pressure hose and used to flush the remaining pesticide from the container. The hydrant or water source should have an anti-siphon valve or a back-flow protection device attached.

1. Remove the cap from the pesticide container. Empty pesticide into the spray tank and allow the container to drain for 30 seconds.
2. Insert the pressure-rinser nozzle by puncturing through the lower side (not the bottom) of the pesticide container.
3. Hold the pesticide container upside down over the spray tank opening so rinsate will run into the spray tank.
4. Rinse for the length of time recommended by the manufacturer (usually 30 seconds or more). Rotate the nozzle to rinse all inside surfaces.
5. Rinse caps in a bucket of water for at least one minute and pour this rinse water into the spray tank.
6. Return the container to the supplier or pesticide container recycling site or dispose of the pesticide container according to label directions. Plastic caps and containers usually are made from different materials, and often are recycled separately. For more information on pesticide container recycling sites, contact your local Extension office.

Triple-rinsing

Triple-rinsing can be done as follows:

1. Remove the cap from the pesticide container. Empty all remaining pesticide into the spray tank, allowing the container to drain for 30 seconds.
2. Fill the container 20 percent full of water or rinse solution (i.e., fertilizer solution).
3. Secure the pesticide container cap.
4. Swirl the liquid within the container to rinse all inside surfaces.
5. Remove the cap from the container. Pour the rinsate from the pesticide container to the spray tank and drain for 30 seconds or more.
6. Repeat steps 2 through 5 two more times.
7. Puncture the container so that it cannot be reused.
8. Return the container to the supplier or pesticide container recycling site or dispose of the pesticide container according to label directions. Usually, plastic caps and containers are made from different materials and typically are recycled separately. For more information on pesticide container recycling sites, contact your local Extension office.
When Rinsing Is Not Possible

In certain situations it is not possible to triple- or pressure-rinse pesticide containers. Thorough removal of the pesticide material packaged in bags or pressurized cans may be done as follows:

**Bags**

1. Empty contents of the bag into the spray tank.
2. Shake the bag to remove as much product as possible.
3. Cut the sides and folds to fully open the bag; add the remaining product to the tank.
4. Dispose of the empty bag in a sanitary landfill, if allowed by state and local laws/regulations. Some labels may allow alternate disposal methods.

**Pressurized cans**

1. Spray any remaining contents according to label instructions. Be sure to use it on the proper site and to use it at the correct rate, as listed on the label.
2. Dispose of the empty can according to label directions in a sanitary landfill if allowed by state and local laws/regulations.

Disposal of Excess Pesticide Waste

The best way to dispose of small amounts of pesticide is to apply it to a labeled site (specific plant, animal, or structure) for which the product is registered. Always double check the product label to be certain that the site is listed and that the maximum application rate will not be exceeded.

Large quantities of stored excess pesticides may be hazardous. When disposing of large quantities of such materials, contact the Nebraska Department of Environmental Quality (402-471-2186) or the Nebraska Department of Agriculture (402-471-2394) for specific disposal instructions.

The Nebraska Department of Agriculture occasionally sponsors disposal programs for excess or unwanted pesticides.

Preventing accidental poisonings and damage to the environment requires pesticides to be transported, stored, and disposed of in a safe manner. Read and follow the label carefully. It tells you how to use pesticides, provides information about special hazards, and gives proper storage and disposal methods.
Vehicle Maintenance Checklist

Cab Interior

_____ Clean cab — no food wrappers or trash
_____ Extra change of clothes
_____ Post emergency phone numbers: 911 for help involving spills, leaks, and fires
    Poison Center 800-222-1222
    For aid in human poisonings
    NE State Patrol 800-525-5555
    To report chemical spills or vehicle accidents
_____ Record of on-board pesticides
_____ Label and MSDS available
_____ First aid kit
_____ Pesticides NOT stored in cab
_____ Pesticide application equipment NOT present

On-board Pesticide Containers

_____ Lockable pesticide storage compartment
_____ Containers properly sealed and secured
_____ Legible labels on all containers
_____ Pesticides in original containers
_____ Adequate amount of pesticides for day’s use
_____ Empty containers properly rinsed and positioned for removal at end of day. Never reuse pesticide containers!

Spill Control

_____ Absorbent materials and rags on board
_____ Shovel, broom, plastic bags on board
_____ Pesticide spill kit with chemical-resistant gloves, coveralls, goggles, absorbent material, shovel, disposal bag or container

Equipment Check

_____ Sprayers NOT pressurized
_____ Supplies in moisture-proof containers
_____ Lids fit securely on pesticide tanks
_____ Spray hoses and fittings in good condition
_____ Pressure gauges operable
_____ All application equipment cleaned
_____ Water containers labeled

Personal Protective Equipment

_____ Goggles or other eye protection
_____ Chemical-resistant gloves
_____ Boots, apron, hat — if required by label
_____ Respirator — stored in sealed plastic bag
_____ Other — as directed by the label

Tires

_____ Proper pressure
_____ Tread wear acceptable
_____ No cuts or cracks
_____ Spare tire inflated properly

Lights

_____ High beam headlights
_____ Low beam headlights
_____ Turn signals
_____ Running lights
_____ Emergency flashers
_____ Tail lights
_____ Brake lights
_____ Backup lights

Wipers

_____ Wiper blades in good condition
_____ Washer fluid dispenser filled
_____ Washer fluid pump in working order

General Vehicle Maintenance

_____ Horn in good working order
_____ Seat belts in good working order
_____ Brakes in good working order
_____ Windshield free of obstructions
_____ Truck bed free of debris

Vehicle ID ______________________________________ Notes____________________________________
Inspected by _____________________________________ _________________________________
Date ____________________________________________ _________________________________

Adapted from Pesticides and Commercial Vehicle Maintenance, Purdue University.
Pesticide Storage Checklist

Safety is the key in proper pesticide storage. If you answer “no” to any of the statements below, you should correct your storage facility immediately.

Enter date of each inspection: _____________ _____________ _____________

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</thead>
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<td>No smoking signs posted</td>
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<td>Fire extinguisher in good working order</td>
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<td>Storage room locked, limited access to keys</td>
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<td>Storage room posted: Pesticides — Keep Out!</td>
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<td>Storage site well lit and ventilated</td>
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</table>

Adapted from Pesticides and Commercial Vehicle Maintenance, Purdue University.
What’s New in Plant Pathology

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

Disease Management Products

During the past year several new products have become available for disease management. The new products are summarized in Tables 1 and 2, as well as included in the 2014 Guide for Weed Management in Nebraska with Insecticide and Fungicide Information. In addition, fungicides labeled for use on sorghum and sunflower have also been added to the publication.

Among the products is a new seed treatment nematicide with a new biological mode of action. The organism in the new nematicide, Clariva pn is Pasteuria nishizawae Pn1. This organism is one of several Pasteuria species of bacteria. These bacteria are unique among bacteria in that they are gram positive and can form both fungal-like mycelia and endospores. All of the species are obligate parasites requiring living hosts for survival. Much of the past research on this species has proven parasitism on cyst nematodes in the genera Globodera and especially Heterodera, such as soybean cyst nematode (Atibalentja et al., 2004). Endospores produced by the bacteria attach to the outer cuticle of nematodes when they are in the infective second juvenile stage (J2’s). Bacterial endospores will be produced once again later in adult females and cysts. Endospores on J2 cuticles do not germinate to produce a germ tube until the nematode infects the soybean root. Then, the bacteria begin dividing and growing forming structures that look like cauliflower in the J2/J3 nematodes and leads to a sporulation cluster in the J4 and females. The structures continue to grow into endospores that fill the cavity of the infected nematode and are eventually released into the soil when the nematode body disintegrates (Noel, et al., 2005).

Disease Identification and Management Resources

The electronic resources formerly housed at the Plant Disease Central website have been consolidated to the comprehensive Crop Watch website. Disease identification and management resources can be found sorted under each crop heading labeled, “Disease Management” and includes a list of relevant Crop Watch newsletter articles, UNL Extension Publications and other resources.
Table 1. New Foliar Fungicides

<table>
<thead>
<tr>
<th>Foliar Fungicides</th>
<th>Active Ingredient</th>
<th>Fungicide Class</th>
<th>Labeled Crops</th>
</tr>
</thead>
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<tr>
<td>Aproach</td>
<td>picoxystrobin</td>
<td>strobilurin</td>
<td>barley, chickpea, dry bean, corn, oats, rye, sorghum, soybean, triticale, wheat and others</td>
</tr>
<tr>
<td>Eminent 125SL</td>
<td>tetraconazole</td>
<td>triazole</td>
<td>sugar beet,</td>
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<td>Endura</td>
<td>boscalid</td>
<td>carboxamide</td>
<td>dry bean, potato, soybean, and others</td>
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<tr>
<td>Fortix</td>
<td>fluoxastrobin + flutriafol</td>
<td>strobilurin + triazole</td>
<td>corn, soybean, sugar beet and others</td>
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<td>Quadris Top</td>
<td>azoxystrobin + difenoconazole</td>
<td>strobilurin + triazole</td>
<td>chickpea, millet, oats, potato, rye, soybean, sugar beet, and others</td>
</tr>
<tr>
<td>Satori</td>
<td>azoxystrobin</td>
<td>strobilurin</td>
<td>barley, dry bean, chickpea, corn, potato, sorghum, soybean, sunflower (for oil), triticale, wheat and others</td>
</tr>
</tbody>
</table>

Table 2. New Seed Treatment Nematicide

<table>
<thead>
<tr>
<th>Seed Treatment Nematicide</th>
<th>Active Ingredient</th>
<th>Labeled Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clariva pn</td>
<td>Pasteuria nishizawae – Pn1</td>
<td>soybean</td>
</tr>
</tbody>
</table>

Literature Cited


Corn Disease Update

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

The growing conditions during 2013 contributed to several disease problems in corn. Cold and wet conditions early led to development of seedling diseases. The hail damaged corn in many areas of the state during the season led to ear rot diseases that were exacerbated by cooler conditions and increased grain moisture. Diseases have been a problem throughout the season and could extend beyond harvest into storage of some corn.

Seedling Diseases Appearing in Corn

Cool soil temperatures and episodes of rainfall contributed to the development of seedling diseases in corn in 2013. The most common seedling diseases that were identified in samples submitted to the UNL Plant and Pest Diagnostic Clinic were those caused by *Pythium* and less frequently, *Fusarium* species.

Seedling diseases can be caused by any of several common soilborne organisms, such as *Pythium*, *Fusarium*, *Rhizoctonia* or plant parasitic nematodes. Seedling diseases are often difficult to diagnose because their symptoms are very similar and may be easily confused with those caused by other problems. Sometimes, diagnosis may be of limited value because management is often the same for several seedling diseases. Microscopic examination and other laboratory analyses of the diseased seedlings can often identify the cause(s) of the problems. Seedling diseases can be confused with insect injury, herbicide damage, planting problems, or environmental stresses that often have similar symptoms. For more information on differentiating early season chemical damage and seedling diseases, see the article, “Differentiating Chemical and Disease Symptoms in the Field” in the 2014 Crop Production Clinic proceedings. Some of the possible symptoms of seedling diseases are:

- Rotted seed prior to germination
- Rotted or discolored seedlings after germination prior to emergence
- Post-emergence seedling damping off
- Root decay

At least 14 species of *Pythium* have been previously identified that can cause seedling blight and root rot. These pathogens require excessive moisture because they produce motile swimming zoospores that infect plant roots. The pathogen overwinters in soil and infected plant debris by producing thick-walled oospores that can survive for several years in the absence of a suitable host or favorable weather conditions.

Although uncommon, *Pythium* may also cause stalk rot disease in corn during extended periods of wetness during the middle and later portions of the growing season. Symptoms of *Pythium* stalk rot can cause collapse of the lower stalks at or near the soil surface. Stalks may appear collapsed, twisted, and water-soaked and could be confused with bacterial stalk rot, but lack the characteristic foul odor.

There are more than six *Fusarium* species that can cause seedling diseases and root rots, as well and several are common in Nebraska fields. Stressed plants due to weather extremes (temperature and moisture), herbicide damage, and physical injury are more prone to infection and disease caused by *Fusarium* species.

Management

Unfortunately, resistance is not available for diseases caused by *Pythium* and *Fusarium*. Although improved field drainage can help reduce seedling disease severity, the most common method for disease management is with the use of seed treatment fungicides. Crop rotation can provide some reduction in disease.

Most seed corn is already treated with more than one seed treatment fungicide, often an insecticide, and, sometimes with a nematicide option. These products can provide protection against some of the pathogens that cause seedling diseases. But, in spite of their activity, diseases may still develop, such as during extended periods of inclement weather or under severe pathogen pressure. However, seed treatments will only provide protection during the first few weeks immediately after planting. You can minimize the likelihood of developing
seedling diseases by planting high quality seed at appropriate planting depths and soil conditions to support rapid plant growth and emergence.

Stalk Rot Diseases

The crop stress created by the growing conditions in 2013 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. High winds in October 2013 led to lodging in corn where some stalks were weakened by stalk rot diseases and other problems.

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

There is nothing that can 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 prior to fields with lower incidence of stalk rot diseases 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/sendlt/ec1868.pdf

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

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.
Grain Storage Management to Minimize Mold and Mycotoxins

High grain moisture at the end of the 2013 season delayed harvest for many farmers, but some chose to continue harvest in spite of high moisture. In addition, the corn in many parts of Nebraska experienced damage caused by hail that predisposed it to infection to ear rotting fungi. Some of the high moisture and/or damaged corn was placed in bins for storage and is at increased risk for grain mold development in the bin and reduced quality. 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 at least every 3 days 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 any level of mycotoxin contamination it is recommended to partially fill the bin(s) initially, such as 1/4 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.

For More Information

Additional information on these and other diseases can also be found at the website Crop Watch at http://cropwatch.unl.edu/ under “Corn – Disease Management” 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
Wheat Disease Update

Stephen Wegulo, Extension Plant Pathologist

Disease Occurrence in 2013

In 2013, cool, wet weather early in the growing season delayed wheat development by 2-3 weeks. On May 7, stripe rust was confirmed in research plots at the Agricultural Research and Development Center (ARDC) near Mead. Wheat in the plots was still in the early stages of development, having been delayed by prolonged cold spring temperatures. By mid-May, temperatures had warmed up considerably, reaching a record breaking +100° F on May 14. These warm temperatures slowed down and eventually stopped stripe rust development at the hot spot where it was found on May 7 at the ARDC. Overall, stripe rust occurred to a limited extent in southcentral and southeast Nebraska and was found only in localized hot spots. In June, low levels of stripe rust were observed in some wheat fields in the Nebraska Panhandle.

Leaf rust arrived in early June in southcentral and southeastern Nebraska, which was slightly later than its normal arrival time of mid- to late May. By mid-June, due to the warm, wet weather that had prevailed since mid-May, severe levels of leaf rust had developed in unsprayed fields planted with susceptible cultivars in southcentral and southeast Nebraska. In unsprayed research plots at the ARDC and at Havelock Research Farm in Lincoln, very high levels of leaf rust severity were observed on susceptible cultivars and breeding lines.

Other fungal diseases observed during the 2013 growing season included loose smut, common bunt, tan spot, Septoria tritici blotch, powdery mildew, and low to moderate levels of Fusarium head blight (scab). Overall, scab development was sporadic in southcentral and southeast Nebraska. At the ARDC, severe levels of scab developed in research plots planted with susceptible cultivars.

Bacterial streak, also known as black chaff when it affects heads of wheat and other small grains, was more prevalent, especially in the eastern half of the state, than in previous years. Prolonged rainfall during the 2013 growing season favored development of bacterial streak in wheat fields. At Havelock Research Farm, very severe levels of bacterial streak were observed on triticale in a breeding nursery.

Wheat soilborne mosaic virus (WSBMV) was widespread in southeast Nebraska in late April to early May due to the cool, wet weather early in the growing season. As temperatures warmed up, symptoms of wheat streak mosaic virus (WSMV) and Triticum mosaic virus (TriMV) became more noticeable. However, incidence of these viruses was generally low. Barley yellow dwarf virus (BYDV) was also observed at low levels.

Freeze injury was observed in many wheat fields throughout the state. In one field in south central Nebraska, extensive bleaching of wheat heads observed in early June was determined to have been caused by freeze injury that had occurred earlier in the growing season. Several wheat fields surveyed on June 11 in west central Nebraska also showed widespread freeze injury.

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 14 days 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. Aphid control is effective only if high infestations occur. WSBMV is managed by planting resistant cultivars.

Bacterial streak and black chaff can be managed by avoiding the use of infested seed. Seed lots can be assayed to determine how much they are infested. There is no commercial seed treatment available to reduce infestation in affected seed lots. Cultivars known to be highly susceptible should be avoided. In irrigated wheat, irrigation should be managed to avoid prolonged periods of wetness.

