Nebraska Lincoln EXTENSION

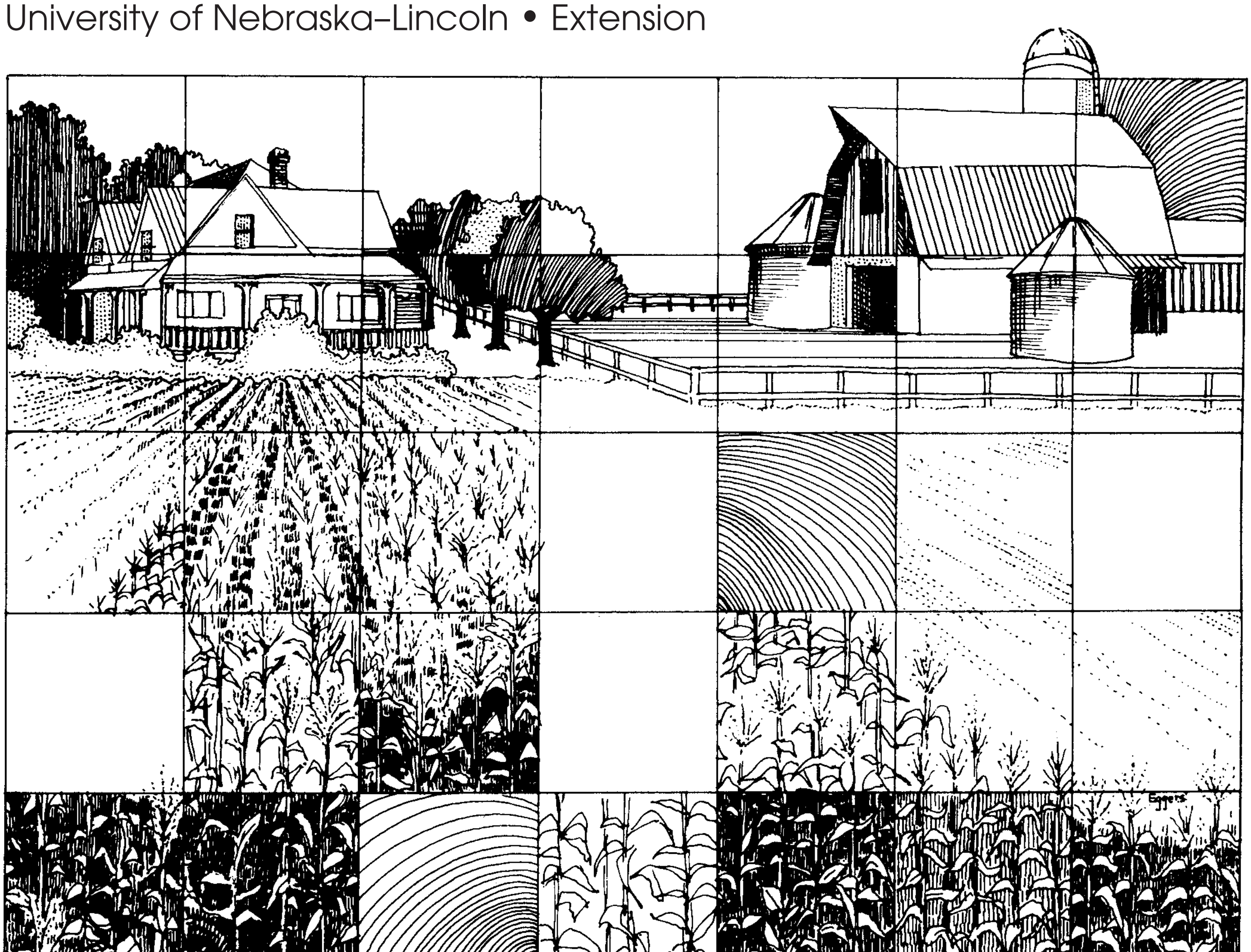
Responsive. Innovative. Trusted.

# CROP PRODUCTION CLINICS

PROCEEDINGS 2015

agronomy.unl.edu/cpc

University of Nebraska–Lincoln • Extension



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

# FOREWORD

The University of Nebraska–Lincoln Extension is pleased to present the 7th 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 *2015 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.

The Crop Production Clinics are the successor to the Crop Protection Clinics (1974 to 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 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.

**2015 Crop Production Clinics**

January 6, Gering Civic Center, Gering
January 7, Sandhills Convention Center, North Platte
January 8, Adams County Fairgrounds, Hastings
January 13, Younes Conference Center, Kearney
January 14, Holthus Convention Center, York
January 15, Beatrice Country Club, Beatrice
January 20, Atkinson Community Center, Atkinson
January 21, Lifelong Learning Center, Northeast Community College, Norfolk
January 22, ARDC, Saunders County Extension Office, Mead

Have a happy and safe 2015 growing season.

Sincerely,

Amit J. Jhala
Crop Production Clinics Coordinator
Extension Weed Management Specialist
Department of Agronomy and Horticulture
University of Nebraska-Lincoln
Lincoln, 68583 NE
E mail: amit.jhala@unl.edu
Tel: 402-472-1534

# 2015 Crop Production Clinics
# Program Participants and Proceedings Authors


Tony Adesemoye
Assistant Professor
West Central Research & Extension Center
North Platte, NE 69101-7751
(308) 696-6708
tony.adesemoye@unl.edu

Erin Bauer
Extension Associate
Agronomy and Horticulture
Lincoln, NE
(402) 472-9548
ebauer2@unl.edu

Fred Baxendale
Professor
Entomology
Lincoln, NE
(402) 472-8699
fbaxendale1@unl.edu

Ben Beckman
Extension Assistant
Agronomy and Horticulture
Lincoln, NE
(402) 472-9566
ben.beckman@unl.edu

Humberto Blanco
Assistant Professor
Agronomy & Horticulture
Lincoln, NE
(402) 472-1510
hblanco2@unl.edu

Jeff Bradshaw
Entomologist
Panhandle Research and Extension Center
Scottsbluff, NE
(308) 632-1230
jbradshaw2@unl.edu

Chuck Burr
Extension Educator
Phelps-Gosper Counties
Holdrege, NE
(308) 995-4222
cburr1@unl.edu

Kenneth Cassman
Professor
Agronomy & Horticulture
Lincoln, NE 68583
(402) 472-6270
kcassman1@unl.edu

Emilee Dorn
Extension Assistant
Agronomy and Horticulture
Lincoln, NE
(402) 472-9543
emilee.dorn@unl.edu

Roger Elmore
Extension Cropping Systems Agronomist
Agronomy & Horticulture
Lincoln, NE
(402) 472-1451
roger.elmore@unl.edu

Richard Ferguson
Soils Specialist
Agronomy and Horticulture
Lincoln, NE
(402) 472-1144
rferguson1@unl.edu