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. In severely affected fields, increasing the fan speed on the harvest combine can remove some of the scabby grain, which usually is lighter than healthy grain. Scabby grain usually contains the mycotoxin deoxynivalenol (DON). Therefore, testing grain from affected fields for DON concentration is recommended. Cleaning grain with seed cleaning equipment can also reduce the proportion of scabby kernels and therefore DON levels.
Soybean Disease Update

Loren J. Giesler, Extension Plant Pathologist

Although the 2013 production season was good for soybean production and many growers had great yields, we did have our share of soybean disease issues. Excessive early season moisture resulted in many fields being affected by Pythium. Later in the season we had some heavy rainfall events that resulted in Phytophthora stem and root rot. Other diseases associated with later reproductive stages also showed up and included Brown Stem Rot, SDS and White Mold. This article will help to identify, differentiate and manage these diseases that occurred in 2013. Additional information on disease identification can be found at the UNL Crop Watch Web Site.

Early Season Seedling Diseases

There are several pathogens involved in damping off seedling diseases. The most common in Nebraska are Fusarium, Phytophthora, Pythium, and Rhizoctonia. All four are capable of killing the developing soybean seedling or causing damage that affects the ability of the plant to achieve its full yield potential. In 2013, Pythium was the most common seedling disease problem due to cooler soil temperatures.

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

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

Criteria for assessing the use of seed treatment fungicides to manage seedling disease problems: (If these conditions are part of your production system your risk is greater.)

- History of a stand problem
- No-till
- Early planting date when soils are cool
- Poor seed quality

Phytophthora Root and Stem Rot (Phytophthora sojae)

Phytophthora root and stem rot of soybean, is caused by, a 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° F and high soil moisture. We have observed in the past that dry conditions followed by heavy rain events can result in higher amounts of Phytophthora. This is most likely due to the plants being slightly stressed and high 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 to the leaf stem (petiole).

Management of Phytophthora Root and Stem Rot

Genetic Resistance. Using resistant varieties is the most effective way to manage Phytophthora root and stem rot of soybean. Genetic resistance in the host is expressed in terms of Rps (“resistant to Phytophthora sojae”) genes. The race-specific genes are complete resistance to a specific race of P. sojae and genes are denoted as Rps 1a, 1b, 1c,1d,1k, 3,6,7. The pathogen exists in races or biotypes that interact with these genes. In a resistant reaction, the plant survives infection; susceptible varieties are killed when infection occurs. Race-specific resistance is effective in the early stages of germination.

The other parameter on which soybean varieties are rated for P. sojae is partial resistance (also called field resistance or tolerance). Soybean varieties with high levels of partial resistance can become infected with Phytophthora but the symptoms are not as severe as highly susceptible varieties. In field research trials conducted in Nebraska, good partial resistance performed as well as...
varieties with resistance genes and partial resistance. In fields where the *P. sojae* biotype is aggressive against the resistance genes available in commercial varieties, this is the only choice for management with genetics. If possible, a combination of good partial resistance and an Rps gene are recommended. Partial resistance alone will not be as effective during early growth stages or under high disease pressure.

**Cultural Practices.** Anything which can be done to improve soil drainage and structure will reduce disease potential. Soil drainage can be improved through tilling in many cases. Compacted soils will also result in increased disease levels. Crop rotation should also be done, as continuous soybean production will increase fungal inoculum and promote development of new biotypes.

**Fungicide application.** Seed treatment fungicides containing mefenoxam or metalaxyl should be used in fields with a history of this disease. Note that many products require increased rates for activity against Phytophthora.

**Brown Stem Rot (Phialophora gregata)**

The fungus survives in plant residue on which spores are produced from pre-colonized 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. Foliar symptoms will not develop if air temperatures are high (above 85° F) during the R3-R4 growth stages. Field distribution will typically be patches or pockets of plants being affected.

**Favorable Environmental Conditions**

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

**Management of Brown Stem Rot**

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

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

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

**Sudden Death Syndrome (Fusarium virguliforme syn. Fusarium solani f. sp. glycines)**

The sudden death syndrome (SDS) pathogen is spread with soil; thus, the methods used to prevent soybean cyst nematode spread are also applicable to preventing spread of SDS. For symptoms to develop there needs to be high soil moisture available at flowering. As this is a soilborne disease, it will not spread rapidly across the field from individual spots that show up. Infected areas in a field can also have an oblong distribution in the direction of tillage or equipment traffic.

**Symptoms**

The first signs of SDS appear as scattered yellow or white spots on the leaves in the upper portion of the canopy. In the intermediate stage, these spots eventually coalesce to form brown streaks between the veins (interveinal necrosis). On these leaves only the midvein and major lateral veins remain green. As the disease reaches the more advanced stages, premature defoliation occurs with petioles (leaf stems) remaining on the plant. The progression from early symptoms to defoliation will occur rapidly (less than 14 days in most cases). Symptoms
Favorable Environmental Conditions

Sudden death syndrome is favored in high-yield environments. The disease is more prevalent during cool, wet growing seasons and is favored by early planting in cool soils. Hot, dry weather appears to slow disease development, but depending on the stage and infections which may have occurred prior to dry weather it can become severe under these conditions. Heavy rains around flowering time promote foliar symptom development. The series of events for weather in 2013 is why this disease occurred more severely in some areas.

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.

Sclerotinia Stem Rot (White Mold)
(Sclerotinia sclerotiorum)

Sclerotinia stem rot, also referred to as white mold, is caused by a fungal pathogen that can reside in soybean fields an indefinite amount of time. The fungus survives from year to year as hard dark structures called sclerotia. Sclerotia are variously shaped bodies of tightly packed white mycelium covered with a dark, melanized protective coat. Saturated soils and a full canopy favor the emergence of apothecia from the sclerotia, which are mushroom-like bodies that produce millions of airborne spores almost daily over a 7- to 10-day period. These spores are released during favorable weather conditions and can travel to other fields in air currents.

Spores infect plants like soybean primarily through colonized blossoms that are senescing but they can also infect through injured plant tissue. Free moisture must be present on the plant surface for infection to occur. Flowers on the tips of small pods provide a common entrance for the fungus. Invasion of the pod and eventually the stem may lead to lesions covered with sclerotia. During harvest these survival structures are scattered back onto the soil. Thus, inoculum for the next three or more seasons has been distributed.

Sclerotinia should not be planted in narrow rows. Avoid planting varieties which are short and do not lodge will reduce disease potential.

Cultural Practices. Row spacing has been shown to influence this disease, with narrow rows resulting in more Sclerotinia stem rot. Fields with a history of Sclerotinia should not be planted in narrow rows. Avoid irrigation during flowering. The common corn-soybean rotation will not reduce the potential for disease development. Utilizing a longer rotation with corn and wheat has been shown to reduce pathogen buildup and disease risk. As several weeds can be a host for this fungus, it is important to maintain good weed control during rotation years.

Fungicide application. Foliar fungicide applications are typically only recommended to be considered in seed fields or fields with a history of severe disease development. Sclerotinia suppressive herbicides may also be considered. Fungicides applied at the R1 growth stage (beginning bloom) have been shown to provide better control than applications at R3 (beginning pod).
Specialty Crops Update – 2013

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

Introduction

This report will summarize some of the major and unusual disease occurrences encountered during 2013 for sugar beets, dry beans, sunflowers, field peas, corn, chickpeas, fenugreek, and potatoes. Overall, conditions in western Nebraska in 2013 were different from that of 2012, and more similar to the years 2009-2011. Most of the summer was characterized by cooler temperatures with higher levels of rainfall than the tremendously dry conditions in 2012.

These climatic conditions had a substantial influence on the appearance of certain plant production problems experienced during the season. For example, white mold in dry beans, rust on sunflowers and several foliar diseases on sugar beets, were more prevalent than in previous years. Furthermore, the bacterial pathogen, *Pseudomonas syringae* was often identified causing very similar leaf spot diseases in numerous crops in 2013, including sugar beets, dry beans, corn, sunflowers, and yellow field peas.

Sugar Beets

**Root rots**

Root rot diseases in 2013 were back as substantial problems again similar to 2011. The dry rot canker variant of Rhizoctonia root rot was again identified from approximately a dozen fields in both Scotts Bluff and Morrill counties. 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 have conducted some preliminary studies that have proven that this a different species of *Rhizoctonia* than the “typical” pathogen, *R. solani*, and thus confirming its identity as a distinct root rot pathogen causing a different disease than the “typical” *Rhizoctonia* root and crown rot isolates.

Early season reports and specimens were obtained from Wyoming and Colorado that indicated a *Fusarium*-like disease. At least one field in Colorado was destroyed before July due to this issue. This disease was somewhat atypical because the fungus completely colonized the entire internal tap root, rather than being restricted primarily to the vascular elements. Furthermore, the discoloration of the root was more of a light brown to tan color compared with a darker brown to maroon color typically seen with *Fusarium* diseases.

**Nematodes**

Cyst nematodes continued to appear in fields scattered throughout the area, but were not devastating to yield in 2013. We also continued investigations focused on managing this pest with the use of a novel biocontrol organism (bacterium) applied as a seed treatment.

**Foliar Diseases**

Cercospora leaf spot (CLS) was a more severe problem this year. We saw some unusual activity into September with the additional moisture from the occurrence of several rain events. The most severe damage generally observed with the disease, occurs when night temperatures (midnight to 7 AM) exceed 70° F. However, high humidity or long periods of leaf wetness are also required, which were present to a higher degree this year.

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

Another very unusual disease was found in numerous locations throughout western Box Butte County in 2013. Alternaria leaf spot was noted early in the season causing substantial damage to foliage, as a result of the cooler wetter
conditions. Although the leaf symptoms appear to be quite serious, the disease disappears when temperatures warm up and new leaves continue to grow. It did just that in July and August but it was still an unknown and worrisome issue for those producers affected by the disease.

**Dry Beans**

Dry beans in 2013 were inexplicably unaffected by our traditional bacterial pathogens. Some halo blight and brown spot (both caused by unrelated pathovars of *Pseudomonas syringae*) were identified from some locations, but overall were not as damaging as we have seen in the past. The cooler weather further resulted in widespread, but sporadic white mold problems. Rust appeared late in some areas but did not affect yields.

**Corn**

Normally, our most severe and consistently occurring disease of corn in western Nebraska is Goss’ wilt. It has not been as problematic overall in recent years, but was very prevalent early in May and June of 2013. However, the cooler weather did provide the opportunity for a fairly rare bacterial disease called chocolate spot (caused by the fluorescent bacterium, *Pseudomonas syringae*) to cause early damage to young plants and lower leaves. However, the warmer weather that came in mid-summer halted the progression of this disease, allowing new growth to appear and “outgrow” the disease.

**Sunflowers**

The primary disease problem in 2013 (like that of 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.

A bacterial leaf spot, caused by *Pseudomonas syringae* was also encountered frequently, for the same reason as that with corn, dry beans, and sugar beets. The rust disease was back and present throughout the region, but appeared late enough in the season that it did not seriously affect yields. We did conduct some studies on both rust and Sclerotinia (white mold) head rot and were able to artificially produce levels of disease, which we have had trouble doing in drier years.

**Potatoes**

2013 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 thought to seriously affect yields or quality at this time in Nebraska.

The disease is caused by a bacterial pathogen and is transmitted by the potato psyllid. 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.

Nevertheless, 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 insect vector’s tolerance to cold temperatures and thus potentially determining its ability to overwinter in Nebraska, developing a new app for scouting psyllids, and creating extension-oriented educational publications for producers and consultants throughout the U.S.

**Chickpeas**

Ascochyta blight was more prevalent this year, as a result of the weather. Some moderate levels of disease were observed late in the season but they did not affect yields due to the onset of disease toward the end of the season. The conditions required for this disease are similar to that of CLS for sugar beet – warm, but not hot with high humidity 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 (Field Peas and Fenugreek)

Fenugreek is a new alternative crop that is being tested for production potential in western Nebraska. It is a legume whose seeds are utilized as a spice in various curries in Asia. The crop also has additional benefits that could potentially be used in human medicine or as a source of gluten-free food products. Several root diseases were observed including those caused by *Fusarium* and *Rhizoctonia*, but overall were not damaging. Few other serious potential disease issues have been noted.

A large increase in field peas was seen across the region in 2013. A bacterial blight (again caused by *Pseudomonas syringae*) was the most common and consistently identified disease from numerous (dozens) fields wherever the crop was produced. This pathogen is related to those causing halo blight and brown spot of dry beans, but they are all distinct and do not cross-infect. It is also similar to those *Pseudomonas* pathogens infecting corn, sugar beets, and sunflowers. The presence of these diseases can be readily explained by our cool wet weather early in the season. Fortunately, none were adversely affected after the diseases receded with the arrival of warm temperatures in mid-summer.
The Nebraska N loss assessment tool addresses mean losses of N to leaching, volatilization, and denitrification, and estimates nitrous oxide (NO) emission for field-management situations. It is intended for use by producers and their advisors and can be used to estimate the effects of alternative practices on N losses. This publication provides the basis and procedure for use of the tool. Development of the tool’s components was done in consideration of information from diverse sources, including from simulations conducted with the Nitrogen Loss and Environmental Assessment Package (NLEAP; Delgado et al., 2010) and the California N-index (Delgado et al., 2008), but with final determination from consensus of the authors.

Denitrification

Denitrification is affected by N source and rate, and soil drainage. Estimated denitrification is first estimated as percent of application rate:

- 8% for UAN or urea surface applied
- 7% for ammonium sulfate or ammonium nitrate surface applied
- 10% for NH₃ is injected
- 8% * (1 + 0.54*t/25) for fall manure application, where t = ton per acre of dry weight of manure, both for surface applied or incorporated; and
- 8% * (1+0.48*t/25) for spring manure application, both for surface applied or incorporated.

Multiply the above estimates by:
- 1.1 if fertilizer N other than anhydrous ammonia is incorporated
- (0.33 + 0.65*SOM/2.5)
- 2 if drainage is somewhat poor and 3 if drainage is poor if not tile drained; 1 if tile drained
- 0.9 if >40% of the N is applied in-season by side-dress or fertigation
- 0.9 if fall or spring tilled.

Denitrification decreases as soil sand content increases. The adjustment for sand content is to add lb/ac N to denitrification losses according to (%sand – 10) * -0.06.

Ammonia volatilization

Ammonia loss (NH₃-Nᵥ) to volatilization is affected by the ammoniac N application rate, the ammonia volatilization constant for the N source, placement, soil pH, and use of a urease inhibitor. Equations to estimate a base loss of NH₃-N to volatilization on a neutral soil pH are given in Table 1. Adjust this loss factor by multiplying by:
- 0.6 if a urease inhibitor is used
- 0.9 if ammonium thiosulfate is applied
- 0.75 for split or fertigation application
- 2.0 if soil pH > 7.2.

Leaching of Nitrate-N

Leaching of nitrate-N is a function of water from precipitation and irrigation in inches (TW), the difference in available N and N uptake (Nₐₜₜ), soil hydrology class, method of application, use of a nitrification inhibitor, split application, and fertilizer compared with manure N. Base leached nitrate-N for surface applied UAN = -50 + 1.32*TW + 0.173*Nₐₜₜ in lb/ac/yr. Adjust this leaching loss rate for other factors by multiplying:
Table 1. Base estimates of NH₃ volatilization were estimated as the application rate of ammoniac N (AmN; urea and ammonium) multiplied by the ammonia volatilization constant (AVC) for seven days (d) without >0.25” rain or irrigation, and adjusted for days until rainfall or irrigation up to seven days.