Loren Giesler
Extension Plant Pathologist
Department of Plant Pathology
Lincoln, NE
(402) 472-2559
lgiesler1@unl.edu

Keith Glewen
Extension Educator
Saunders County
Ithaca, NE
(402) 624-8030
kglewen1@unl.edu

Patricio Grassini
Assistant Professor
Agronomy & Horticulture
Lincoln, NE
(402) 472-5554
pgrassini2@unl.edu

Pierce Hansen
Extension Assistant
Agronomy and Horticulture

Bob Harveson
Extension Plant Pathologist
Panhandle Research and Extension Center
Scottsbluff, NE
(308) 632-1230
rharveson2@unl.edu

Susan Harvey
Research Technician
Entomology
Scottsbluff, NE
(308) 632-1250
sharvey2@unl.edu

Gary Hergert
Nutrient Management and Soil Quality Specialist
Panhandle Research and Extension Center
Scottsbluff, NE
(308) 632-1372
ghergert1@unl.edu

Tom Hoegemeyer
Professor of Practice
Agronomy & Horticulture
Lincoln, NE 68583
(402) 472-7049
thoegemeyer2@unl.edu

Tom Hunt
Extension Entomologist
Haskell Ag Lab
Concord, NE
(402) 584-3863
thunt2@unl.edu

Jan Hygnstrom
Program Coordinator
Agronomy and Horticulture

Tamra Jackson-Ziems
Extension Plant Pathologist
Department of Plant Pathology
Lincoln, NE
(402) 472-2858
tjackson3@unl.edu

Jim Jansen
Agricultural Economics
Lincoln, NE
(402) 472-2235
s-jjansen7@unl.edu

Keith Jarvi
Extension Educator
Northeast Research and Extension Center
Norfolk, NE
(402) 375-4310
kjarvi1@unl.edu

Amit Jhala
Weed Management Specialist
Agronomy and Horticulture
Lincoln, NE
(402) 472-1534
amit.jhala@unl.edu

Jessica Johnson
Assistant Extension Educator
Panhandle Research and
Extension Center
Scottsbluff, NE
(308) 632-1247
jjohnson@unl.edu

Shirpat T. Kamble
Extension Urban Entomologist
Entomology
Lincoln, NE
(402) 472-6857
skamble1@unl.edu

Bob Klein
Western Nebraska Crop Specialist
West Central Research and Extension
Center
North Platte, NE
(308) 696-6705
rklein1@unl.edu

Stevan Knezevic
Integrated Weed Management
Specialist
Haskell Ag Lab
Concord, NE
(402) 584-3808
sknezevic2@unl.edu

Kevin Korus
Extension Educator
Plant Pathology
Lincoln, NE
(402) 472-2559
kkorus2@unl.edu

William Kranz
Irrigation Specialist
Haskell Ag Lab
Concord, NE
(402) 584-3857
wkranz1@unl.edu

Brian Krienke
Assistant Extension Educator
Agronomy & Horticulture
Lincoln, NE 68583
(402) 472-5147
krienke.brian@unl.edu

Greg Kruger
Cropping Systems Specialist
West Central Research and
Extension Center
North Platte, NE
(308) 696-6715
gkruger2@unl.edu

Tim Lemmons
Extension Educator
Northeast Research & Extension
Center
Norfolk, NE
(402) 370-4061
tlemmons2@unl.edu

Brad Lubben
Extension Policy Specialist
Agricultural Economics
Lincoln, NE
(402) 472-2235
blubben2@unl.edu

Derrel Martin
Irrigation and Water Resources
Biological Systems Engineering
Lincoln, NE
(402) 472-1586
dmartin2@unl.edu

Chris McCullough
Graduate Research Assistant
Entomology

Lance Meinke
Professor
Entomology
Lincoln, NE
(402) 472-8707
lmeinke1@unl.edu

Francisco Morell Soler
Post-Doc Research Associate
Agronomy and Horticulture
fmorellsoler2@unl.edu

Aaron Nygren
Extension Educator
Colfax County
Schuyler, NE
(402) 352-3821
anygren2@unl.edu

Clyde Ogg
Pesticide Safety Educator
Agronomy and Horticulture
Lincoln, NE
(402) 472-1632
cogg1@unl.edu

Wayne Ohnesorg
Extension Educator
Pierce County
Pierce, NE
(402) 329-4821
wohnesorg2@unl.edu

Tapan B. Pathak
Extension Educator
School of Natural Resources
Lincoln NE 68583-0987
(402) 472-1483
tpathak2@unl.edu

Silvana Paula-Moraes
EMBRAPA Cerrados, Penaltina,
Brazil
Silvana.moraes@embrapa.br

Julie Peterson
Assistant Professor
West Central Research & Extension
Center
North Platte, NE
(308) 696-6704
julie.peterson@unl.edu

Chris Proctor
Post-Doc Research Associate
Agronomy & Horticulture
Lincoln, NE 68583
(402) 472-2811
caproctor@unl.edu

Randy Pryor
Extension Educator
Saline County
Wilber, NE
(402) 821-2151
rpryor1@unl.edu

Daren Redfearn
Associate Professor
Agronomy & Horticulture
Lincoln, NE 68583
(402) 472-2662
dredfearn2@unl.edu

Jennifer Rees
Extension Educator
Clay County
Clay Center, NE
(402) 762-3644
jrees2@unl.edu

Craig L. Romary
Environmental Programs Specialist
Nebraska Department of Agriculture

Leah Sandall
Lecturer
Agronomy & Horticulture
Lincoln, NE 68583
(402) 472-9295
lsandall5@unl.edu

Lowell Sandell
Extension Educator - Weed Science
Agronomy and Horticulture

Debalin Sarangi
Graduate Student
Weed Science

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
cshapiro1@unl.edu

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

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

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

Zachary Stewart
Ph.D. Student
Agronomy

John Thomas
Associate Extension Educator
Panhandle Research & Extension
Center
Alliance, NE
jthomas2@unl.edu

Laura Thompson
Assistant Extension Educator
Southeast Research & Extension
Center
Ithaca, NE
(402) 624-8000
laura.thompson@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

Carlos Urrea
Associate Professor
Panhandle Research & Extension
Center
Scottsbluff, NE
(308) 632-0556
currea2@unl.edu

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

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

Allan Vyhnalek
Extension Educator
Platte County
Columbus, NE
(402) 563-4901
avyhnalek2@unl.edu

David Wangila
Entomology
Graduate Research Assistant

Stephen Wegulo
Extension Plant Pathologist
Department of Plant Pathology
Lincoln, NE
(402) 472-8735
swegulo2@unl.edu

Tyler Williams
Extension Educator
West Central Research & Extension
Center
Holdrege, NE
(308) 995-4222
tyler.williams@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

Roger Wilson
Budget Analyst Farm Mgmt
Agricultural Economics
Lincoln, NE
(402) 472-1771
rwilson6@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

Haishun Yang
Associate Professor
Agronomy and Horticulture
Lincoln, NE
(402) 472-6372
hyang2@unl.edu

Gary Zoubek
Extension Educator
York County
York, NE
(402) 362-5508
gzoubek1@unl.edu

# AGRIBUSINESS MANAGEMENT AND MARKETING



# CROP PRODUCTION



# ENTOMOLOGY

# IRRIGATION & WATER MANAGEMENT



# PESTICIDE EDUCATION

# PLANT PATHOLOGY

**Subject** **Page**



# SOIL FERTILITY

**Subject** **Page**



# WEED SCIENCE

**Subject** **Page**

# Understanding Your Farm Bill Options

**Tim Lemmons, Ext. Educator UN-L NEREC**
**Dr. Brad Lubben, Extension Farm Policy Specialist, UN-L**

With the passage of the Agricultural Act of 2014, comes a new set of options, elections, and enrollments for crop and livestock producers. This article will provide insight into the functionality of the options available to crop producers and considerations when making an election decision.