<table>
<thead>
<tr>
<th>Fertilizer product</th>
<th>Application method</th>
<th>Adjustment equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea N</td>
<td>Surface</td>
<td>NH₃-Nᵥ = AmN<em>0.15</em>d/7; d≤7</td>
</tr>
<tr>
<td></td>
<td>Incorporated/injected</td>
<td>NH₃-Nᵥ = AmN*0.03</td>
</tr>
<tr>
<td>Ammonium N</td>
<td>Surface</td>
<td>NH₃-Nᵥ = AmN<em>0.08</em>d/7; d≤7</td>
</tr>
<tr>
<td></td>
<td>Incorporated/injected</td>
<td>NH₃-Nᵥ = AmN*0.01</td>
</tr>
<tr>
<td>Anhydrous ammonia</td>
<td>Injected</td>
<td>NH₃-Nᵥ = AmN*0.02</td>
</tr>
<tr>
<td>Manure, solid</td>
<td>Surface</td>
<td>NH₃-Nᵥ = AmN*(0.82-0.25d + 0.018d²); d≤7</td>
</tr>
<tr>
<td>Manure, slurry</td>
<td>Surface</td>
<td>NH₃-Nᵥ = AmN*(1.0-0.19d + 0.012d²); d≤7</td>
</tr>
<tr>
<td>Manure</td>
<td>Injected/incorporated</td>
<td>NH₃-Nᵥ = AmN*0.02</td>
</tr>
</tbody>
</table>

- 0.75 if a nitrification inhibitor or controlled release fertilizer is used with spring application
- 0.9 if a nitrification inhibitor or controlled release fertilizer is used with fall application
- 0.96 if ammonium thiosulfate is applied alone or with other applied fertilizer N
- 0.75 if > 40% of N is applied in June or July
- 0.80 if corn crop was preceded by a fall or winter cover crop
- 1.2 if N fertilizer is incorporated
- 1.3 if fall applied fertilizer
- 0.85 if >50% of available N is from manure surface applied or incorporated
- 1.1 if tile drained but only if somewhat poor or poor drainage
- 1.25 if fall tilled
- 1.13 if spring tilled

Nitrous oxide emission

Base N₂O emission with UAN surface applied in lb/ac/yr is 2.6 + 0.013 Nrate or 0.94 + 0.015N + 0.15D – 0.00039*N*D, where D = the estimated denitrification rate. Add (0.01 * total water, “/yr). Multiply this sum by:
- 0.85 if a nitrification or a urease inhibitor is used
- 1.4 if N fertilizer is anhydrous ammonia
- 1.3 if N fertilizer is urea
- 1.2 if UAN is injected

- 0.75 for N applied as controlled release fertilizer
- 0.7, 1.0, 1.3, and 1.5 for hydrologic class A, B, C, and D
- 2.0 if drainage is somewhat poor or worse.

The tool estimates N losses for the current crop of corn. Much less N is applied on average for the corn soybean rotation compared to continuous corn. Estimated mean N losses for the corn year of the corn-soybean rotation compared to continuous corn are 65% leaching, 100% denitrification, 80% volatilization, and 80% N₂O emission. Losses are less with soybean than with corn and mean annual losses for the corn-soybean rotation compared with continuous corn are estimated to be 25% leaching, 50% denitrification, 40% volatilization, and 60% N₂O.

**INPUT Information**

Required input information is generally easily available.
- Select county from a dropdown list (determines default values for precipitation)
- Select soil unit (determines pH, hydraulic class, and drainage)
- Enter previous crop (Index assumes current crop is corn)
- Enter corn yield goal
- Select irrigation type (give amount applied and NO₃-N ppm)
  - None
  - Pivot
  - Furrow
  - Drip
- Check for tile drainage, tillage, and cover crop.

![Image of the Nitrogen Loss Assessment Tool](image-url)
• UAN surface
• UAN incorporated/injected
• UAN sidedress surface
• UAN sidedress injected
• UAN fertigation
• Urea surface
• Urea incorporated
• Anhydrous injected
• Other surface
• Other incorporated/injected

If manure is applied, select manure type from a dropdown list. Select: days to incorporation; units = t/ac, 1000 gal/ac or ac-in/ac; default and changeable values for dry matter content, NH4-N and organic N contents; rate of application; and time between applications in years.

• Feedlot solid
• Feedlot holding pond
• Swine or dairy slurry
• Swine or dairy solid
• Poultry solid

Revise default values if desired for rainfall, soil organic matter and pH values.

**Outputs**

The outputs are estimated mean losses to each process in pounds per acre N:

• Denitrification
• Leaching
• Volatilization
• N₂O emission.

The results can be saved to the “Report” worksheet.

**Citation**

The Importance of Soil Sampling

Gary Hergert, UNL Soil and Nutrient Management Specialist
Tim Shaver, UNL Nutrient Management Specialist
Richard Ferguson, UNL Soil Specialist
Charles Shapiro, UNL Soil and Crop Nutrition Specialist
Charles Wortmann, UNL Soil and Nutrient Management Specialist

Introduction

Soil testing is a recommended means of predicting the kind and amount of fertilizers needed to maximize crop yields. However, many farmers still do not use this relatively simple tool to increase fertilizer efficiency. Producers still apply fertilizer where none is required or at higher rates than required to optimize yields. Others apply inadequate rates or use ineffective application methods. While soil test recommendations for nutrient requirements and optimum rates needed for maximum profit are not always totally correct, they are superior to no soil testing program at all.

Soil testing can detect soil nutrient levels prior to planting quite well; however, soil testing cannot predict future factors that may influence crop yields. Soil testing is a practical and common-sense means of using reliable chemical analyses to assess nutrient levels in soils in order to make decisions to improve fertilizer use. The producer must understand the limitations and capabilities of soil tests in order to develop a fertilizer management strategy.

Soil Testing:

The components of a successful soil testing and fertilizer recommendation system include laboratory analyses, good soil samples, correlation-calibration information, and interpretation.

The top eight inches of soil in an acre weighs over two million pounds. The soil sample from a field may weigh about two pounds. When a soil sample is analyzed in the laboratory, the sample weighs less than one ounce. Because the soil sample must accurately represent an entire field or area sampled, soil sampling is the weakest link in the chain of developing a fertilizer management program. For more information refer to UNL NebGuide Guidelines for Soil Sampling (G1740).

The Effect of Soil Variability on Sampling:

Farmers and agronomists have always been aware that soils vary from farm to farm, from field to field, and even within a given field. It is easy to detect noticeable visual differences in soils such as color, slope, erosion, salinity or drainage. Detecting differences in soil chemical properties such as pH, phosphorus (P) or potassium (K) status is much more difficult.

Soil testing has historically focused on determining the average soil test value for a field or area. Soil sampling plans are designed to determine an adequate number of samples to provide a reliable estimate of the mean, the most efficient sampling plan, and some measure of spatial variability. The best sampling plans are ones which give the lowest sampling error at a given cost or the lowest cost at a given sampling error.

Site specific management (SSM) and variable rate application (VRA) have changed the way we think about soil sampling compared to the way it’s been done for the past 50 years. The difficulty with soil testing today is that quantifying a soil test parameter’s variability requires soil sampling at an intensity which allows the variability to be mapped spatially with some degree of confidence.

The following statements summarize the requirements for proper soil sampling, depending on the producer’s objectives:

1. For conventional sampling (compositing cores), the person sampling should take several individual cores for compositing into a single sample for analysis, and take samples from all areas that he determines are different (directed sampling).

2. If the farmer is willing to invest more in soil testing, he should grid sample once on a two-acre basis to determine base maps of soil fertility, then sample at a reduced intensity every four to five years.

Sampling methods:

Depending on soil variability, current guidelines recommend sampling areas no larger than 40 acres per sample with a minimum of 20 to 25 cores. For no-till or minimum tillage, the producer should take...
samples at a shallower sampling depth of two to four inches in addition to a sampling depth of eight to ten inches to monitor surface pH and the buildup or stratification of immobile nutrients.

**Sampling for Site Specific Management:**

Because of the intensity required for site specific management soil sampling, farmers must first look at sampling frequency. In the past many producers sampled fields yearly, often because it was offered as a service by local agrichemical dealers or by consultants. Annual sampling isn’t really beneficial because most soil test values (immobile nutrients, pH) do not change rapidly. Instead, the original process was to collect a good sample, get the results and recommendations, follow the recommendation for four to five years, and then sample again. In Nebraska, annual sampling is necessary only for residual nitrate determination.

Detailed sampling provides significantly more information about soil properties than field average sampling. Because most soil properties (physical or chemical) do not change rapidly, the producer should base soil sampling frequency on the expected change in the parameter measured.

Intensive sampling, whether it is a two-acre grid or directed sampling based on yield maps, remotely sensed images, or other spatial resources, provides much more information than a whole field average sample. The additional information can improve management and possibly reduce input costs by applying nutrients/amendments where they are really needed. This additional information comes with greatly increased sampling and analysis costs, however. The producer may initially sample intensively to establish base fertility maps of fields, then reduce sampling based on the initial map at one-third to one-fourth the initial intensity to develop a cost-effective site-specific soil testing plan. For more information about spatial sampling techniques, refer to University of Nebraska Extension Circulars Soil Sampling for Precision Agriculture (EC154) and Site-Specific Nitrogen Management of Irrigated Corn (EC163).

**Drying the soil sample:**

Soil samples should be air-dried before they go to the laboratory for analysis. In drying soils, the sampler should not apply any heat, but should spread the soil out on clean paper and protect the soil from any contamination (such as fertilizer, dust).

**Chemical Analysis:**

Not all essential plant nutrients are needed in a fertilizer management program as the soil or irrigation water may supply sufficient amounts. Copper, boron, sulfur, or chlorine analysis of all soils would not always provide information useful in deciding what fertilizer nutrients are needed. Therefore, it is reasonable not to test for all nutrients on all samples when a particular nutrient is well supplied by the soil or water. This can save on analytical costs.

No matter how good a chemical test, a soil test value is meaningless unless the producer can relate it to the nutrient status of the soil in order to apply a corrective soil amendment or fertilizer treatment. A single numerical value reported by a soil test (say 11 ppm for phosphorus) has no meaning unless information is gathered to evaluate (1) whether crops will maximize growth and/or yield at that assessed phosphorus level, (2) whether crop growth or yield will be greater when the nutrient phosphorus is added to the soil, and (3) the amount of phosphorus needed for the crop to attain better growth or yield in different soils at different test levels.

**Drought Considerations:**

Accounting for residual soil nitrate-N has become especially important due to recent weather patterns. Drought conditions can have a significant impact on how much N is left in the soil after harvest. The only way to determine the availability of residual soil nitrate-N is through soil sampling.

**Resources:**


Herbicide Update 2014

Amit Jhala, Weed Management Specialist
Lowell Sandell, Weed Science Extension Educator
Stevan Knezevic, Integrated Weed Management Specialist
Greg Kruger, Cropping Systems Specialist
Robert Wilson, Weed Management Specialist

Corn Herbicides

Anthem™ ATZ [Atrazine (42.5%) + Pyroxasulfone (5.15%) + Fluthiacet-methyl (0.15%)]. It can be applied pre-plant, pre-emergence, or early post-emergence for control of broadleaf and grass weeds in all type of corn. Do not apply more than 39 oz/A per growing season in course textured soil and do not apply more than 76.46 oz/A in medium and fine textured soils. Do not harvest or feed grain or stover within 70 days of last application. EPA Reg. No. 279-3449.

Breakfree® NXT ATZ [Acetochlor (33.4) + Atrazine (26.9)]. It is a premix from DuPont for pre-plant and pre-emergence control of selected broadleaf and grass weeds in corn. The application rate is in a range of 1.4 to 3 qts/A depending on soil texture and organic matter content. EPA Reg. No. 62719-671-352. Breakfree® NXT Lite [Acetochlor (46.3%) + Atrazine (18.3)]. EPA Reg. No. 62719-670-352.

Callisto® GT [Glyphosate (34%) + Mesotrione (3.4%)]. It is a new premix from Syngenta for post-emergence weed control in Roundup Ready corn. Do not apply more than one time per year and do not apply more than 2 pints/A per year. Do not harvest forage, grain or stover within 45 days after application. EPA Reg. No. 100-1470.

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. EPA Reg. No. 352-873.

Lexar® EZ [S-metolachlor (19%) + Atrazine (18.61%) + mesotrione (2.44%)]. Lumax EZ [S-metolachlor (27.1%) + Atrazine (10.2%) + mesotrione (2.71%)]. Lexar EZ and Lumax EZ are products of Syngenta for pre-emergence control of annual grasses and broadleaf weeds in corn and grain sorghum. The application rate of Lumax EZ is 2.75-3.25 qts/A and for Lexar EZ is 3-3.5 qts/A. EPA Reg. No. 100-1414 for Lexar EZ and 100-1442 for Lumax EZ.

Realm™Q [rimsulfuron (7.5%) + mesotrione (31.25%)]. Realm Q is a new premix herbicide from Du Pont 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 an HPPD inhibitor (Group 27). EPA Reg. No. 352-837.

Zemax™ [S-metolachlor (36.8) + mesotrione (3.68%)]. 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. 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. It is also labeled for early post-emergence application in corn. MOA: Pyroxasulfone is a seedling growth inhibitor. Application rates of Zidua may vary depending on soil texture. EPA Reg. No. 7969-338.

Sorghum Herbicide

Huskie™ [pyrasulfotole (3.3%) + bromoxynil (26.3%)]. 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 sorghum for seed production. EPA Reg. No. 264-1023.

Soybean Herbicides

Authority®Elite [Sulfentrazone (7.55) + S-metolachlor (68.25)]. It is a soil applied herbicide for control of broadleaf, grass and sedge weeds in soybeans. The crop rotation restriction for corn and sorghum is 10 months. It should not be applied more than 38.7 fl oz/A per year. EPA Reg. No. 279-3442.

Authority®Maxx [Sulfentrazone (62.12) + Clorimuron-ethyl (3.88)]. It can be applied pre-plant or pre-emergence in soybean for broadleaf and partial grass weed control. The application rate is 6 to 9 oz/A depending on soil texture and organic matter content. EPA Reg. No. 279-9560.
Flexstar® GT 3.5 [Fomesafen (5.88%) + Glyphosate (22.4%)]. 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 EPSPS inhibitor (Group 9). EPA Reg. No. 100-1385.

Marvel™ [Fluthiacet-methyl (1.2%) + Fomesafen (30.08%)]. It is a new premix herbicide from FMC for post-emergence weed control in soybean. It can be applied at 5 to 7.25 fl oz/A from pre-plant through full flowering stage (prior to R3). It is a contact herbicide therefore, a good coverage is essential for optimum weed control. Do not apply more than 7.25 fl oz/A per application and 9.75 fl oz/A per year. EPA Reg. No. 279-3455.

OpTill® PRO [saflufenacil (17.8%) + imazethapyr (32%) + dimethenamid-P (63.9%)]. It is one of the Kigor 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 and residual pre-emergence weed control in soybean. EPA Reg. No. 7969-332.

Pummel™ [metolachlor (5 lb ai/gal) + imazethapyr (0.25 lb ae/gal)]. Pummel is a new product from MANA to be used for preplant or preemergence control of annual grasses and many broadleaf weeds in soybeans. The use rate is from 1.6 to 2 pt/a depending upon soil type and organic matter. EPA Reg. No. 66222-251.

Torment™ [fomesafen (2 lb ae/gal) + imazethapyr (0.5 lb ae/gal)]. Torment is a new product from MANA that can be applied preplant, preemergence or early post emergence control of broadleaf and grass weeds in soybeans. The use rate is 1 pt/a when soil applied and 0.75 to 1 pt/a with a minimum 15 GPA carrier volume when applied post emergence. EPA Reg. No. 66222-249.

Wheat Herbicide

Finesse® Grass and Broadleaf [chlorsulfuron (25%) + flucarbazone-sodium (46.7%)]. Finesse Grass and Broadleaf is for use in wheat. The use rate ranges from 0.6 to 0.9 oz/a depending on the target weed. Consult the label for wheat appropriate wheat growth stage for application and rotational crop restrictions. EPA Reg. No. 352-718.

Herbicides Labeled for Use in Multiple Crops

Anthem™ [pyroxsulfone + 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: Pyroxsulfone is a seedling growth inhibitor (Group 15) and fluthiacet-methyl is a PPO inhibitor (Group 14). EPA Reg. No.279-3450.

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

Fierce™ [flumioxazin (33.5%) + pyroxsulfone (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 pyroxsulfone is a seedling growth inhibitor. EPA Reg. No. 63588-93-59639.

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

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

Pyroxsulfone 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 dimethenamid-P (small seeded broadleaves and most annual grasses).

Warrant® [acetochlor (33%)]. Warrant is an encapsulated formulation of acetochlor from Monsanto. It is now labeled for pre-plant, at-planting or pre-emergence to soybeans and sorghum at 1.25 to 2 qts/A depending on soil texture and organic matter content. It can also apply post-emergence to soybean and sorghum. EPA Reg. No. 524-591.
Emerging Issues for Australian Spraying: Bigger Sprayers, Bigger Droplets, New Problems?

Bill Gordon
Bill Gordon Consulting Pty Ltd
GRDC Code: BGC00002

Keywords: Spray Application, Sprayer Speed, Wheel Tracks

Take Home Messages:

- Increased spraying capacity should improve spray results (due to improved timeliness), if the target is susceptible, the rate of product is robust, the machine is operated within its limits and the meteorological conditions are appropriate for spraying operations.

- Higher travel speeds during spraying creates many problems that result from poor deposition and poor control, particularly adjacent to the wheels and the centre of the sprayer.

Introduction

In Australia growers continue to purchase larger sprayers (usually self-propelled) to increase the number of acres per hour they can cover, with the main aim to improve the timeliness of their spray applications. This may have had both positive and negative effects on their spray results, depending on what practices have been used to increase that capacity.

Increasing spraying capacity by completing more sprayed acres per hour has also come with an increase in the level of spray drift events we have seen in Australia. Our regulators have responded with many new rules on the product labels, including the use of downwind no spray zones, droplet size requirements and specific rules about wind speed and inversions.

In many instances the use of larger droplets can still provide good efficacy, however we have seen that the combination of higher travel speeds and larger droplets has created some new problems in the field, such as poorer control adjacent to the wheel tracks, particularly in standing stubble.

Impacts of increased spray capacity on deposition and drift risk.

Impact of Increased Speed:

The greatest temptation for operators of self-propelled sprayers is to travel at higher speeds than they may have previously considered, simply because their machines allow them to do so.

Increased speed can produce effects at the nozzle, at the target, and around the machine itself.

- Increased travel speeds increases the air movement past the nozzle narrowing the effective sprayed width of each nozzle and can lead to detrainment (escape) of smaller droplets from the pattern, which increases the risk of spray drift. Narrower patterns may also impact on the overlap of the spray patterns, unless the nozzle height above the target is adequate.

- When using a coarse spray quality (or larger droplets), the larger droplets tend to hold their trajectory (direction as a function of downward velocity from the nozzle and forward travel speed of the sprayer). Faster travel speeds tend to increase the horizontal movement of larger droplets. This can lead to shadowing or misses of smaller weeds behind the stubble, more spray depositing on one side of the target than the other, and poorer penetration into larger canopies.

- Increased travel speed (typically above 9-10 MPH) increases the wake affect produced by the machine and increases the air displaced by the tyres and wheels. This can result in reduced deposition of spray droplets in the wheel track and in the areas adjacent to the wheels (particularly on the downwind side of the sprayer). Poor weed control in the wheel tracks is often reduced with higher clearance machines (compared to trailing rigs), but it can often be further improved with additional wheel track nozzles for knock down (non-residual) products, provided that dust is not the major contributor to the problem.
For more information on issues related to wheel tracks see the GRDC factsheet: “Weed Control in Wheel Tracks”

Impact of Increased Boom Width:

If a suitable travel speed is used, increasing the boom width can greatly improve capacity. Where the boom height and stability can be maintained this should result improve the application efficiency. When increasing boom width it is important to consider the optimum boom width, which is likely to be a multiple of the harvester and seeder width to minimize the number of wheel tracks in the field.

In many Australian cropping regions the use of wide booms (typically more than 100 feet) usually requires automatic height control to maintain a suitable height above the target (weed, top of stubble or crop height). Auto height control may be limited in its effectiveness when poorly setup or when travelling at higher speeds (above 14-15 MPH). As a result of higher travel speeds, wider booms are often set at heights well above that required to maintain a double overlap. Greater release heights increase the potential for detrainment of small droplets as well as the lateral (forward) movement of larger droplets.

For further information on height control systems see the GRDC factsheet “Spray Height Control”

Impact of Increasing Tank Size:

Increased tank size can mean more spraying time in the field due to less filling operations, increasing productivity. Productivity can also be increased by reducing fill times through larger pumps, providing more filling points, or the use portable mixing sites and water carts.

However, when mixing larger tank volumes careful consideration should be given to the agitation requirements of the mix, the actual mixing order and the mixing procedure. Issues such as compaction of the soil and the need for wheel track renovation should also be considered before increasing the size of the machine.

Suggestions for farmer and advisors conducting field inspections (after spraying)

Knowledge of the application method can be critical in identifying if this has contributed to reduced efficacy in the field.

When inspecting the results of a spray job I believe that growers and advisors should be equipped with the following information to determine if application has impacted on the anticipated efficacy:

- Actual products used, mixing amounts and mixing order
- Dates and times of application
- Details of the water source and water quality used
- Carrier Volumes, Speed (minimum, average and maximum), Nozzles (brand, type orifice size and spray angle) and the Pressures (at the nozzle)
- Weather parameters for each load, especially wind direction, temperature and humidity (including at the target).
- Direction of travel of the sprayer / GPS map of areas sprayed
- Details of automatic rate controller settings, such as minimum pressure/speed/flow hold or settings
- Nozzle charts to indicate spray quality (droplet size) at various pressures and speeds
- Decontamination procedure following previous spray job

Essentially this means ensuring that good spray records are maintained, and that you have a copy before you conduct and inspection.

Assessing the results of spray jobs

If there is an issue with the application, often the pattern is repeated within the paddock. This requires the advisor to conduct their inspections at an appropriate number of locations within each paddock that represent the variability in field conditions and sprayer operation.

- When inspecting a spray job, look at multiple passes by the sprayer and multiple sets of wheel tracks, which should include both directions of travel.
- Compare efficacy in the midpoint of boom, adjacent to wheels, between the wheel tracks and at the overlaps of the boom (particularly where auto section control is used to ensure is it engaging correctly).
- Compare ends of runs and areas where speed may be lower (hence pressure or duty cycle) with points in the spray runs where desired speed is obtained.
• Inspect and compare control in the stubble line (both sides of the stubble relative to the direction of travel and to the wind direction) with areas in between the stubble line (in the inter-row space).

• Inspect control on both sides of target weeds, relative to direction of travel and wind direction.

• Inspect fence line control and corners of fields for potential green bridges.

• Map areas of poor control relative to other parts of the field in relation to soil type, moisture, cropping history to the evaluate the potential impact of factors such as plant stress, and to monitor the potential for resistance development over time.

• Assess control of susceptible species outside of the application area to identify potential off target movement.

**Conclusion**

With the emergence of harder to kill weeds, the potential for resistance development, and slow development of new herbicides we cannot afford to accept poor control in any part of the field, nor can we put at risk access to the products that are currently available.

Understanding the factors that influence spray deposition, and how to identify these in the field can assist growers (and advisors) to recognize if there is a problem with the application technique. It is only when a problem is identified that it can be fixed.

**Contact Details**

Bill Gordon Consulting  
+61 (0) 429 976 565  
bill.gordon@bigpond.com
Prescribed Fire for Grassland Management

Steve Young, Weed Ecologist
Dirac Twidwell, Rangeland Ecologist

Ecosystem Transitions in the Prairies

A combination of settled areas and elimination of fire has resulted in a significant change to plant and animal communities that once dominated the prairies and grasslands of the Great Plains. The bison was the first to be eliminated from these areas and with it entire food webs were affected, including those depended on by humans (e.g., Native Americans). While the decline in bison was rapid, the native plant communities that was once dominant have gone through a slower transition to more weedy and less functionally diverse species. The European settlement brought with it plants from European origin that are weedy and now dominate field borders, road sides, and other locations, in addition to localized infestations in rangeland prairies.

Further changes in plant communities of the prairies have included encroachment by woody species. Eastern redcedar (*Juniperus virginiana* L.), a native tree, has had the most significant increase in distribution following the loss of fire and it now covers over 1 million ha in the central Midwest states of Illinois, Indiana, Iowa and Missouri (Pierce and Reich 2010). Similarly, eastern redcedar has become well-distributed throughout the adjacent Mountain Prairie region in states like Nebraska, Kansas and the Dakotas (Briggs et al. 2002; Stubbendieck et al. 2003; Kaul et al. 2006) and into Oklahoma and parts of Texas eastern redcedar and Ashe juniper have created closed canopy woodlands (Figure 1).

Importance of Fire

The elimination of fire, the ecological process responsible for maintaining open prairies in the Great Plains since the last glacial maximum (Twidwell et al. 2013), has now become a significant concern in many regions of the U.S. Long-term research throughout the Great Plains shows the loss of fire from prairies and the increase in woody plants, especially cedar, has decreased livestock production 75%, decimated grassland birds and other wildlife, and greatly decreased plant biodiversity (Twidwell et al. 2013). Nebraska landowners have made similar observations. For example, in the Loess Canyons of west central Nebraska, a landowner with over 400 ha of grassland has witnessed a decline in livestock stocking rate of 70% in the last 50 years (SL Young, personal communication).

Elimination of fire in rangeland systems and cedar encroachment has also resulted in excessive, volatile fuel loads that can result in catastrophic wildfires too intense for fire suppression to be successful (Twidwell et al. 2013). Recent droughts in the southern Great Plains, combined with decades of cedar encroachment into prairies, has already led to unprecedented losses of life and property and skyrocketing suppression costs. In 2011 alone, wildfires burned 4.4 million acres in the south-central U.S, which was more than the rest of the country combined (NIFC, 2013). In Texas alone, wildfires in 2011 destroyed 2900 homes, killed 10 people, incurred firefighting costs of more than $330 million, and cost an additional $500 million in insurance claims. For Nebraska, the 2012 wildfire season demonstrated that the central and northern plains are also at risk. Wildfires burned more than 300,000 acres last year in Nebraska, by far the largest amount over the last 15 years (NIFC 2013). As human dwellings continue to expand into natural areas and cedar continues to move into rangelands, wildfire poses an increasing threat to life and property in this region.

Prairies, Fire and Livestock

Grasslands account for 40 to 50% of the land area in many of the Great Plains states and livestock production is the primary ecosystem service for the majority of landowners. In Nebraska alone, nearly 2 million head of beef cows utilize grasslands, and are the key component of this state’s largest single industry. Prescribed fire is critical
for a healthy and functioning grassland ecosystem and should be part of proper grazing management in rangelands (Fuhlendorf et al. 2012). Fire markedly increases forage quality for a few months following fire (Allred et al. 2011) and prevents decreases in herbage production by preventing invasion of undesirable species (e.g. eastern redcedar). Fire can therefore be used to manage the quality and quantity of forage used throughout annual cattle production life cycles.

**Restoring Prairies**

While fire is not often used as a restoration option, fire can decrease cedar abundance in rangelands and restore grassland dominance (Twidwell et al. 2009, 2013). Eastern redcedar does not resprout, so trees are killed when fire completely scorches or consumes the foliage. Meeting restoration objectives therefore demands that prescribed fire practitioners burn in conditions that produce fires of sufficient intensity to cause this effect (Twidwell et al. 2013). In prairies with low levels of cedar encroachment, low intensity fires can easily kill young cedar seedlings. However, as cedars increase in size, considerably more intense fires are needed. To meet restoration objectives, prescribed fire managers should consider targeting lower fuel moisture conditions or accumulate greater grass fuel loads to increase fire intensities beyond the threshold needed to kill cedar trees.

Restoration in areas that have been converted to other land uses often requires intensive approaches that maximize chemical, mechanical, and cultural practices to reduce weed seed loads in the soil seedbank (Young and Claassen 2008a). In areas where native plants have been established previously, but are being suppressed by dense populations of invasive plant species, a different approach is needed that simply releases the desirable plant species (Young and Claassen 2008b). The micro-site conditions including soil nutrients, water holding capacity, microbial communities, and existing weedy plant populations all play a significant role and need to be accounted for when restoring native or desirable plant populations, especially in poorly managed sites or where extreme conditions exist. The reintroduction of prescribed fire to these systems would aid restoration efforts that have the establishment of native plant populations is a top priority.

**Effects of Climate**

Changing climate has caused increasing frequencies of extreme events (e.g., flooding, drought) in parts of the world, which are predicted to continue and impact many regions, including the Great Plains. Extreme events are already a natural feature of climate in the Great Plains with the region having experienced especially severe droughts and floods during the last two decades. Projections of increased temperatures in coming decades are expected to result in reduced summer rainfall, increased evaporation rates, and heavier precipitation events, which will increase the potential for both drought and floods (HPRCC 2010).

In grasslands of the Great Plains, drought has impacted native plant communities directly through reductions in rainfall and indirectly through interception by eastern redcedar trees. The reduction and diversion of precipitation is changing plant community composition with some species declining and others continuing to expand their range. The establishment of desirable plant populations in the Great Plains during extreme conditions might be more challenging and may require expertise from those in other regions.

The occurrence and potential increase in drought events is a cause for concern in areas of human residences that are near or surrounded by stands of eastern redcedar. In the western U.S., fire frequency has coincided with drought conditions (e.g., high temperatures, low precipitation) and resulted in catastrophic losses of both human dwellings and natural areas. Obviously, natural areas can recover from a fire more quickly than homes, residences, and city structures, but often the question for natural areas is: What will it return to?

**Ecosystem Services from Prairies**

Grasslands contain natural resources that are vital for sustaining healthy ecosystems. Havstad et al. (2007) has illustrated the effect of water and water-related resources on ecosystem services of grasslands, which includes nutrient cycling (regulating), wildlife habitat (supporting), recreation (cultural) and livestock (provisioning). The effect of invasive plant species establishment in these ecosystems can be devastating in terms of the permanent alteration of ecosystem composition, structure and resulting function. Ecosystems that are out of balance can lead to a service losses and create increased potential for losses at the catastrophic scale (e.g., wild fires).

The establishment of native plant populations in prairies is an effective tool for providing competition with invasive plants and thus restoring the health and function of the ecosystem. Native plant communities consist of plant functional groups that vary in ecological, morphological, physiological, biochemical, or life history characteristics that overlap with the characteristics of invasive species (Young et al. 2009). What results is a more resilient plant community that can compete with and prevent or slow the establishment of an invasive plant species.

**Helping Land Managers with Prairie Restoration**

Managing grasslands infested or threatened by eastern redcedar can be quite a dilemma for land managers and owners. The realization that control and/or restoration measures need to be initiated is apparent for most. However, there can be uncertainty associated with costs, methods, and restoration technologies.
In order to address the uncertainties, several local, state, and federal agencies are available to provide expertise and information on management of grasslands, including eastern redcedar, in the Central Prairie. For example, the University of Nebraska-Lincoln Extension and Nebraska Game and Parks Commission provide both research-based and applied practical information that landowners can access through the internet or the local field office. Also, the Nebraska State Forest and the USDA Natural Resources Conservation Service (NRCS) have specific recommendations for landowners dealing with challenging management issues, such as eastern redcedar. Interestingly, Nebraska has a higher number of landowner prescribed burn cooperatives, such as the Twin Platte Weed Management Area and the Loess Canyons Rangeland Alliance, than any other state in the country. Connecting with other landowners using prescribed fire can help bring people together for coordinated activities, workshops, training, or simply discussion sessions and meetings at the local gathering spot.

Even with the vast amount of information available on grassland management and its relative ease of accessibility, the rate of adoption of current and proven techniques remains low. There exists a need to work directly with as many progressive landowners as possible and then invite others to view or be involved in the process. This active involvement eliminates the risk for those not fully convinced of the importance to make the necessary changes, but understanding the importance to do so. Through this process, demonstration and dialogue help all participants see what is needed for their own operations.

**Summary**

Prairies contain natural resources that are vital for sustaining healthy ecosystems. Eastern redcedar, a native invasive tree species, is a major driver in the overall reduction of Central Prairie grassland ecosystem services, which include nutrient cycling (regulating), wildlife habitat (supporting), recreation (cultural) and livestock (provisioning). In addition, an established stand of eastern redcedar creates a monoculture plant community that excludes both native and desirable plant species. Ultimately, a poorly functioning ecosystem can have wide-ranging effects that occur at scales of individual plant communities to entire biomes and result in natural disasters, such as catastrophic fires, wide-spread erosion, and loss of production.

Therefore, landowners need to be proactive in managing grasslands by judiciously using prescribed fires. The benefits include:

- Improved forage quality and maintaining herbage production for livestock
- Increased plant diversity
- Habitat provided for grassland birds and other wildlife
- Reduced amount of volatile fuel loads
- Prevent encroachment of eastern redcedar

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, 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 problem weed further east in 2013 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 grows larger, the effectiveness of postemergence herbicides diminish.

Kochia in Nebraska has developed resistance to five major herbicide families (MOA Group Number): triazines (5) (atrazine, metribuzin), imidazolinones (2) (Pursuit, Raptor), sulfonylureas (2) (Ally, Permit, UpBeet), growth regulators (4) (2,4-D, dicamba), and EPSP synthetase inhibitors (9) (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 glyphosate, you probably also have resistance to imidazolinones and sulfonylureas (2), but kochia plants have generally been susceptible to atrazine (5) and dicamba (4).

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.

Since the initial reports of glyphosate-resistant kochia in Kansas in 2007, glyphosate-resistant kochia has been reported in Nebraska, Colorado, Montana, and North Dakota. A survey was conducted in the fall of 2012 to examine the presence of glyphosate-resistant kochia in the sugarbeet growing regions of Colorado, Montana, Nebraska, and Wyoming (see map). Kochia seed was collected from 56 fields from the four states. Seed was cleaned, planted, and 3 inch tall seedlings were treated with increasing concentrations of Roundup PowerMAX. The lethal dose of glyphosate required to provide 90% kochia control (LD90) was calculated for each of the 56 field sites. The LD90 for kochia populations collected in Montana ranged from 25 to 64 ounces/acre, in Wyoming from 24 to 215 ounces/acre, in Nebraska from 12 to 44 ounces/acre, and from 28 to 318 ounces/acre in Colorado. The recommended rate of Roundup PowerMAX for weed control in sugarbeet is 33 ounces/acre so 58% of the kochia populations examined in this survey would not have been suppressed by a 33 ounces/acre dose of Roundup PowerMAX. The different kochia populations were also tested for resistance to UpBeet a herbicide belonging to the sulfonylurea family of herbicides.
Approximately 50% of the kochia populations demonstrated resistance to UpBeet.