## General Overview of the Farm Bill

The Agricultural Act of 2014 presents crop producers with several decisions, prior to making a program election. These include opportunities to first update program yields, then program base acres. Producers choosing not to update either yields or base acres, will retain those reported in previous farm bill programs. After the decision has been made to update yields and base acres, the producer will be asked to make a program election; these include:

- No participation
- Agricultural Risk Coverage – County Coverage or ARC-CO
- Agricultural Risk Coverage – Individual Coverage or ARC-IC
- Price Loss Coverage or PLC

The 2014 Farm Bill provides commodity coverage under ARC-CO, ARC-IC, and PLC for the following:

| | | |
|---|---|---|
| • Barley | • Lentils | • Rice, MG |
| • Corn | • Mustard Seed | • Safflower |
| • Canola | • Oats | • Sunflower |
| • Crambe | • Peanuts | • Sesame Seed |
| • Flaxseed | • Dry Peas | • Wheat |
| • Garbanzo, lg | • Rapeseed | • Soybean |
| • Garbanzo, sm | • Rice, LG | • Grain Sorghum |

### Updating Crop Yields

The default option available to crop producers for all covered program crops on the farm, is the currently reported countercyclical yield. Individual program crop yields for each farm, by FSA farm number, are available from your local FSA office. The alternative, is to update the program crop yields to represent 90% of a simple average yield (2008-2012), for each program crop grown on the farm. Most producers will recall that in 2012, Nebraska suffered from wide-spread drought conditions. In years where the individual farm yield for a covered crop was less than 75% of the county average, the county average may be substituted. If a program crop was not planted in a given year, it will not be included in the average calculation. In years where a crop was planted, but evidence of yield does not exist, 75% of the county yield average may be used. The following table provides an example of a yield update for a corn farm.

**Table 1. Example of Program Yield – Corn 2008 - 2012**

| Category | Year | | | | |
|---|---|---|---|---|---|
| | **2008** | **2009** | **2010** | **2011** | **2012** |
| **Yield per Planted Acre** | Planted: No Evidence | 160 | 167 | No Acres Planted | 54 |
| **Substitute Yield: 75% of County Average (08-12)** | 120 | 120 | 120 | 120 | 120 |
| **Calc. Yield** | 120 | 160 | 167 | Not Used | 120 |
| **Sum** | 567 | **Average** | 141.75 | **90% PY** | 127.6 |

The decision to update program yields is a "one-time" only opportunity.

While the decision to update program yields may seem simple, producers must recall that this is a crop-by-crop decision. Situations may exist where individual program crop yield updates are less than the default counter-cyclical yields. Every effort should be made to carefully compare the default vs. updated yield options.

### Update Base Acres

The 2014 Farm Bill authorizes a current farm owner a one-time opportunity to update their farm base acres. The default option is to retain the farm's base acres as of Sept. 30, 2013. The alternative is to reallocate the farm's base acres using the reported planted and prevent planted acres from 2009 to 2012. There are a few caveats for consideration:

- Total farm base acres may include CRP exit acres
- The farm's total base acres may not increase beyond the current base with consideration for CRP expiration
- Farm's may not be reconstituted for the purpose of increasing total base acres

The decision to reallocate acres is an all or nothing opportunity. Reallocations will be based on actual historic plantings, one may not choose to reallocate all acres into one crop or another. If base acres were planted to a non-program crop, then that planting will not be considered when making a calculation. The following table provides an illustration of program base reallocation.

**Table 2. Example of Program Base Acre Reallocation**

| Crop | Base Acres on 9/13 | 2009 Crop Plant | 2010 Crop Plant | 2011 Crop Plant | 2012 Crop Plant | 2009-12 Average Plantings | Reallocate Percent | Reallocated Base Acre Option |
|---|---|---|---|---|---|---|---|---|
| **Corn** | 100 | 150 | 100 | 150 | 50 | 110 | 46% | 138 |
| **Soybean** | 100 | 100 | 150 | 100 | 200 | 130 | 54% | 162 |
| **Alfalfa** | NC | 50 | 50 | 50 | 50 | NC | NC | NC |
| **Wheat** | 30 | 0 | 0 | 0 | 0 | 0 | 0% | 0 |
| **Sorghum** | 70 | 0 | 0 | 0 | 0 | 0 | 0% | 0 |
| **Total** | 300 | 300 | 300 | 300 | 300 | 240 | 100% | 300 |

When considering the decision to update base acres, one must also consider the probability of receiving a program payment on program base acres that are not planted to the program crop. As will be discussed later, the 2014 Farm Bill ARC-CO and PLC program payments are made on total base acres that a farm holds for the giving crop. For example, consider the farm illustrated above. Should the farm base acres be reallocated, the base for sorghum will be permanently lost and redistributed to corn and soybean. It is possible that any given program year may trigger payments in sorghum; however, the farm will have forfeited the potential payments through reallocation. While there is no guarantee that sorghum will trigger payments, there is the possibility. The same holds true for any crop with base acreage on the given farm.

The loss of potential payment must be considered when making a decision to update base acres. The decision to reallocate also affects base acres for all future farm programs as well.

## 2014 Farm Program Elections

The 2014 Farm Bill gives crop producers an opportunity to participate in one of three programs; ARC-CO, ARC-IC, and PLC. This program provides a one-time irrevocable election opportunity on a farm-by-farm, crop-by-crop basis. The program election is made by all parties on the farm that have an interest in the farm. If the farm is entirely rented by a single party at the time of election, then the renting party will make the election decision for all current, past, and future operators. If more than one party has an interest in the farm, all parties must be in agreement on the election chosen. If an agreement cannot be reached, the farm will default to the PLC program and 2014 program payments are forfeited.

## Agricultural Risk Coverage – County

Agricultural Risk Coverage – County or ARC-CO provides regional revenue risk coverage through a shallow-loss payment program. The decision to participate in this program is made on a crop-by-crop basis. The decision to participant is not separated by practice, for example, one may not elect ARC-CO for irrigated corn, but not rain-fed. If the corn crop, for example, is given an ARC-CO election, it effects all corn acres, regardless of practice. This section will address the calculation of benchmarks, payment eligibility, and payment calculation.