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.

Table 1 provides suggestions for managing kochia in corn, small grains and dry beans. Information is also provided on rotational restrictions for various herbicides to sensitive crops.
Soybean Treatments

- Roundup PowerMax
- Boundary fb Cobra: 96 a
- Valor SX fb Cobra: 81 b
- Authority Assist fb Cadet: 91 a

Percent kochia control

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Wheat Treatments

- Roundup PowerMax
- Agility SG: 78 b
- Starane NXT: 85 a
- Huskie: 86 a

Percent kochia control
Fallow Treatments

Roundup PowerMax 84 b
Rage D-Tech 83 b
Sharpen
Clarity 92 a

Percent kochia control

Sugarbeet Treatments

Roundup PowerMax
Nortron fb Progress + Upbeet 3X 41 a
Nortron fb Progress + Upbeet 41 a
Nortron fb Progress 30 b

Percent kochia control
Kochia Sampling Sites across Colorado, Montana, Nebraska, and Wyoming.
## Table 1. Managing Glyphosate-Resistant Kochia in Western Nebraska and Southeastern Wyoming

### Adding Herbicide Diversity in Corn for Kochia Control

<table>
<thead>
<tr>
<th>Herbicide used in corn</th>
<th>Rotational Crops</th>
<th>Sugarbeet</th>
<th>Dry bean</th>
<th>Small grain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preemergence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharpen @ 2 oz/A + Prowl H₂O @ 32 oz/A</td>
<td>12</td>
<td>12</td>
<td>4-12+</td>
<td></td>
</tr>
<tr>
<td>TripleFlex @ 1.5 pt/A</td>
<td>24</td>
<td>12</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Valor @ 2 oz/A</td>
<td>12</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Verdict @ 12 oz/A</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Zidua @ 2 oz/A + Prowl H₂O @ 32 oz/A</td>
<td>12</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td><strong>Postemergence with glyphosate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Armezon @ 0.5 oz/A</td>
<td>18</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Clarity @ 8 oz/A</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Laudis @ 3 oz/A + Buctril @ 6 oz/A</td>
<td>18</td>
<td>12*</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Prowl H₂O @ 32 oz/A</td>
<td>12</td>
<td>0</td>
<td>4-12+</td>
<td></td>
</tr>
<tr>
<td>Require Q @ 4 oz/A</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Resolve Q @ 1.2 oz/A</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Status @ 5 oz/A</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Starane Ultra @ 7 oz/A</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

*Crops grown under sprinkler irrigation + 12 months for oats

### Adding Herbicide Diversity in Small Grains for Kochia Control

<table>
<thead>
<tr>
<th>Herbicide used in small grain</th>
<th>Rotational Crops</th>
<th>Sugarbeet</th>
<th>Dry bean</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Postemergence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronate Advanced @ 19 oz/A</td>
<td>2</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Huskie @ 13.5 oz/A + MCPA @ 12 oz/A</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Starane NXT @ 14 oz/A</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

### Adding Herbicide Diversity in Dry Bean for Kochia Control

<table>
<thead>
<tr>
<th>Herbicide used in dry bean</th>
<th>Rotational Crops</th>
<th>Sugarbeet</th>
<th>Corn</th>
<th>Small grain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At planting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prowl H₂O @ 32 oz/A</td>
<td>12</td>
<td>12</td>
<td>4-12+</td>
<td></td>
</tr>
<tr>
<td>Sonalan @ 32 oz/A</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Postemergence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raptor @ 4 oz/A + Basagran @ 16 oz/A</td>
<td>18-26*</td>
<td>8.5</td>
<td>4-9+</td>
<td></td>
</tr>
</tbody>
</table>

*Dry bean grown under sprinkler irrigation + Oats more sensitive than wheat or barley
Glyphosate-Resistant Giant Ragweed in Nebraska

Jon Scott, Weed Science Technologist
Stevan Knezevic, Integrated Weed Management Specialist

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 sugar beets. 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 relied on glyphosate 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, Spuny 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 preemergence 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 suspected 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 a suspected 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.

1. Giant ragweed resistance to glyphosate

Field experiments were conducted in 2012 and 2013 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) at three different growth stages (4”, 8”, and 12”). Weed control was assessed visually at 7, 14, and 21 days after treatment (DAT) using a scale ranging from 0 (no weed control) to 100% (complete weed control). Based on visual injury ratings, glyphosate alone dose response curves were described for 4”, 8”, and 12” tall giant ragweed (Figure 1) and ED90 (80% control) and ED90 (90% control) were determined (Table 1). The ED90 values at 21 DAT for 4”, 8”, and 12” tall giant ragweed were 307, 786, and 1316 oz/A. The resistance level was calculated by dividing ED90 (90% control) value of herbicide by respective labeled rate of 22 oz/A of glyphosate. The estimated level of glyphosate resistance for 4”, 8”, and 12” tall giant ragweed 21 DAT was 14X, 36X, and 60X, 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 for this GR giant ragweed population 14 times the label rate is required. Therefore, we confirmed that depending upon the application timing the level of resistance ranged from 14 to 60 times the label rate.
Dose response studies were described for glyphosate (22 oz/A) tank-mixed with four saflufenacil doses (0, 0.5X, 1X, 2X, and 4X) applied early postemergence (EPOST) at three different growth stages (4”, 8”, and 12”) (Figure 2). Visual weed control was estimated 7, 14, and 21 DAT. Based on visual evaluation, glyphosate + saflufenacil for control of 4”, 8”, and 12” tall giant ragweed with glyphosate at the recommended rate (22 oz/A) tankmixed with Saflufenacil for control of 4”, 8”, and 12” tall giant ragweed at 7, 14, and 21 DAT based on visual injury ratings in 2012 at David City, NE.

### Table 1: Values of ED₉₀ (80% control) and ED₉₀ (90% control) for control of 4”, 8”, and 12” tall giant ragweed with glyphosate at 7, 14, and 21 DAT.

<table>
<thead>
<tr>
<th>Weed Species</th>
<th>Height (Inch)</th>
<th>DAT</th>
<th>ED₉₀ (±SE)</th>
<th>ED₉₀ (±SE)</th>
<th>Resistance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giant Ragweed</td>
<td>4”</td>
<td>7</td>
<td>278 (50)</td>
<td>598 (156)</td>
<td>27X</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
<td>201 (21)</td>
<td>331 (52)</td>
<td>15X</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td></td>
<td>193 (36)</td>
<td>307 (88)</td>
<td>14X</td>
</tr>
<tr>
<td></td>
<td>8”</td>
<td>7</td>
<td>763 (173)</td>
<td>1879 (653)</td>
<td>85X</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
<td>423 (52)</td>
<td>662 (123)</td>
<td>30X</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td></td>
<td>398 (120)</td>
<td>786 (360)</td>
<td>36X</td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>7</td>
<td>&gt; 100X</td>
<td>&gt; 100X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
<td>380 (142)</td>
<td>825 (453)</td>
<td>38X</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td></td>
<td>641 (246)</td>
<td>1316 (762)</td>
<td>60X</td>
</tr>
</tbody>
</table>

2. Giant control with Saflufenacil and Dicamba

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 early postemergence (EPOST) at three different growth stages (4”, 8”, and 12”) (Figure 3). The dose response curves were used to estimate the ED₉₀ (80% control) and ED₉₀ (90% control) (Table 2). The ED₉₀ values at 14 DAT for 4”, 8”, and 12” tall giant ragweed were 3, 10, and 22 oz/A, respectively; and at 21 DAT the ED₉₀ values were 5, 9, and 11 oz/A for 4”, 8”, and 12” growth stage, respectively. These values indicated that all the three growth stages of GR
giant ragweed were controlled by Glyphosate + Dicamba at the label rates.

Table 3: Values of ED₈₀ (80% control) and ED₉₀ (90% control) for control of 4”, 8”, and 12” tall giant ragweed with glyphosate (22 oz/A) tankmixed with Dicamba at 7, 14, and 21 DAT based on visual injury ratings in 2012 in David City, NE.

<table>
<thead>
<tr>
<th>Weed Species</th>
<th>Height (Inch)</th>
<th>DAT</th>
<th>ED₈₀ (±SE)</th>
<th>ED₉₀ (±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giant Ragweed</td>
<td>4”</td>
<td>7</td>
<td>55 (18)</td>
<td>151 (78)</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>2</td>
<td>3 (1)</td>
<td>5 (3)</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>1</td>
<td>5 (1)</td>
<td>9 (2)</td>
</tr>
<tr>
<td></td>
<td>8”</td>
<td>7</td>
<td>127 (55)</td>
<td>424 (277)</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>4</td>
<td>10 (2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>5</td>
<td></td>
<td>9 (2)</td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>7</td>
<td>&gt; 500</td>
<td>&gt; 500</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>11</td>
<td>22 (8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>6</td>
<td>11 (2)</td>
<td></td>
</tr>
</tbody>
</table>

These results concluded that the suspected giant ragweed population was glyphosate-resistant because the labeled 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 - 60X at growth stages of 4”, 8” and 12”. From the control standpoint, glyphosate (22 oz/A) tankmixed with Dicamba provided good control of all the three growth stages at 21 DAT.

3. Early Pre Plant (EPP) control in corn

About 90% Giant ragweed population emerges in the month or April, thus we evaluated 12 EPP treatments in corn (Table 4). All treatments provided over 90% control for the first 35 days (Table 4), suggesting that giant ragweed control is possible with EPP treatments.

In addition, this early emergence pattern of Giant ragweed is actually a weakness of this weed that can be used in making effective weed management plans. This population can be effectively controlled by a simple disking and cultivation before planting the crop. Also a slight delay in crop planting to allow time for disking and cultivation would be useful.

Table 4. Giant Ragweed: EPP Control in Corn – David City.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product</th>
<th>Rate</th>
<th>Units</th>
<th>35 DAT</th>
<th>63 DAT</th>
<th>75 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Atrazine</td>
<td>2 qt</td>
<td></td>
<td>100</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>Balance Flexx</td>
<td>6 oz</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Balance Flexx</td>
<td>6 oz</td>
<td></td>
<td>97</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Atrazine</td>
<td>1 qt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Corvus</td>
<td>5.6 oz</td>
<td></td>
<td>90</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>Fierce</td>
<td>3 oz</td>
<td></td>
<td>100</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>7</td>
<td>Guardsman</td>
<td>4 pt</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>Lumax EZ</td>
<td>2.7 qt</td>
<td></td>
<td>97</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>Sharpex</td>
<td>3 oz</td>
<td></td>
<td>90</td>
<td>73</td>
<td>57</td>
</tr>
<tr>
<td>10</td>
<td>Valor</td>
<td>2 oz</td>
<td></td>
<td>93</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>11</td>
<td>Atrazine</td>
<td>1 qt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Zemax</td>
<td>2 qt</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

4. PRE and POST control in corn:

Field studies were conducted by David City, NE to evaluate commonly used PRE and POST herbicides in corn to control GR giant ragweed (Table 5). Visual estimates recorded 30 DAT indicated that applications of any of the 12 treatments provided at least 90% control. For example, PRE application of 2qt of atrazine followed by 16oz of 2,4D at V4 corn provided 100% for 60 DAT.
### Table 5. Giant Ragweed: PRE and POST Control in Corn – David City.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product (PRE)</th>
<th>Rate</th>
<th>Growth Stage</th>
<th>Product (POST)</th>
<th>Rate</th>
<th>Growth Stage</th>
<th>~30 DAT</th>
<th>~60 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Non-treated Check</td>
<td>0</td>
<td>0</td>
<td>Atrazine 2 qt</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Atrazine</td>
<td>2 qt</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Balance Flexx</td>
<td>6 oz</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Balance Flexx</td>
<td>6 oz</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Callisto 1 qt</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>0</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Corvus 5.6 oz</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>93</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Corvus 5.6 oz</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>93</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Guardsman Max 4 pt</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>93</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Lumax EZ 2.7 qt</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>94</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sharpen 3 oz</td>
<td>PRE</td>
<td>Distinct</td>
<td>6 oz</td>
<td>POST</td>
<td>69</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Verdict 16 oz</td>
<td>PRE</td>
<td>Status</td>
<td>5 oz</td>
<td>POST</td>
<td>87</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Zemax 2 qt</td>
<td>PRE</td>
<td>Status</td>
<td>5 oz</td>
<td>POST</td>
<td>89</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

LSD

All postemergence treatments included NIS and AMS; results averaged from 2 studies

### 5. PRE and POST control in soybean:

Field studies were conducted in David City, NE to evaluate commonly used PRE and POST herbicides in soybean to control GR giant ragweed (Table 6). Visual estimates recorded 30 DAT indicated that applications of any of the 12 treatments provided about 90% (Table 6). For example, PRE application of Authority First followed by a tankmix of Raptor and Ultra Blazer provided 100% for 60 DAT.

### Table 6. Giant Ragweed: PRE and POST Control in Soybean.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product (PRE)</th>
<th>Rate</th>
<th>Growth Stage</th>
<th>Product (POST)</th>
<th>Rate</th>
<th>Growth Stage</th>
<th>~30 DAT</th>
<th>~60 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Non-treated</td>
<td>0</td>
<td>0</td>
<td>Atrazine</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Authority First/Sonic</td>
<td>6.4 oz</td>
<td>PRE</td>
<td>Raptor Ulta Blazer</td>
<td>4 oz</td>
<td>POST</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Envive</td>
<td>3.5 oz</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>FirstRate</td>
<td>0.6 oz</td>
<td>PRE</td>
<td>2,4-D</td>
<td>16 oz</td>
<td>POST</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Gangster V &amp; FR Valor SX</td>
<td>2.6 oz</td>
<td>PRE</td>
<td>Raptor Ultra Blazer</td>
<td>4 oz</td>
<td>POST</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>Op Till</td>
<td>20. oz</td>
<td>PRE</td>
<td>Phoenix</td>
<td>12.5 oz</td>
<td>POST</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>Pursuit</td>
<td>4 oz</td>
<td>POST</td>
<td>Phoenix</td>
<td>12.5 oz</td>
<td>POST</td>
<td>90</td>
<td>98</td>
</tr>
<tr>
<td>8</td>
<td>Pursuit</td>
<td>4 oz</td>
<td>PRE</td>
<td>Phoenix</td>
<td>12.5 oz</td>
<td>POST</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>Scepter</td>
<td>2.8 oz</td>
<td>PRE</td>
<td>Phoenix</td>
<td>12.5 oz</td>
<td>POST</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>Sencor</td>
<td>8 oz</td>
<td>PRE</td>
<td>Phoenix</td>
<td>12.5 oz</td>
<td>POST</td>
<td>84</td>
<td>98</td>
</tr>
<tr>
<td>11</td>
<td>Valor SX</td>
<td>3.0 oz</td>
<td>PRE</td>
<td>FirstRate</td>
<td>0.3 oz</td>
<td>POST</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>Valor XLT</td>
<td>5 oz</td>
<td>PRE</td>
<td>Raptor Ultra Blazer</td>
<td>4 oz</td>
<td>POST</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

LSD

All postemergence treatments included NIS and AMS
6. **POST control in soybean:**

Field studies were conducted in David City, NE to evaluate commonly used POST herbicides in soybean to control GR giant ragweed (Table 7). Visual estimates recorded 30 DAT indicated that applications of Flexstar GT at 3.5pts/acre provided 96% control, Phoenux (12.5oz) and First Rate (0.3oz) provided only 80%.