*ARC-CO Program Benchmark*

The basic formula for the ARC-CO benchmark is:

Olympic Ave. 5-year yield x Olympic Ave. 5-year NAMP* x 0.86

*NAMP = National Average Market Price

The ARC-CO program benchmark is based on the 5-year Olympic average crop yield times the 5-year Olympic crop NAMP x 86%. The following table demonstrates an example of calculating an ARC-CO:

**Table 3. Example of calculating an ARC-CO benchmark**

| Crop | Year | Planted Yield | NAMP | |
|---|---|---|---|---|
| Corn – Irr. | 2009 | ***179.5*** | ***$3.70***** | |
| Corn – Irr. | 2010 | 189.6 | $5.18 | |
| Corn – Irr. | 2011 | ***210*** | $6.22 | |
| Corn – Irr. | 2012 | 191 | ***$6.89*** | |
| *Corn – Irr.* | 2013 | 192 | $4.50 | *Total* |
| | Ave. | ~191 | $5.30 | $1,011.60 |
| | | | 86% Rate | $869.98 |

*** - The ARC program stipulates that any year in which the NAMP is less than the PLC reference price, the PLC price will be substituted*
*Shaded cells represent removed high and low values*

The calculation of the benchmark is a rolling average, which means that for each successive year of the program, a new year is added, and the oldest year is dropped.

*ARC-CO Payment Eligibility*

The ARC-CO program payment eligibility is triggered when the actual performance for a program crop is less than the benchmark. The actual performance is calculated using the following formula:

Actual Crop Yield x Crop NAMP = Actual Revenue

To be eligible for payment, the farm must have base acres for the triggering program crop. The farm must also have proven compliance with the conservation requirement of the local FSA office.

*ARC-CO Payment Calculation*

Payment on the ARC-CO program is calculated using the following formula:

(ARC-CO Benchmark – ARC-CO Actual Revenue) x crop total base acres x 85%

Payment on the ACR-CO program is calculated by multiplying the difference between the program crop benchmark and the program actual revenue by 85% of the farm's total base acres for the given crop.

This calculation is made on a farm-by-farm, crop-by-crop basis for every crop grown in the county. If the county demonstrates that more than 25% or more of its total planted or prevent plant acres was planted to a given practice, then it may be separated out. For example, a county may have a unique program benchmark for both irrigated corn and rain-fed corn. The decision to separate farming practices is at the discretion of the FSA office. For counties where separate practice benchmarks are not made, a blended yield of both irrigated and rain-fed will be used to calculate benchmark and actual revenues.

ARC-CO is called a shallow loss program, because of its legislated payment limitation. The total payment may not exceed 10% of the total benchmark. Consider the following figure:

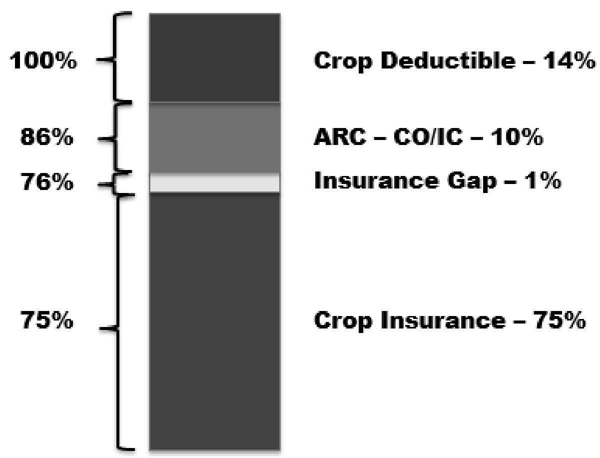



**Figure 1. Shallow-loss program payment horizon**

The graphic demonstrates the total benchmark horizon available for a given crop. The ARC-CO program assumes a 14% deductible loss on the benchmark coverage. Once the actual revenue reaches 86% of the benchmark, the ARC-CO program begins to pay, but only for 10% of the total benchmark. After that point, the producer's crop insurance program is expected to take over and cover any additional losses.

*When to Use*

The most common question regarding ARC-CO, is when to select it over other program options. The decision to elect ARC-CO must consider that the program is based on county-wide crop performance and may not represent the performance potential of the individual farm. The decision to elect ARC-CO should be made whenever the producer reasonably believes that the future prices for the covered program crop will not stay below the PLC reference price for multiple years.

**Agricultural Risk Coverage – Individual Farm**

This program is similar to the ARC-CO election; however, it is based on the benchmark and actual performance of each farm. When the ARC-IC election is made, it affects all program crops grown on the farm. For example, one may not elect to place corn into the ARC-IC program, but not soybean. It is an all-in, all-out election. The program election is made on a farm-by-farm basis; however, if multiple farms are enrolled in the ARC-IC program, the benchmark will represent the average of all. Thus, for example, if 4 farms are enrolled in the ARC-IC program, there will only be one ARC-IC benchmark revenue. The remainder of this section will address calculating the program benchmark revenue, payment eligibility, and payment calculation.

*ARC-IC Program Benchmark Calculation*

The ARC-IC benchmark revenue calculation is represented as the 5-year Olympic average of the total farm revenue. The following table demonstrates the benchmark calculation for a farm with only one crop grown:

**Table 3. Example of a single crop ARC-IC calculation**

| Crop | Year | Planted Yield | NAMP | Gross Revenue |
|---|---|---|---|---|
| Corn – Irr. | 2009 | 179.5 | $3.70** | *$664.15*** |
| Corn – Irr. | 2010 | 189.6 | $5.18 | $982.13 |
| Corn – Irr. | 2011 | 210 | $6.22 | $1,306.20 |
| Corn – Irr. | 2012 | 191 | $6.89 | *$1,316.00* |
| *Corn – Irr.* | *2013* | *191* | $4.50 | *$859.50* |
| | | | Ave. | $1,049.28 |
| | | | 86% Rate | $902.38 |

*** - The ARC program stipulates that any year in which the NAMP is less than the PLC reference price, the PLC price will be substituted*

*Shaded cells represent removed high and low values*

The same procedure is used to calculate the benchmark revenues for each program commodity grown on the farm, and the total revenues are added together in proportion to the average total planted acres. The following table represents an illustration of a farm with multiple crops planted:

**Table 4. Example of a multi-crop ARC-IC farm**

| Crop | 5YOA | Ratio | Total |
|---|---|---|---|
| Corn | $1,049.28 | .79 | $828.93 |
| Soybeans | $897 | .21 | $188.37 |
| | | Total Bench | $1,017.27 |
| | | 86% Rate | $874.85 |

In this example, the given farm has planted corn on 79% of the total acres, and soybeans have been planted on 21% of the total acres. As more crops and farms are added to the election, the total benchmark changes to represent that farm's contribution to the total. The final ARC-IC average revenue is then multiplied by 86% to represent the ARC-IC benchmark. The calculation of the benchmark does not consider the farm's total base acres.

*ARC-IC Program Payment Eligibility*

The ARC-IC program payment eligibility is triggered whenever the actual revenue falls below the program benchmark revenue. The payment on the ARC-IC program considers only the actual planted acres on the farms, up to the total base acres on the farm. The operator may choose to plant whatever he/she likes, regardless of the base acre constitution of the farm.

*ARC-IC Program Payment Calculation*

The ARC-IC program payment is calculated using the following formula:

(ARC-IC Benchmark Revenue – ARC-IC Actual Revenue) x Total Farm Base Acres x 65%

The ARC-IC program payment is calculated by multiplying the difference between the benchmark revenue and the actual revenue by 65% of the farm(s) total program base acres. Again, it doesn't matter what the base acres represent, or what is planted on them; however, programs payments will only be made on 65% of the total base.

Refer to figure 1 when considering the payment horizons for ARC-IC, as they are identical to ARC-CO. The crop deductible will still be 14%. Furthermore, the ARC-IC program only pays up to 10% of the total benchmark revenue, making it a shallow-loss program, same as ARC-CO. After the 10% benchmark revenue loss, the individual insurance program is expected to take over.

*When to Use*

The decision to use ARC-IC must consider several points. It is important to note that ARC-IC payments are only made on 65% of the farm base acres, while ARC-CO makes payment on 85% of the base acres. This represents the probability of payment. In a wide-area risk coverage program, the probability of loss is spread out across a much wider area. There is a stronger probability that a loss in a crop in one area of the county will be offset by overages in another. At the farm level, there is a greater probability of an event affecting a greater portion of the acres. To compensate, ARC-IC has the possibility of paying more often on fewer acres, while ARC-CO has the possibility of paying less often, but on more acres.

ARC-IC becomes more attractive when it only represents a single farm with a low number of program crops. The more crops grown, the greater the chance that a loss in one commodity will be made up by another. ARC-IC also gives the operator greater flexibility in what is planted. Recall that ARC-CO payments are based only the number of program base acres present, while ARC-IC is based on the actual plantings made.

The advantage of the ARC-IC program is that since it is based on the farm unit, it becomes a better representation of the farm when comparing performance as a risk management option.

**Price Loss Coverage**

The price loss coverage or PLC program is offered in tandem with the ARC-CO program, with similar election options. Specifically, this program is elected on a crop-by-crop, farm-by-farm basis. Just like ARC-CO, when a crop is selected for PLC, it affects all practices used as well. Irrigated and rain-fed options will not be separated for program election.

The PLC program provides only price level loss coverage, similar to the old counter-cyclical program. For program payment to be made, the NAMP must fall below a trigger price level. In the 2014 Farm Bill, this trigger price is referred to as the reference price. The following table demonstrates the various reference and trigger prices of the 2008 and 2014 Farm Bills:

**Table. 5 Comparison of CCP and PLC price supports**

| Commodity | 2008 CCP Target Price | 2014 Farm Reference Price | 2014 National Loan Rate | Maximum PLC Payment Rate |
|---|---|---|---|---|
| **Corn** | $2.63 | $3.70 | $1.95 | $1.75 |
| **Soybean** | $6.00 | $8.40 | $5.00 | $3.40 |
| **Grain Sorghum** | $2.63 | $3.95 | $1.95 | $2.00 |
| **Wheat** | $4.17 | $5.50 | $2.94 | $2.56 |
| **Barley** | $2.63 | $4.95 | $1.95 | $3.00 |
| **Oats** | $1.79 | $2.40 | $1.39 | $1.01 |

*PLC Program Payments*

PLC program payments are made whenever the NAMP for the program crop falls below the reference price. The payment calculation formula is shown below:

(Crop Reference Price – Crop NAMP) x crop base acres x 85%

PLC payments are made by multiplying the difference between the program crop reference price and the crop NAMP by the farm's program crop acres times 85%. If the farm does not have any base acres for the crop triggering eligibility, then no payment will be made, even if it was planted on the farm.

The maximum possible PLC price is equal to the reference price less the national loan rate. Similar to the ARC-IC and the ARC-CO programs, program payments may be separated based on agricultural practice at the discretion of the FSA office. Typically, practices are separated when 25% or more of the total county acres are represented.

*When to Use*

The PLC program may be considered to be a national-level price risk program, which further separates it from the actual performance of the farm.

The PLC program makes payment on 85% of the crop base acres, regardless of what is actually grown on those acres. This is an effective program when the producer predicts that the NAMP stays below the reference price for multiple years. This program pays from the reference price down to the national loan rate. After that, the farm crop would begin to trigger LDP payments.

*Supplemental Coverage Option Insurance*

An additional advantage of the PLC program is the option to purchase supplemental crop insurance, which bridges the gap between the 14% crop deductible loss and farm's crop insurance election. A discussion of SCO is beyond the scope of this presentation, but should be considered when making a farm program election.

**Summary**

The decision to elect one farm bill program over another, will depend greatly on the producer's prediction of future crop prices. If the operator believes that prices for a given program commodity will stay below the reference price for multiple years, then the logical program election would be Price Loss Coverage. If the operator believes that the price will stay above the reference price for several years, then the logical program election would be ARC-CO. If farm level risk coverage is desired, and the production of the farm is highly variable, then the logical program election would be ARC-IC. One must also consider that ARC-CO and ARC-IC provide risk coverage in the event of yield losses, while PLC offers protection only in the event of price loss.

When choosing between ARC-IC and ARC-CO, the most logical decision point is the number of farms in the decision, the production variability of the farms, and the number of crops on the farm. If there is a single farm with a single owner and a low number of crops, ARC-IC may perform well. If there are multiple farms, with low production variability (such as irrigation), with a high number of crops grown, ARC-IC may not perform well.

**Making the Program Election**

Ultimately, the program election hinges on the producer's prediction of future price variability. The challenge is in the difficulty in make price predictions, especially two, three, or more years out. There are a number of entities, both government and in higher education, which make predictions of where they think commodity prices will move. The following figures represent various price estimates from the USDA and FAPRI (Food Agriculture Policy Research Institute), as well as the legislative reference price in the farm bill.