Table 7. Giant Ragweed: POST Control in Soybean – David City.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product</th>
<th>Rate Units</th>
<th>~30 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FirstRate</td>
<td>0.3 oz</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Harmony SG</td>
<td>0.12 oz</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Classic</td>
<td>0.25 oz</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Phoenix</td>
<td>12.5 oz</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>Raptor</td>
<td>4 oz</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Ultra Blazer</td>
<td>16 oz</td>
<td></td>
</tr>
<tr>
<td>5*</td>
<td>Flexstar GT</td>
<td>3.5 pt</td>
<td>96</td>
</tr>
</tbody>
</table>

*LSD

*All postemergence treatments except 5 included NIS and AMS

**SUMMARY**

Giant Ragweed is an early emerger, thus disking and cultivation before crop planting can effectively control as much as 90% of ragweed seedlings. Many herbicides can be also utilized for EPP, PRE-POST and/or POST control.
Integrated Management of Weeds in Rangeland and Pasture

By Dr. Stevan Knezevic, IWM Specialist

Integrated weed management (IWM) has been commonly described as “a combination of mutually supportive technologies in order to control weeds”. Some have also called it “a multi-disciplinary approach to weed control utilizing the application of numerous alternative control measures”. In practical terms, it means developing a weed management program using a combination of preventive, cultural, mechanical, and chemical practices. It does not mean abandoning chemical weed control. Instead, chemical control is considered to be one of many mutually-supportive weed management options, although a reduction in herbicide use can result from implementing an IWM approach. An IWM approach advocates the use of all available weed control options such as: selection of a well adopted grass mixture with good early season vigor and appropriate disease and pest resistance; optimal plant density; mowing; use of fire and planned grazing; as well as biological and chemical control methods. A single weed control measure is not feasible due to the number of different weed species, their highly variable life cycles, and survival mechanisms. In addition, controlling weeds with only one or two methods gives weeds a chance to adapt to those practices. Therefore, instead of relying on only one or two management tools, the IWM toolbox includes a large number of options.

Below are weed control options for 5 species, including: eastern red cedar, hoary vervain, western ragweed, buckbrush and common mullein. Weed control information presented in this article is based on the data and research studies conducted by my team in Eastern, and North-Central Nebraska. Feel free to call my office with any questions.

Integrated Management of Eastern Redcedar:

Eastern redcedar (Juniperus virginiana L.) is one of 13 juniper species native to the United States. It is the most widespread tree-sized conifer and is native to every state east of the 100th meridian. Throughout this vast range, eastern redcedar grows on many soils and under varying climatic conditions. This adaptability has enhanced eastern redcedar's recent spread into areas where it was formerly rare or absent. Eastern redcedar is a dioecious species, which means individual trees are either male or female. Starting in the 6th or 7th year of growth, female trees produce small, berrylike fruits that are eaten by many birds and some small mammals, which indirectly helps spread the seed via droppings. Digestion actually improves germination.

Eastern redcedar is a problem on grasslands primarily because it reduces forage production and livestock handling. Developing trees alter the microclimate, which encourages a shift from desirable warm-season native grasses to introduced cool-season grasses such as Kentucky bluegrass. Heavy infestations make livestock handling more difficult. All these adverse effects can be reflected in lower rental rates or sale prices for infested grassland. Established infestations usually get worse over time due to overproduction of seeds and established trees et bigger, thus shading grass benight even more. On many sites complete coverage by eastern redcedar can be expected, resulting in total loss of grass production unless controlled. Control measures should be initiated as soon as possible, both to improve effectiveness and reduce total control costs.

As previously described, Nebraska's eastern redcedar infestations have developed over several decades. Likewise, management of these infestations is best viewed as a long-term or on-going effort, both to reduce the initial infestations and prevent them from redeveloping to economically damaging levels. It is best to begin treatment as soon as possible, once treatment has begun considerable time is gained to continue long-term management. The emphasis should be on management of the infestation, rather than eradication. Eradication is not economical, and probably not physically possible in most cases. Instead, it should be recognized that some remaining larger trees, which are the most difficult and expensive to kill, do little damage. In fact, at low
levels, eastern redbedars can be viewed as a potential resource, providing livestock shelter, wildlife habitat, timber products, and aesthetic values. Most important, long-term selective management is considerably less expensive than a more intensive, short-term approach.

If the goal is to just reduce overall number of trees, and stop further spreading (eg. management of wildlife habitat), it is recommended to cut female trees only. Female trees are the ones that produce berry-like fruits. This would allow “male trees” to grow and provide much needed cover for wildlife, or land beautification, while reducing further spreading.

**Manual and Mechanical control:**

Manual and mechanical control involves methods such as digging trees, cutting and mowing. It is very effective for small areas, and it is most efficient on trees up to 2 feet tall. Cutting is an effective method of control because eastern redbedar is a non-sprouter. Trees cut below the lowest branches will not regrow. A variety of handheld or motor-powered cutting tools can be used. Hand-held tools (shears, saws, spade, shovel, heavier hoe) are effective on small trees (<5ft tall), while larger trees require a chain saw or vehicle-mounted shears. The equipment varies from tractor pulled PTO driven shredders to hydraulic drive devices that mount on skid steer loaders. Most of the shredders can easily handle up to 3-4 inch stem diameter trees, while some can cut trees up to 15 inches. In general, cutting is a method that can be time consuming and labor intensive. Cutting alone also fails to remove all of the problem because fallen trees continue to occupy space. Thus, all cut trees should be gathered and burned, or permanently removed from the grassland. Mowing of short trees (<3ft tall) can be conducted using shielded mower shortly after regular cutting and haying.

**Biological control of eastern redbedar:**

Biological control is the use of natural enemies to reduce weed populations to economically acceptable levels. In the case of red cedar control, goats can be utilized as an effective bio-control agent for trees that are up to 3-4 ft tall. Experience from Nebraska suggests that most cedar trees < 24 inches tall were killed by goats utilizing paddock grazing system. The control level was reduced by 50 percent on trees 4-8 feet tall trees, however the goats managed to defoliate bottom branches and stripe bark from branches and trunks up to three inches in diameter.

Generally, goats are browsers with diets consisting of about 70% of non-grassy species, which indicates that they should not compete with cattle for grass. Goats prefer non-grassy species, but they would eat grass if no other species are available. This also suggests that goats in general can help in controlling many plant species that cattle do not eat, including various noxious weeds (eg. leafy spurge, thistles). Goat production can be also a profitable livestock enterprise that provides income through meat and milk production, and leasing fees for goat leased to control various invasive forbs and shrubs. Important factors in managing goats include the use of appropriate stocking rates and quality fencing. In essence, the number of goats needs to be adjusted to the amount of plant material needed to control.

The grazing strategy with the goats should vary depending on the management goals set for the pasture. Adding one or two goats per cow and letting the goats and cattle run together is an excellent maintenance strategy for pasture with moderate to low cedar infestation. However, if the goal is to get a quicker response and try to suppress denser stands then the area needs to be fenced off using temporary fencing. Thus per acre stocking rate should be at least 10 goats/acre of land infested. This stocking rate with moderate cedar infestation should result in significant damage to the trees within 30 days. Higher stocking rates would be better, but will require moving the fence more often. Trees and other perennial plants have high energy reserves in their root systems and repeated defoliation over a few years is required to control them. Cedar trees however, will not resprout and thus, if the goats remove most of the needles and/or bark, the tree will eventually die. Other issues that need to be addressed before getting goats may include predator control (eg. coyotes) and perhaps learning how to raise goats for meat production. A good place to start is at the ATTRA - National Sustainable Agriculture Information Service web site. The page “Goats: Sustainable Production Overview,
Livestock Production Guide”

http://www.attra.org/attra-pub/goatoverview.html has information on numerous topics relating to meat goat production.

Many ranchers in other parts of the US have run cattle and goats together for decades. They view goats both as a profitable part of their business and as a very important part of their grazing land management program.

Use of prescribed fire for redcedar control:

This method is inexpensive and very effective against smaller trees. Its effectiveness declines as tree size increases, however there were cases of successful burning of tall trees. Adequate fine fuel (usually, last year's dead grass) is necessary for satisfactory results. Safety also is a concern since many managers lack experience with fire and the equipment required to conduct fires.

The controlled use of fire is a large subject in itself. It is beyond the scope of this publication to provide detailed instruction on conducting prescribed fires. Two other Nebraska Extension publications provide information on the use of fire in general and on how to safely conduct fires. They are NebGuide G88-894, Grassland Management with Prescribed Burning, and Extension Circular 90-121, Conducting a Prescribed Burn. A fire plan should be prepared and a prescribed-burning permit obtained from the local fire jurisdiction, as required by state law. Specialized fire equipment can be purchased. Two sources are the Ben Meadows Company, 3589 Broad St., Chamblee, GA 30341; and Forestry Suppliers, Inc, Box 8397, Jackson, MS 39284-8397.

Chemical control of eastern redcedar:

Herbicides can also be considered for control of this tree species, however, they should be viewed as just another tool in the integrated management program. Depending on the application method and chemical type, the use of herbicides can be time consuming and expensive, especially when used on denser tree infestations or large tracts of land. Effectiveness also is variable depending on the tree size and label directions and/or restrictions. Therefore, always read and follow herbicide label directions. Herbicide information on control of troublesome plant species, including eastern cedar, is update annually in the Guide for Weed Management in Nebraska (EC-130). In general, herbicides for eastern redcedar control can be used for broadcast application or individual-tree spraying.

Broadcast treatments:

Broadcast application is the most common method of applying herbicides in agricultural settings. The key message for the efficacy of broadcast treatments in eastern redcedar control is: “the shorter the tree the better control”.

Since tree height was the most important factor influencing the level of chemical control (tree injury) with broadcast treatments, the herbicide efficacy data from Nebraska study was categorized by tree height (Table 1). Recommended herbicides for trees that are up to two feet tall include: Surmount, Grazon P&D and Tordon (Table 1). However, the same herbicides will not provide satisfactory control of trees taller than 2 ft, indicating the importance of tree height. Surmount at the rate of 5pts/acre can also cause short-term grass injury in the form of leaf yellowing and top growth burning (Table 1). Cost of Grazon P+D and Tordon 22 K for broadcast applications can range from $21-$26 per acre. Since Surmount is not marketed product yet, its costs is not known.

Individual-tree treatments:

Individual-tree treatments can be applied directly to the tree foliage or to the soil around tree base. Soil treatments can minimize the amount of herbicide used and the exposure to non-target species. However, soil treatments may not be effective unless applied before rainfall, preferably in Spring or Fall. Rain water is needed to move the herbicide into the root zone allowing an easier uptake by a tree. Recommended herbicides for soil application around tree base include Tordon 22K at the rate of 1 cc (ml) per every foot of tree height, Velpar-L at 4 (cc) ml and Spike 20P at 1cc (ml) per every inch of tree diameter. Cost of Tordon is about $85 per gallon, Velpar is about
$65 per gallon and Spike 20P is about $9 per pound of product.

Individual-tree foliage can be also treated with various herbicides (Figure 8). Based on a study conducted in northeastern Nebraska, recommended herbicides for control of 2-10 feet tall trees include Surmount at 1.5% volume per volume (v/v), Grazon P+D at 2.0% (v/v) and Tordon 22K at 1.0% v/v (Table 2).

To help you determine volume per volume basis, for example, the 1% v/v equals 1 gal of product per 100 gallon of water. For smaller back pack sprayers use an equivalent of 1.3 oz of product per every gallon of water. Apply about 1.5 oz of the herbicide spray solution per every foot of tree height. Walk around the tree and just spray enough solution just to get a glisten (shine) on the canopy surface. Solution dripping off the canopy indicates a rate that is too high, and a likely waste of time and money. As an example, it was calculated that 1 gallon of spray solution could cover 15 individual trees that are 6 feet tall at a pressure of 20 PSI and a single nozzle type XR8002.

Grass injury in the form of temporary yellowing and burning of top growth was evident among all treatments especially for Tordon 22K. Roundup is not recommended for use in pasture settings due to poor activity on cedar trees and high injury level to the grass (Table 2). Cost of Grazon P+D and Tordon 22K can ranged from $11-$16 per acre.

Practical hint for chemical control:

Use of selective herbicide treatments should be based on a tree height. Broadcast treatments are effective only on short trees (up to 2-ft tall), while the medium height trees (2 to 10 ft) can be controlled with individual-tree treatments. For broadcast treatments use 6-8 pints of Grazon P&D or 4-5pts of Surmount in a 20 gallon of water per acre. To prepare 1 gall of spray solution for individual-tree canopy treatments use 1.3 oz of Tordon, or 2.6 oz of Grazon P&D, or 2oz of Surmount. For larger spray tanks adjust herbicide rates accordingly.

Take home message:

Since there are many different scenarios under which eastern redcedar trees grow, they obviously can not be managed by a single IWM control method; however, if the methods are implemented in a systematic manner, significant advances in eastern redcedar control can be achieved. Obviously you can not use all of the above described techniques at once. We recommend to use the best combination of techniques for your needs. There are many ways to start developing an IWM program. The easiest start will be to try a one or two techniques and then add more practices as the time goes on or the field conditions change. Cost of control methods can also vary thus choose the operation that can fit your budget the best.

We recommend to use tree-height as a determining factor for control options. There are many control options for trees that are up to 2 feet tall, which may include: cutting, pulling, digging, mowing, burning, use of goats and broadcasts herbicide application. Trees that are 2-10 feet tall can be controlled effectively by cutting and individual-tree herbicide treatments of soil or foliage. Trees that are over 10 ft in height are the most effectively and economically controlled by cutting. Therefore, in order to save time and labor expenses the main take-home message is to “control redcedar trees while they are small”.
Table 1: Percent eastern redecad control a and grass injury levels at about 100 days after treatment as influenced by the tree height (feet) where herbicide treatments were broadcast applied.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product</th>
<th>Dose</th>
<th>Tree Height (ft)</th>
<th>Grass Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>pt/acre</td>
<td>0 to 1</td>
<td>1 to 2</td>
</tr>
<tr>
<td>1</td>
<td>Surmount</td>
<td>4</td>
<td>84</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Surmount</td>
<td>5</td>
<td>95</td>
<td>81</td>
</tr>
<tr>
<td>3</td>
<td>Grazon P &amp; D</td>
<td>6</td>
<td>90</td>
<td>59</td>
</tr>
<tr>
<td>4</td>
<td>Grazon P &amp; D</td>
<td>8</td>
<td>95</td>
<td>79</td>
</tr>
<tr>
<td>5</td>
<td>Tordon 22K</td>
<td>2</td>
<td>85</td>
<td>65</td>
</tr>
</tbody>
</table>

-Treatments 1, and 2, were mixtures of picloram + fluroxypyr each at 0.66 lbs ae/gal,
-Treatments 3 and 4 were picloram at 0.54 lbs ae/gal + 2,4-D at 2.0 lbs ae/gal,
-Treatment 5 was picloram at 2.0 lbs ae/gal.

Table 2: Percent of eastern redecad and grass injury at 100 days after treatment that were applied to individual-trees.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product</th>
<th>Dose v/v</th>
<th>Tree Injury</th>
<th>Grass Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>1</td>
<td>Surmount</td>
<td>1.0</td>
<td>75</td>
<td>39</td>
</tr>
<tr>
<td>2</td>
<td>Surmount</td>
<td>1.5</td>
<td>89</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>Grazon P &amp; D</td>
<td>2.0</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Tordon 22</td>
<td>1.0</td>
<td>94</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Roundup Ultra</td>
<td>1.0</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td>6</td>
<td>Roundup Ultra</td>
<td>2.0</td>
<td>31</td>
<td>91</td>
</tr>
</tbody>
</table>

-Treatments 1, and 2, were mixtures of picloram + fluroxypyr each at 0.66 lbs ae/gal,
- Treatment 3 was picloram at 0.54 lbs ae/gal + 2,4-D at 2.0 lbs ae/gal,
- Treatment 4 was picloram at 2.0 lbs ae/gal.
- Treatment 5 and 6 were glyphosate at 3.7 ae/gal.
- Dose was a herbicide/water solution on a volume/volume basis.

Biology and Control of Western Ragweed:

Western ragweed (Ambrosia psilostachya) is a commonly found native weed in northeastern Nebraska’s rangeland, prairies and disturbed sites in all soil types. It is a perennial forb from the sunflower family (Asteraceae) that reproduces both by seeds and rhizome. Rhizome is a horizontal creeping root system growing within top 5-10 inches from soil surface. The plants usually grow in sparse groups (patches or clusters). Stem is very erect, up to 3 ft tall, with many branches and long hairs giving the stem a coarse feeling. Leaves are alternate on the upper part of the stem, opposite on the bottom, with many divisions and teeth. Like many other plant species, the overall growth and development depends on the amount and timing of rainfall. Western ragweed, in Nebraska, can flower from July to October, with greenish-yellow flowers positioned on the top of the main stem and branches, and produces an inch long bur-like fruits with a single seed within each bur.

Western ragweed provides forage for deer and the fruits are an important food source for upland game-birds, wild turkeys and songbirds. Native Americans also made a tea from the whole plants to treat colds and cramps. Western ragweed has almost no value to livestock because of its low palatability. With other forage limited, it may be eaten. Pollen produced in late summer causing late summer hay fever in many people, due to presence of volatile oils, which can also cause skin irritation.
Due to its low value for livestock forage, it is a concern to livestock producers and ranchers. This weed can be controlled by various means. Mowing the plants when they are 4-6 inch tall can reduce ragweed population considerably for the season. Mowing can be done one or two times per season depending on the amount of rainfall during the season. One mowing done in mid June is effective if the season is dry, due to lack of moisture needed for weed regrowth. If the season is wet, an additional mowing is needed in July-August. Herbicides can be also very effective in providing season long control. Herbicide application should be conducted when ragweed plants are 3-5 inches tall. The list of effective herbicides and their rates per acre includes: Salvo (12 oz/acre), 2,4-D-Ester (1qrt/acre), Grazon P+D (32 oz/acre), Weedmaster (32oz/acre), Ally or Cimarron (0.25oz/acre), and Vista (22 oz/acre).