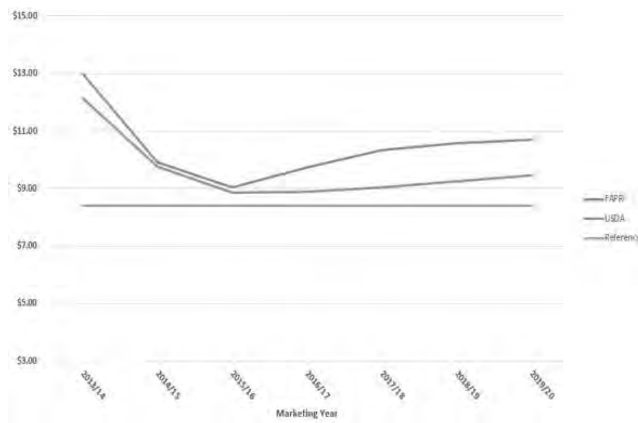



**Figure 1. Soybean commodity price estimates**

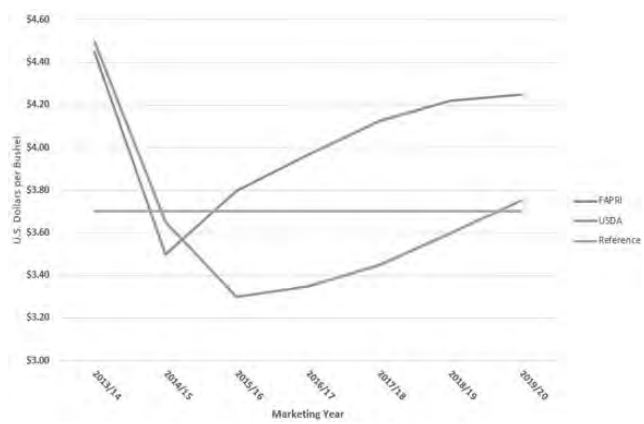



**Figure 2. Corn commodity price estimates**

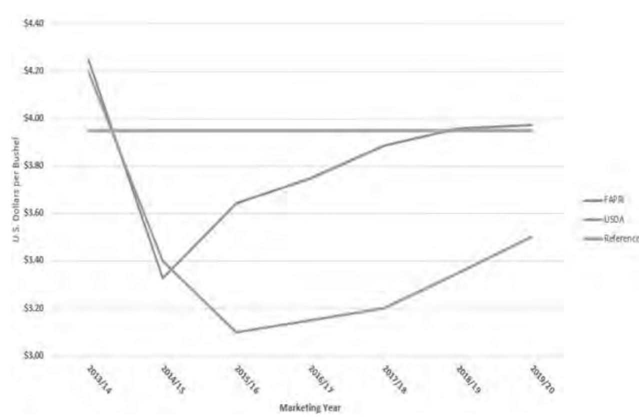



**Figure 3. Sorghum commodity price estimates**

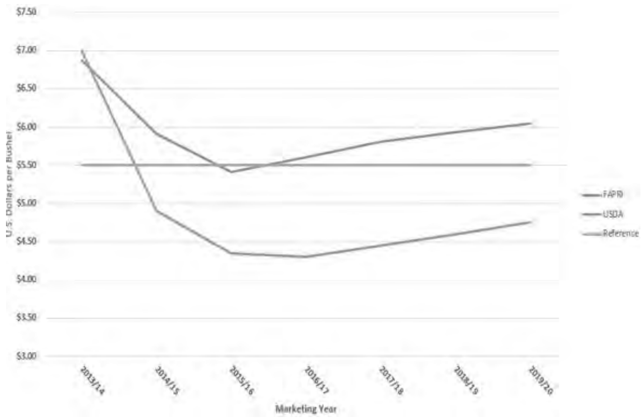



**Figure 4. Wheat commodity price estimates**

As illustrated, the task of predicting commodity prices accurately may be a challenge. Therefore, it is recommended that producers evaluate their program options from the perspective of maximizing their risk coverage, rather than seeking to maximize overall farm program payments. Approaching the farm bill election from a risk perspective, gives emphasis to the importance of the combined effect of commodity marketing efforts, crop production management, cropping practices, and crop insurance decision.

## Summary

The 2014 Farm Bill program, titled the Agricultural Act of 2014, offers producers a spectrum of risk management options, based on their own predictions of farm, county, and national price and yield predictions. Producers have the option of working through their own predictions using the computer-based program calculators available on-line at the following addresses:

https://afpc.tamu.edu/models/decisionaid.php
https://usda.afpc.tamu.edu/
http://farmbilltoolbox.farmdoc.illinois.edu/

For more assistance in analyzing the farm bill election options, please contact your local UNL extension office. Online information and links to farm bill resources are available at http://farmbill.unl.edu.

Tim Lemmons, Extension Educator, University of Nebraska-Lincoln, Northeast Research and Extension Center. Phone: 402-371-4061 or by email: tlemmons2@unl.edu

# Farmland Management Update

**Allan Vyhnalek, Extension Educator**

Farmland values and cash rents have reached their peak or have started to decline headed into the 2015 cropping year. This will be due to the fact that cash revenue from the 2014-2015 crop will be lower with the lower commodity prices. This article will summarize land price and rental data and make observations about 2015 farmland values and rental rates.

### Land Values Level

Depending on location and land classification, farmland values are at various stages around the current peak, some rising, some steady, and others declining. See table one

**Table 1. Average Farmland Values for selected areas of Nebraska**

| Area | Current reported Price | Change from 2013 |
|---|---|---|
| | Avg. $/Acre | % |
| Eastern | 7285 | 0.3 |
| Northeast | 6460 | 4.0 |
| Southeast | 6185 | 8.0 |
| Central | 4195 | 18.0 |
| South | 4815 | 9.0 |
| North | 1220 | 20.0 |
| Southwest | 1985 | 12.0 |
| Northwest | 855 | 20.0 |

(Nebraska Farm Real Estate Market Survey, 2014)

Land values are being supported with strong cash sales, the lack of availability of land being sold, low interest rates, high livestock prices, and very high demand by producers looking to add land to their operations.

### Cash Rents Increases Are Slowing

Cash rental rates for farmland have reached all-time highs in several regions of the state, while others have started to decline. See Table two

**Table 2. Cash Rental Rates for Center Pivot Irrigated Land**

| Area | Current reported Price | Change from 2013 |
|---|---|---|
| | Avg. $/Acre | % |
| Eastern | 355 | 0.0 |
| Northeast | 370 | -2.0 |
| **Southeast** | **335** | **-3.0** |
| **Central** | **260** | **-33.0** |
| **South** | **270** | **-14.0** |
| **North** | **250** | **-6.0** |
| **Southwest** | **305** | **13.0** |
| **Northwest** | **200** | **-11.0** |

(Nebraska Farm Real Estate Market Survey, 2014)

## The Landlord/Tenant Relationship

Ideally, landowners should seek to capture an optimum rental rate for their investment. Why “optimum: and not “maximum”? Optimum, in this case includes the idea that the business relationship is maintained by negotiating a rental rate with both parties consider acceptable. In many cases, the integrity of the tenant, the quality of the business relationship, and the wishes of the landowner are more important than garnering the maximum possible rental rate or crop share percentage. Similarly, the tenant seeks an optimum rate to rent land. In many cases, the tenant may be willing to pay a little more to acquire land from an owner with whom they have a good business relationship, or ground that is close to their main operation.