**Biology and Control of Common Mullein:**

Common mullein (*Verbascum thapsus*) is a weed species on the increase in northeastern Nebraska’s rangeland, woodland, and pastures. It is a biennial plant that reproduces only by seeds, but it is a prolific seed producer. Taproot of this species can access soil moisture from a deeper profile at much better rate than fibrous roots of pasture grasses, giving common mullein the competitive advantage over grass, especially during dry years.

Common mullein usually starts growing sparsely as individual plants and then spreads further if not controlled. A cluster of leaves, commonly known as a rosette, with a thick hair cover is a distinct identifying feature of this species. Stem is also woolly, erect, 2-6 ft tall, with no branches. Leaves are opposite, elliptic to ovate. Like many other plant species, the overall growth and development depends on the amount and timing of rainfall. Common mullein, in Nebraska, can flower in June and July, with yellowish flowers, and it has no value to livestock because of its low palatability.

Ranchers need to control this species because heavy stands can reduce grass production as much as 50%, especially in dry years, and the common mullein plants have no value for livestock forage. This weed can be controlled by various means. The best strategy is to control while the density is low. Density of this species can easily expand from few to hundreds plants per acre just over couple of years due to prolific seed production. Sparse populations can be controlled by mechanical removal using a spade or shovel in late April and early May. Individual plants can be dug out or cut just at the soil surfaces as long as whole rosette is removed. Single mowing of new 1-2 feet tall plants can reduce population and seed production for the season, especially in dry years. Herbicides can be also effective tools in providing season long control. However, one thing to note is that a thick wooly coat of hairs on the leaves can reduce herbicide uptake and level of control. Herbicide application should be conducted when the rosette has 6-12 leaves, before the stem starts to grow, which is usually in May. The list of effective herbicides and their rates per acre includes: Grazon P+D (3-4 pints/acre), Cimarron (0.75-1 oz/acre), and a 3-way-mix of Cimarron (0.5oz ) with Glean (0.5oz) and RangeStar (32 oz). Make sure to use enough additives such as Crop Oil at 1-2 q/acre to help herbicide penetrate the thick wooly coat.

**Biology and Control of Hoary Vervain:**

Hoary vervain (*Verbena stricta*), also known as wooly verbena or tall vervain, is a commonly found native weed in northeastern Nebraska’s on over-grazed rangeland, prairies and disturbed sites in all soil types. There are several other types of vervain in Nebraska (prostrate, white, and blue), of which most have similar growth forms and habits as hoary vervain. Hoary vervain is a perennial forb from the vervain family (*Verbenaceae*) that reproduces by seeds. The taproot (perennial structure) produces individual erect plants. Stem is nearly round, simple or branched above and can be up to 5 ft tall, covered with soft white hairs. Leaves are opposite, leaf blades are ovate with many teeth. Lower surface is pubescent with highly visible veins. Like many other plan species, the overall growth and development depends on the amount and timing of rainfall. Hoary vervain, in Nebraska, can flower from May to September, with blue or purple flowers positioned on the top of the main stem and branches and producing a two seeded fruit.

Hoary vervain provides forage for deer while seeds are important food source for small mammals and upland birds. Native Americans also made a tea from the leaves to treat stomachache. Hoary vervain has no value to livestock because of its low palatability.

This weed can be controlled by various means. Mowing the plants when they are 3-5 inches tall can reduce vervain population considerably for the season. Mowing can be done one or two times per season depending on the amount of rainfall during the
season. One mowing done in mid June can be effective (>75% control) if the season is dry, due to lack of moisture needed for weed regrowth. If the season is wet, an additional mowing is needed in July-August. Herbicides can be also very effective in providing a season long control. Herbicide application should be conducted when vervain plants are 3-5 inches tall, which is usually in early part of June. The list of effective herbicides, their rates and cost per acre includes: Salvo (12 oz/acre, $4), Grazon P+D (32 oz/acre, $8), Weedmaster (32oz/acre, $6), Ally or Cimarron (0.25oz/acre, $6), and Vista (22 oz/acre, $8).

Biology and Control of Buckbrush:

Buckbrush (Symphoricarpos orbiculatus) is a commonly found native weed in northeastern Nebraska’s rangeland, woodland, ravines and along streams. It is a perennial forb that reproduces both by seeds and rhizome. Rhizome is a horizontal creeping root system growing within 2-12 inches of top soil. Rhizome can access soil moisture from a deeper profile at much better rate than fibrous roots of pasture grasses, giving buckbrush the competitive advantage over grass, especially during dry years.

Buckbrush plants usually start growing in sparse groups (patches or clusters) and then spread further if not controlled. Stem is erect, 2-6 ft tall, brownish, somewhat smooth, with many branches. Leaves are opposite, elliptic to ovate with pointed tips. Like many other plant species, the overall growth and development depends on the amount and timing of rainfall.

Buckbrush, in Nebraska, can flower from July to August, with greenish-white to purple flowers. Buckbrush can provide forage for deer early in the season, while the fruits are an important food source for upland game-birds, wild turkeys and songbirds. Buckbrush has no value to livestock because of its low palatability.

Ranchers need to control this species because heavy stands of buckbrush can reduce grass production as much as 80%, especially in dry years, and the buckbrush plants have no value for livestock forage. This weed can be controlled by various means. Goats and sheep can reduce the stands of buckbrush considerably if kept confined in the area. Single mowing of new 1-2 feet tall plants can also reduce buckbrush population, especially in dry years. Additional mowing will be needed in wet years.

Mowing can also help remove previous years growth to prepare the site for broadcast applications of herbicides. Herbicides are the most effective tools in providing season long control. Herbicide application should be conducted when the new growth is 6-12 inches tall. The list of effective herbicides and their rates per acre includes: 2,4-D-Ester (2-3 qrt/acre), Grazon P+D (1-2 qrt/acre), Telar (1.0 oz/acre); mix of Cimarron (0.25oz ) with WeedMaster (16 oz); mix of Cimarron (0.25oz/acre) with RangeStar (16 oz/acre), and Cimarron (Ally, Escort) used alone at 0.5oz/acre.
HPPD-Resistant Waterhemp in Nebraska

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. For example, in the United States, waterhemp was among the first weed species identified with multiple resistance. There has been confirmed report of a 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 (Patzoldt et al. 2002); and glyphosate (EPSP Synthase inhibitors–Group 9 herbicides), ALS, and PPO-inhibiting herbicides (Lepleiter and Bradley 2008). 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.

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 23 confirmed cases of glyphosate-resistant weeds in the last 10 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-k要想ial (horseweed), giant ragweed, waterhemp, 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 (Carotenoid Biosynthesis inhibitors–Group 27 herbicides) 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 that mode of action. Resistance occurred in a seed corn production system where HPPD-inhibiting herbicides were repeatedly used for the last five years. This basically gives us evidence that waterhemp can develop resistance to any herbicide used extensively for its control. 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 2013 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. Dose response curves were developed for POST applications of HPPD-inhibiting herbicides e.g. Callisto (mesotrione), Laudis (tembotrione), and Impact (topramezone) and PREapplications 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 Callisto (Mesotione) rates (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_{50} (80% control) and ED_{80} (90% control) were determined (Table 1). The ED_{50} values at 6, 13, and 23 DAT were 47, 39, and 39 oz/A, respectively.
Table 1. Values of ED₈₀ (80% control) and ED₉₀ (90% control) for control of 3-inch tall waterhemp with Callisto at 6, 13, and 23 DAT based on visual ratings in 2011.

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Height (Inch)</th>
<th>DAT</th>
<th>ED₈₀ (±SE)</th>
<th>ED₉₀ (±SE)</th>
<th>Resistance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterhemp</td>
<td>3&quot;</td>
<td>6</td>
<td>18 (3)</td>
<td>47 (14)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>21 (3)</td>
<td>39 (9)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>17 (6)</td>
<td>39 (21)</td>
<td>13</td>
</tr>
</tbody>
</table>

The resistance level was calculated by dividing ED₉₀ (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 ED₅₀, ED₆₀, ED₇₀, and ED₈₀ values for control of 6-inch (Table 2) and 12-inch (Table 3) tall waterhemp. The ED₅₀ 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 ED₈₀ values were not calculated due to lack of high enough rates of herbicide to provide 90% control. ED₅₀ is an effective dose that provides 50% weed control, while ED₈₀ provides 80% control. The effective doses were compared and the resistance level was determined by dividing ED₈₀ (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 for 6-inch tall waterhemp to Callisto, Laudis and Impact was 13X, 10X and 7X, respectively (Table 2).

In 12-inch tall waterhemp, ED₅₀, ED₆₀, and ED₇₀ 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 ED₇₀ 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.

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.

Table 2. Values of ED₅₀ (50% control), ED₆₀ (60% control), and ED₇₀ (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.

<table>
<thead>
<tr>
<th>Weed Species</th>
<th>Height (Inch)</th>
<th>DAT</th>
<th>ED₅₀ (±SE)</th>
<th>ED₆₀ (±SE)</th>
<th>ED₇₀ (±SE)</th>
<th>Resistance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterhemp</td>
<td>6&quot;</td>
<td>13</td>
<td>9 (1)</td>
<td>14 (2)</td>
<td>38 (4)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>10 (1)</td>
<td>16 (2)</td>
<td>44 (6)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>9 (2)</td>
<td>14 (2)</td>
<td>39 (6)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>6&quot;</td>
<td>13</td>
<td>4 (1)</td>
<td>7 (1)</td>
<td>21 (7)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>5 (1)</td>
<td>8 (2)</td>
<td>27 (16)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>7 (1)</td>
<td>11 (2)</td>
<td>31 (6)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>6&quot;</td>
<td>13</td>
<td>0.6 (0.2)</td>
<td>1 (0.2)</td>
<td>4 (0.7)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>1 (0.1)</td>
<td>2 (0.1)</td>
<td>4 (0.4)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>2 (0.2)</td>
<td>3 (0.3)</td>
<td>7 (2)</td>
<td>7</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Weed Species</th>
<th>Height (Inch)</th>
<th>DAT</th>
<th>ED$_{50}$ (±SE)</th>
<th>ED$_{60}$ (±SE)</th>
<th>ED$_{70}$ (±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterhemp</td>
<td>12''</td>
<td>14</td>
<td>19 (4)</td>
<td>37 (13)</td>
<td>75 (37)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>31 (7)</td>
<td>57 (17)</td>
<td>112 (45)</td>
</tr>
<tr>
<td></td>
<td>12''</td>
<td>14</td>
<td>4 (0.5)</td>
<td>9 (1)</td>
<td>21 (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>9 (1)</td>
<td>20 (2)</td>
<td>49 (6)</td>
</tr>
<tr>
<td></td>
<td>12''</td>
<td>14</td>
<td>1 (0.1)</td>
<td>2 (0.3)</td>
<td>4 (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>2 (0.3)</td>
<td>4 (1)</td>
<td>9 (1)</td>
</tr>
</tbody>
</table>
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 metolachlor for the initial 20 days. However, as the metolachlor activity diminishes, the rating of waterhemp 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.

**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.**

<table>
<thead>
<tr>
<th>Weed Species</th>
<th>DAT</th>
<th>ED$_{50}$ (±SE)</th>
<th>ED$_{60}$ (±SE)</th>
<th>ED$_{80}$ (±SE)</th>
<th>Resistance level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Callisto (oz/A)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterhemp</td>
<td>20</td>
<td>9 (2)</td>
<td>14 (3)</td>
<td>48 (16)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>12 (2)</td>
<td>16 (2)</td>
<td>39 (8)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>20 (2)</td>
<td>27 (3)</td>
<td>62 (14)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>32 (7)</td>
<td>50 (15)</td>
<td>147 (78)</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Callisto in a tankmix (oz/A)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1 (0.4)</td>
<td>2 (0.6)</td>
<td>8 (2)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.5 (1)</td>
<td>4 (1)</td>
<td>17 (6)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>6 (2)</td>
<td>11 (3)</td>
<td>45 (12)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>20 (4)</td>
<td>30 (7)</td>
<td>82 (35)</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lumax (qt/A)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1.7 (0.2)</td>
<td>2 (0.2)</td>
<td>3.9 (0.4)</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2 (0.2)</td>
<td>3 (0.2)</td>
<td>4.3 (0.4)</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>3 (0.4)</td>
<td>4 (0.4)</td>
<td>6 (1)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>6 (1)</td>
<td>8 (1)</td>
<td>17 (3)</td>
<td>6</td>
</tr>
</tbody>
</table>
Study 3: Control of HPPD-resistant waterhemp in corn

Different combinations of PRE (Table 5), POST (Table 6), and PRE followed by POST (Table 7) herbicides were evaluated to control HPPD-resistant waterhemp.

PRE tankmixes of Lumax (2.7qt/A)+Harness (1.5 pt/A); Corvus (5.6oz)+atrazine (1.6qts), and Zidua (2.5 oz/A)+Sharpen (3oz/A)+Atrazine (1pt) provided excellent PRE control, > 90% for 41 DAT (Table 5).

Table 5. Visual estimates (% control) at 31, 41, and 61 DAT with PRE herbicides.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product</th>
<th>Rate Units</th>
<th>31 DAT</th>
<th>41 DAT</th>
<th>61 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lumaz EZ Harness</td>
<td>2.7 qt/A 1.5 pt/A</td>
<td>100</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>2</td>
<td>Corvus Atrazine</td>
<td>5.6 oz/A 1.6 qt/A</td>
<td>94</td>
<td>92</td>
<td>88</td>
</tr>
<tr>
<td>3</td>
<td>Zidua Sharpen Atrazine</td>
<td>2.5 oz/A 3 oz/A 1 pt/A</td>
<td>100</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>4</td>
<td>Verdict Outlook Atrazine</td>
<td>15 oz/A 3 oz/A 1 oz/A</td>
<td>97</td>
<td>92</td>
<td>86</td>
</tr>
<tr>
<td>5</td>
<td>Zidua Verdict</td>
<td>4 oz/A 4.5 oz/A 2 pt/A</td>
<td>85</td>
<td>63</td>
<td>57</td>
</tr>
<tr>
<td>6</td>
<td>Zidua Verdict</td>
<td>5 oz/A</td>
<td>96</td>
<td>87</td>
<td>73</td>
</tr>
<tr>
<td>7</td>
<td>Zidua Verdict</td>
<td>4 oz/A</td>
<td>95</td>
<td>91</td>
<td>87</td>
</tr>
<tr>
<td>8</td>
<td>Surestart</td>
<td>2.5 pt/A</td>
<td>98</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>9</td>
<td>Anthem ATZ</td>
<td>32 oz/A</td>
<td>97</td>
<td>86</td>
<td>87</td>
</tr>
</tbody>
</table>

For POST control, several treatments provide excellent 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 (20oz) provided also excellent control (>90%) at 41 DAT.

Table 6. Visual estimates (% control) at 12, 29, and 41 DAT with POST herbicides.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product</th>
<th>Rate Units</th>
<th>12 DAT</th>
<th>29 DAT</th>
<th>41 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Touchdown Total AMS</td>
<td>36 oz/A 17 lb/100 gal</td>
<td>97</td>
<td>93</td>
<td>96</td>
</tr>
<tr>
<td>2</td>
<td>Callisto Extra Liberty Atrazine</td>
<td>20 oz/A 29 oz/A 17 lb/100 gal</td>
<td>99</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>Tricor Callisto Extra Atrazine COC AMS</td>
<td>4 oz/A 20 oz/A 1 % v/v 17 lb/100 gal</td>
<td>93</td>
<td>91</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>Callisto Cadet Atrazine AMS</td>
<td>3 oz/A 0.9 oz/A 17 lb/100 gal</td>
<td>55</td>
<td>33</td>
<td>42</td>
</tr>
<tr>
<td>5</td>
<td>Status Callisto Atrazine COC AMS</td>
<td>5 oz/A 20 oz/A 1 % v/v 17 lb/100 gal</td>
<td>90</td>
<td>92</td>
<td>93</td>
</tr>
</tbody>
</table>

In PRE followed by POST applications, we evaluated 15 tankmix options (Table 7). Most treatments provided 80-100% control for 30 DAT after PRE or POST application (see Table 7 for various combinations of herbicides).

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.
Table 7. Visual estimates (% control) at 31 Days after PRE treatment and 18 and 29 days after POST treatment of herbicide products applied to control HPPD-resistant waterhemp.