Landlord/tenant relationships often become strained during periods of high yields and good crop prices, when landowners question if they are receiving enough compensation for their land. Similarly, periods of low yields or low prices cause tenants to question if they are paying too much.

The one emotion that has to be avoided during the lease negotiation process is greed. Greed is a powerful emotion that casts doubt on the trust developed between the landlord and tenant. Without trust between the parties, a solid lease arrangement cannot be established successfully. The best way for landlords and tenants to build trust with one another during these uncertain financial times is to develop a clear two-way channel of communication.

Landlords need to clearly state their expectations of the tenant, preferably in the form of a written lease agreement. Lease agreements, cash rent or crop share, should clearly outline who is responsible for which expenses. Agreements should also include a lease termination date, and outline expectations for tillage, mowing, fences and weed control. Landlords should also have an open discussion with tenants about the current and future goals of the operation as well as the rising costs they are facing.

Tenants should be reporting planting dates, disease or insect pressure, moisture events, irrigation use, yield, unexpected expenses and price received to landowners. When a clear channel of communication is developed, there is less room for speculation and greed.

## The Great Balancing Act

Getting landlords and tenants to agree on a cash rental rate for 2015 will be a great balancing act.

On the landlord’s side, the taxes have skyrocketed in the past few years. Ask anyone that owns farmland to talk about this and you can practically see the steam coming out their ears.

On the tenant’s side, it’s not $7 per bushel corn and $15 per bushel soybeans anymore. With the last USDA acreage and carry-over estimates, the corn and soybean prices plummeted. Current cash price for corn and soybeans are around $3.20 and $9.20 respectively at local elevators. Expenses are not likely to go down. Most estimates that have been released indicate that the expense of raising one bushel of corn will be somewhere between $4.10 and $4.70 depending on whether the land is rented or owned.

Frustrated landlords can often be heard saying, "Well, that farmer made too much money the past several years, and I am not dropping my rent, not with land taxes where they are at."

So, herein lays the dilemma. The tenant that cannot or should not pay more rent and a landowner that is unwilling to maintain or lower rent.

Farmland is a traded commodity, which is ultimately governed by local supply and demand. In many farm communities across the state, demand for farmland is exceeding the supply. Thus, land cash rental rates are not likely to go down significantly for the upcoming year.

Both landlords and tenants need to use a sharp pencil. Landlords need to get out a calculator and really determine what the true expense per acre taxes are imposing. Some landlords may think their rent should go up by $25 per acre when actual tax expense per acre per year maybe $5-7. Tenants may also have added expenses (like fertilizer and chemical packages, new machinery, better, more costly seed genetics,) over the past few years as commodity prices saw record highs. However, some of these expenses could be cut in 2015 to reduce their break-even cost. Though, tenants should be careful not to jeopardize productivity or stewardship of the land to reduce their cost.

Key strategies for 2015 are: 1) cool heads will prevail; 2) share information with each party so no one feels like there is an advantage of 'secret' information given to the other party; 3) Consider lowering rents, keeping rents steady, or only increasing rents by the actual increase in land taxes. What you do will depend on your situation and where you rent is currently. 4) Consider going to some type of flex lease, or modified crop share agreement to more evenly share the risks and rewards of farming.

**Lease Considerations for 2015**

Some tenants may try to skimp on inputs for 2015. Landlords should consider provisions in their lease that allow for soil tests to be completed at the end of the lease. If the test results for certain nutrients are deficient, the landlord is compensated. Likewise, if the tenant has just invested in improving the soil fertility and is now removed from the lease, a provision should be in place to have that tenant compensated for his investment which will be utilized by the next tenant.

Another area which needs to be examined is the ownership of the irrigation equipment. There seems to be quite a bit of variance in which party owns the equipment across Nebraska. In a typical cash farmland lease, the landlord owns all irrigation equipment. Nevertheless, in many cases, the tenant is bearing the cost of installing equipment, most notably, providing the center pivot. When the tenant is providing part of the irrigation equipment, the rent should be lowered to reflect the contribution of the tenant.

In some cases the landlord has made no contribution to purchasing or maintaining irrigation equipment, but feel entitled to irrigation cash lease rates. This is simply not appropriate. In this case, the landlord has a 'good' dryland or rainfed farm and should get very good dryland rent, but not irrigated cash rental rates.

Also be sure to check your lease for items like: sub-leasing and hunting rights. In some cases the landlord is fine with the tenant sub-leasing the crop ground, hay, or cornstalks. In other cases, the landlord does not want to allow that. This should be discussed and noted in the written lease. For cropland, the hunting rights belong to the tenant unless the landlord specifically holds the rights out of the lease.

For more lease considerations, please refer to: http://agecon.unl.edu/realestate.html and refer to the Frequently Asked Questions link for farmland leases.

**Summary**

The great balancing act for farmland rental arrangements of 2015 is an interesting situation. Working through the cash rental rate will be a challenge and one worthy of excellent communications from both the landlord and the tenant.

Allan Vyhnalek, Extension Educator, University of Nebraska-Lincoln, Extension in Platte County. Phone: 402-563-4901 or e-mail avyhnalek2@unl.edu

# 2015 Crop Production Cost Control

**Robert Tigner, UNL Extension Educator**
**Jessica Johnson, UNL Extension Educator**
**Roger Wilson UNL Farm Budget Specialist**

The current crop economics environment has changed significantly from the 2012-early 2014 period. The 2015 crop season cost projections are significantly above anticipated revenues. Cost control will be key, probably for 2-3 growing seasons, to financial viability.

## Crop Budgeting and Costs Control

A first step in crop production cost control is the enterprise budgeting process. The enterprise budget can be either self-produced by crop producers or the UNL Extension 2015 Nebraska Crop Budgets can be modified by the user. In either case, accuracy of the projections is important. Budgets consist of two main sections: Projected Revenue and Projected expenses. A third section for analysis is often included which will calculate net revenue or loss and cost of production per unit of production.

Most budgets that are constructed are full economic budgets, meaning that all costs are accounted for in the budget. These costs are cash costs as well as fixed non-cash costs. Cash costs include items such as seed, fertilizer, fuel and hired labor. Non-cash costs include the investment in machinery, land or management input. Some items of production may have both cash and non-cash components such as property tax and the investment land or machinery.

## 2015 Nebraska Crop Production Cost Projections

As of the writing of this article (6 Nov 2014), current information from agronomic sources leads to the thinking that most cash cost (seed, crop chemicals and fertilizer) will remain constant compared to 2014. The prices of many crop inputs are little changed from early 2014. But some prices are currently unknown, seed and fertilizer for instance. The best information is that these too will remain constant compared to 2014.