<table>
<thead>
<tr>
<th>ID</th>
<th>Product (PRE)</th>
<th>Rate</th>
<th>Units</th>
<th>Growth Stage</th>
<th>Product (POST)</th>
<th>Rate</th>
<th>Units</th>
<th>Growth Stage</th>
<th>18 DAT</th>
<th>29 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lumax EZ</td>
<td>2.7 qt/A</td>
<td>PRE</td>
<td>100</td>
<td>Status</td>
<td>5 oz/A</td>
<td>POST</td>
<td></td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>Aatrex</td>
<td>1.93 pt/A</td>
<td>PRE</td>
<td></td>
<td>Aatrex</td>
<td>0.8 pt/A</td>
<td>POST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harness</td>
<td>1.5 pt/A</td>
<td>PRE</td>
<td></td>
<td>COC</td>
<td>1 % v/v</td>
<td>POST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Corvus</td>
<td>5.6 oz/A</td>
<td>PRE</td>
<td>97</td>
<td>Status</td>
<td>5 oz/A</td>
<td>POST</td>
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LSD
List of References

Glyphosate-Resistant Waterhemp

Amit Jhala, Extension Weed Management Specialist
Lowell Sandell, Weed Science Extension Educator

Greenhouse Dose Response

University of Nebraska-Lincoln greenhouse studies have confirmed glyphosate resistance in common waterhemp from six Nebraska counties: Antelope, Dodge, Lancaster, Pawnee, Seward, and Washington. Waterhemp, a summer annual broadleaf weed, was already one of the most problematic weeds in corn and soybean production, but glyphosate resistance adds a new wrinkle to its control. Glyphosate-resistant common waterhemp has been confirmed in 12 states over the last eight years.

In 2012 UNL weed scientists fielded several phone calls from growers about control failures of common waterhemp despite the repeated application of glyphosate. In fall 2012 common waterhemp seeds were collected from fields in selected counties (Antelope, Dodge, Lancaster, Pawnee, Seward, and Washington) and glyphosate dose response studies were conducted in a UNL greenhouse. Glyphosate (Touchdown HiTech) was applied at several rates (0.25x to 16x the recommended rate of 24 fl oz/acre) with appropriate adjuvants to confirm the level of resistance in these common waterhemp populations.

Dose response analysis was performed to estimate the ED50 (effective dose required to control 50% population) and ED90 (effective dose required to control 90% population) values for each common waterhemp population. Comparisons of dose response curves clearly showed glyphosate resistance at a minimum of six times the normal rate (shown as 6x) at the ED90 value (Table 1). For example, 90% control of glyphosate-susceptible common waterhemp was achieved with a labeled rate of glyphosate (24 fl oz/acre); while the population from Antelope County needed a minimum of 147 fl oz/acre or about six times the recommended rate. In some cases, as much as 599 fl oz/acre (25x) of glyphosate was required to achieve 90% control (Table 1). Overall results suggested that the level of resistance was 6x to 25x in samples collected from Antelope, Dodge, Lancaster, Pawnee, Seward, and Washington County. Regardless of whether glyphosate-resistant common waterhemp is present in a given county in Nebraska, there is a good chance it will evolve resistance at some point based upon what has happened in other states.

Field Dose Response

An in-field glyphosate dose response study was conducted on a glyphosate-resistant waterhemp site near Fremont, NE in 2013. The Dodge County seed used in the greenhouse dose response study (Table 1) was from the site near Fremont, NE in which the in-field dose response was conducted.

Glyphosate was applied at six rates (0, 0.5x, 1x, 2x, 4x and 8x the suggested label use rate) on two plant heights (10cm and 20cm). Visual injury was evaluated at 28 and 56 days after treatments (Figures 1 and 2). The level of resistance at the ED50 and ED90 were similar between the greenhouse results at 21 DAT for the Dodge Co population and the in-field response of the plants in the 20cm application timing at 28 DAT (Tables 1 and 2).

Waterhemp Biology

The extended germination window of common waterhemp (May to August), increase in no-tillage crop production, and ability of waterhemp to evolve resistance to herbicide(s) have contributed to success of this weed species. Furthermore, it is a dioecious species, which means male and female flowers occur on separate plants and reproduction requires pollen movement. Resistance genes can be spread long distances via pollen and outcrossing.

A member of the pigweed family, common waterhemp is a competitive weed and the evolution of glyphosate resistance means it will require an effective integrated weed management program to achieve acceptable control. Continuing to rely only on glyphosate will only speed up the evolution of glyphosate-resistant weeds and diminish the effectiveness of glyphosate-based crops and weed control programs.

Waterhemp Management Considerations

Control of glyphosate-resistant waterhemp will require an integrated approach including:

- residual herbicides with different modes of action followed by labeled post-emergence herbicides other than glyphosate throughout the cropping system,
- crop rotation, and
- a combination of tillage systems.

When combined, these efforts will help slow the evolution of new glyphosate-resistant weed populations in Nebraska.

The confirmation of glyphosate-resistance in Nebraska waterhemp is further evidence of an ever-evolving weed spectrum, and further proof that using only glyphosate for weed control in corn and soybean is not a sustainable approach to weed management. In the face of herbicide selection pressure, common waterhemp has repeatedly proven to be an ecological survivor. In Nebraska, common waterhemp populations resistant to ALS (Pursuit), triazine (Atrazine), growth regulator (2,4-D), HPPD (Callisto), and now glyphosate (Roundup) have been confirmed. The common denominator in all instances...
where resistance evolved was near continuous use of the same or similar herbicide management approach with little or no diversity in herbicide mode of action used for many years.

Glyphosate-resistant weeds continue to be an increasing problem in Nebraska. Glyphosate-resistant marestail (horseweed), kochia, and giant ragweed previously were confirmed in Nebraska and have become very problematic in certain areas of the state. The confirmation of glyphosate-resistant common waterhemp will be an additional challenge to Nebraska growers. Resistance to any herbicide mode of action is troubling, but multiple-resistance (resistance in a weed population to more than one herbicide mode of action) is of particular concern. Common waterhemp populations with resistance to multiple herbicides have been confirmed in Iowa and Illinois. This resistance stacking is alarming and limits herbicide options for managing common waterhemp.

Table 1: Values of ED50 and ED90 and the level of resistance for common waterhemp populations based on a visual control estimates at 21 days after treatment in a dose response study with glyphosate (Touchdown HiTech) in greenhouse a.

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<th>ED90</th>
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<td>147</td>
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<td>Washington</td>
<td>32</td>
<td>1.33x</td>
<td>440</td>
<td>18x</td>
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aAbbreviations: ED50, effective dose required to control 50% population; ED90, effective dose required to control 90% population.
bResistance level at the ED50 and ED90 was calculated by dividing the ED50 and ED90 value of resistant population by recommended rate of glyphosate (1x use rate= 24 fl oz/acre of Touchdown HiTech).

Figure 1. In-field glyphosate dose response of waterhemp at Fremont, NE 2013. 28 DAT.
Figure 2. In-field glyphosate dose response of waterhemp at Fremont, NE 2013. 56 DAT.

Table 2. ED50 and ED90 values from an in-field glyphosate dose response trial near Fremont, NE 2013.

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<tr>
<td><strong>28DAT</strong></td>
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<tr>
<td>ED50</td>
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<td>0x*</td>
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<tr>
<td>ED90</td>
<td>1846 (278)</td>
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* Resistance level based on a standard field use rate of 840 gr ae/ha.
Glyphosate-resistant Horseweed (Marestail) on the Increase in NE and USA

Stevan Knezevic, Integrated Weed Management Specialist
Greg Kruger, Cropping System Specialist

Weed resistance to herbicides is not a new thing. It began to occur as soon as man started using chemicals for weed control. One of the earliest cases of weed resistance occurred about 50 years ago in pigweed species showing resistance to atrazine. There is well documented literature about weed resistance. For example, 40 dicot and 15 monocot species are known to have biotypes resistant to triazine herbicides. Also, at least 50 weed species have been reported to have biotypes resistant to one or more of 15 other herbicides, or herbicide families (www.weedscience.com). Repeated use of the same herbicide was the main reason for weed resistance to herbicides worldwide.

The widespread use of glyphosate-tolerant crops resulted in repeated use of the same glyphosate alone to control weeds, creating a single selection pressure on weed populations. Therefore, special attention should be given to proper management of herbicide tolerant crops to avoid the evolution of glyphosate-resistant weed populations. Prior to the introduction of glyphosate-tolerant crops there were only few weed species known to have evolved resistance to glyphosate worldwide. Resistance resulted from repeated glyphosate applications in species such as rigid ryegrass (Lolium rigidum) in Australia and California and goosegrass (Eleusine indica) in Malaysia. However, the number of glyphosate-resistant weeds increased to 11 in just over 10 years of repeated glyphosate use over a much larger land area (>100 million acres) due to introduction of Roundup-Ready technology in North America. Current examples of glyphosate-resistant weeds in the US include: waterhemp (Amaranthus rubis Sauer), horseweed (marestail) (Conyza canadensis), giant ragweed (Ambrosia trifida), common ragweed (Ambrosia artemisiifolia), kochia (Kochia scoparia), and Palmer amaranth (Amaranthus palmeri). These weeds are found in various parts of the Midwest, the main corn and soybean producing regions in the US.

Horseweed (marestail) was the first weed species exhibiting resistance to glyphosate in our state. It should not be surprising as there are many populations of horseweed with various levels of resistance to glyphosate in at least 15 other states in the US.

Here is an example of the results from a greenhouse study of a suspected case of glyphosate resistance from 2005. The objective of the study was to develop dose response curves for glyphosate on five horseweed populations, and from those curves to determine the ED_{50} dose (dose needed to provide 90% weed control) and to compare the level of resistance between populations.

Horseweed seed was collected from five populations, of which three were from Nebraska and two were from Indiana. The seed for the susceptible population (control) was obtained from a local pasture field that has never been sprayed with glyphosate. The 2nd population was collected from the UNL-ARDC bulk farm acres which were in a rotation of glyphosate-resistant soybean and conventional corn for five years. The 3rd population was collected from a private farm in the Ashland area where a field had several years of glyphosate-resistant soybean and glyphosate-resistant corn in rotation. The seed from two populations from Indiana were obtained through a weed survey conducted by Dr. Bill Johnson, Purdue University.

A herbicide bioassay was conducted in a greenhouse facility where a total of eight glyphosate rates (0, 0.25X, 0.5X, 1X, 2X, 4X, 8X, 16X of label rate) were applied at two weed growth stages (2-4" and 5-6" horseweed rosette stage). Visual rating of weed control were done at 7, 14 and 21 days after treatment (DAT) based on a scale from 0 to 100 (where 0 = no injury and 100 = plant death). Visual ratings were used to describe dose response curves, which were utilized further to determine the ED_{50} and ED_{90} dose for each population. ED_{50} is an effective dose that provides 50% weed control, while ED_{90} provides 90% control. Glyphosate resistance level was determined by comparing the ED_{50} and ED_{90} values across five populations.

Glyphosate dose response curves were described (Figure 1) and calculated ED_{50} and ED_{90} values were determined. The ED_{90} values at 21 DAT were 15, 50, 93, 69 and 88 oz/a of a 3 lb ae/gal glyphosate formulation for the susceptible population, ARDC, Ashland and Indiana 1 and 2, respectively (Figure 1). Glyphosate resistance level ranged from 3-6 times the label rate depending on the application time. For example, a 90% suppression of the susceptible plants was achieved with a 1x rate while there was a need to increase the dose to 3.4X, 6.3X, 4.7X and 5.9X in order to achieve the same level of control of populations from ARDC, Ashland and Indiana 1 and Indiana 2 populations, respectively (Table 1).

Studies conducted in Indiana and Ohio have shown that multiple resistant horseweed with resistance to glyphosate and ALS-inhibiting herbicides exists. This provides evidence for the need to use burndown applications in the fall or spring and plant into a field once the horseweed has been controlled. Postemergence only
herbicide programs run the risk of being ineffective. Additionally, research has shown that the use of tillage prior to soybean or corn planting to bury horseweed seed is an effective means for reducing the population. Lastly, the use of synthetic auxin herbicides (2,4-D and/or dicamba) in addition to glyphosate are relatively effective for managing horseweed.

What does the above resistance mean to Nebraska and US producers?

It means that it is an overdue time to re-evaluate the weed control strategies in glyphosate-resistant crops. Continuous use of a single mode-of-action (eg. glyphosate) will lead to an increase in populations of glyphosate-resistant weeds (Table 2). Thus, it is a time to start implementing resistance management programs in our fields. Below are several simple guidelines to reduce the chance for glyphosate resistance on any farm:

1. Scout fields prior to the application of any herbicide to determine the weed species.
2. Rotate herbicides, and avoid using same herbicide mode-of-action on the same field in sequential growing seasons or more than once per year.
3. Limit the number of applications of a glyphosate or any other single herbicide in a single growing season.
4. Use mixtures of POST herbicides that each control the weeds in question, but have a different site-of-action. Some of the postemergence broadleaf herbicides will also provide additional soil residual activity for prolonged weed control. Utilize residual based herbicides when possible.
5. Plant into a weed free field. Use other herbicides alone or with glyphosate as burndown treatments for winter annuals including horseweed either in the fall or spring before crop planting, as it is easier to control those species while they are small.
6. On glyphosate-resistant crops use soil applied herbicides followed by glyphosate. This will provide additional modes-of-action for weed control, thus reducing a chance for weed resistance. Soil applied herbicides would also provide a longer “comfort zone” for weed control early in the season by delaying the critical time for weed removal and reducing the need for multiple glyphosate applications later on in the season.
7. Scout fields after application to detect weed escapes or changes in weed species composition (weed shifts). If a potentially resistant weed has been detected, use alternative control methods to prevent the weed from producing seed.
8. Use alternative weed management practices, such as mechanical cultivation, spot spraying with different herbicides, delayed planting, and weed-free crop seeds.
9. Clean equipment before leaving fields infested with or suspected to have resistant weeds.

Utilizing various weed control tools is not a new thing. Changing modes-of-action in your herbicide program is also one of the basic principles of an Integrated Weed Management (IWM) program (eg. integrating several tools for weed control), especially to combat weed resistance/tolerance issues. More information about IWM is provided in our Weed Guide.

We believe that herbicide tolerant crops, especially the ones based on glyphosate herbicide, can remain useful components of the weed management system, however, their value can be preserved only by proper management, and reduced overuse. This practice becomes even more important when other herbicide tolerant crops become more readily available. It is easy to fall into a trap of overusing glyphosate, versus combinations of pre-emergence herbicides or tank mix partners, especially when one glyphosate-resistant crop is grown after another. Therefore, proper stewardship of herbicides in herbicide-tolerant crops, as a component of integrated weed management program, is the key to preserving the long-term benefits of this technology while avoiding many of the concerns about their use, or misuse.
Table 1. Level of glyphosate resistance, and the rate of glyphosate based on formulation (4.5 lbs ae/gal or 3 lbs ae/gal) needed to control each of the five horseweed populations at two plant heights. Results are from the greenhouse bioassay study (Knezevic et al. 2006).

2-4” tall plants

<table>
<thead>
<tr>
<th>Population</th>
<th>Resistance level</th>
<th>Rates of glyphosate to get 90% suppression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4.5 lbs ae/gal</td>
</tr>
<tr>
<td>1.1=NE-pasture</td>
<td>1x</td>
<td>22 oz/acre</td>
</tr>
<tr>
<td>1.2=NE-ARDC</td>
<td>3.4x</td>
<td>75 oz</td>
</tr>
<tr>
<td>1.3=NE-Ashland</td>
<td>6.3x</td>
<td>138 oz</td>
</tr>
<tr>
<td>1.4=IN 1</td>
<td>4.7x</td>
<td>103 oz</td>
</tr>
<tr>
<td>1.5=IN 2</td>
<td>5.9x</td>
<td>130 oz</td>
</tr>
</tbody>
</table>

5-6” tall plants

<table>
<thead>
<tr>
<th>Population</th>
<th>Resistance level</th>
<th>Rates of glyphosate to get 90% suppression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4.5 lbs ae/gal</td>
</tr>
<tr>
<td>1.1=NE-pasture</td>
<td>1x</td>
<td>22 oz/acre</td>
</tr>
<tr>
<td>1.2=NE-ARDC</td>
<td>4.4x</td>
<td>96 oz</td>
</tr>
</tbody>
</table>

Figure 1. Glyphosate dose response curves for five marestail populations. Data were collected at 21 days after glyphosate application on 2-4 inch tall plants. The ED_{90} values were 384, 1308, 2452, 1815 and 2311 g ae/ha for populations from pasture, ARDC, Ashland and Indiana 1 and 2, respectively. The level of resistance for each population were as follows: 1x, 3.4X, 6.3X, 4.7X and 5.9x, respectively.