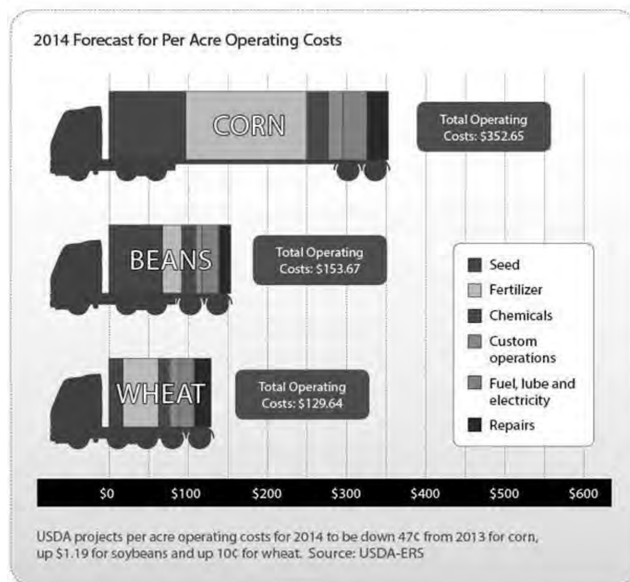
UNL Extension has updated EC 872 Nebraska Crop Production Budgets to assist agronomists and crop producers in their 2015 crop enterprise budgeting. The corn soybean complex budgets, Budgets 15-29 and 46-53, indicate that all Nebraska corn production systems will lose money, using full economic cost, compared to 2015 harvest prices now offered while dryland soybean systems may be a breakeven season for full economic costs. Irrigated soybean budgets indicate losses for 2015 for full economic costs. A few corn systems, Budgets 15 and 26 project cash cost losses near breakeven. Corn budget 15 is continuous corn with yields near 85 bushel (bu) per acre and budget 26 is a Panhandle pivot irrigated budget with a yield of 180 bu. All soybean system budgets indicate positive returns to cash costs. Wheat production cash costs for all budgets, Budgets 61-67, appear likely to be below the harvest prices now offered. Wheat revenue will likely be enough, based on current 2015 harvest prices, to pay some of the fixed costs incurred.

### Adjustments to Crop Costs

Adjustments to cash and non-cash costs will occur over the next months and possibly 2-3 years. These adjustments are likely to take two forms. First adjustments to cash costs and second adjustments to land costs.

The largest cash costs for corn production are seed and fertilizer, seed is the largest for soybean production and fertilizer is the largest for wheat production, Figure 2. The first area of review for crop producers would be these.

**Figure 2, 2014 Forecast of Cash Crop Costs**




Source: USDA ERS, http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx, accessed 6 Nov 2014

UNL Extension CropWatch website, https://cropwatch.unl.edu/economics and http://cropwatch.unl.edu/survivinghighinputcosts have a number of articles and tools that make recommendations for cost reductions that are not yield reducing as well. What the crop producer will try to do is set the marginal cost of an input equal to the marginal revenue, (MC=MR). That is the point where profit maximization is possible. For example if adding 1 more unit of seed at a cost of $3.50 yields $3.50, the crop producer is at MC=MR.

### Recommended Cost Control Considerations

UNL research indicates that following UNL soil fertility recommendations can reduce Nitrogen applications significantly without yield reduction. These practices include manure testing, soil nitrate credit, soil organic matter credit for nitrogen, use of legume nitrogen credits when planting corn or milo and eliminate unnecessary phosphorous, potassium and sulfur.

A second area of significant prospective cost reduction is irrigation. Leaking inefficient water management reduces possible yields from the water pumped. Fixing those problems reduces cost and may improve yields through higher water use efficiency. Reducing water applications near the end of the growing season when adequate soil moisture is present should be considered as well. Using soil moisture monitoring and ET reports or measurements will allow reduced water applications without reduced yields.

Increased residue in crop fields should be considered. Residue conserves soil moisture by reducing evaporation during the growing season and over the non-growing season. Thus no-till cropping systems are water conserving.

Set realistic yield goals to reduce costs and to possibly increase yields. Reducing yield goals below the productivity of the land could reduce revenue by more than the cost of the input. When that happens, crop is not produced at the MC=MR profit maximizing point. The same principle applies when setting yield goals that are unlikely to be achieved. MC then is likely to be higher than the MR realized.

A significant cost for farm operators is the current rental rates for cropland. These costs are likely to be sticky. Adjustments to rental rates are likely to occur over 2 to 3 years rather than rapidly. This has been the pattern in other time periods where land values and rental costs have adjusted either up or down. Land is the residual claimant for crop revenues. This refers to variable costs that must be paid to put the land into cultivation. And over the long-term, operator fixed costs must also be paid. These fixed costs include machinery investment and unpaid labor and management. There is a range of operator fixed cost and variable and so there will be a range of possible rental rates that operators can pay land owners.

Land owners are likely to be negotiating lower rental rates in the coming 2-3 years due to the cost of crop production. Those land owners with rental rates above the ability of even low cost crop producers will need to decide what rental rate is acceptable to them in those negotiations.

## Conclusions

The current cost and revenue environment will be with farm operators and landowners for some period of time. Both parties will be making adjustments in their revenue expectations. These expectations will be lower than recent history. Communication between the parties will increase the likelihood that the adjustments proceed in a constructive manner.

Farm operators are likely to put off purchases of crop inputs until nearer the growing season. Prices of some inputs appear not to have adjusted to the lower revenue that crop producers will experience in the coming year. However doing so may mean that preferred seed hybrids or nitrogen sources may be in limited availability if operators wait too long to commit to purchases.

## Proceedings Forward

Robert Tigner, UNL Extension Educator Red Willow County, robert.tigner@unl.edu.

Jessica Johnson, UNL Extension Educator, Panhandle Research and Extension Center, jjohnson@unl.edu.

Roger Wilson, UNL Farm Budget Specialist rwilson6@unl.edu.

*NebGuides*
2015 Nebraska Crop Budgets EC872

**Notes:**

Figure 1: Blank Crop Production Budget

| **CROP: YEAR:** | | | | |
|---|---|---|---|---|
| ITEM | UNIT | QUANTITY | PRICE | TOTAL |
| GROSS INCOME | | | | |
| | | | | |
| **VARIABLE COSTS** | | | | |
| SEED | | | | |
| SOIL TEST | | | | |
| NITROGEN | | | | |
| PHOSPHATE | | | | |
| POTASH | | | | |
| LIME | | | | |
| PESTICIDES | | | | |
| | | | | |
| | | | | |
| | | | | |
| CROP INSURANCE | | | | |
| | | | | |
| DRYING FUEL | | | | |
| | | | | |
| | | | | |
| | | | | |
| INTEREST ON OPERATING CAPITAL | | | | |
| TOTAL VARIABLE COSTS LISTED ABOVE | | | | |
| FIXED/OVERHEAD COSTS (CUSTOM RATES ARE USED AS A PROXY FOR FIELD OPERATION COSTS) | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| LAND CHARGE | | | | |
| TOTAL FIXED COST LISTED ABOVE | | | | |
| TOTAL VARIABLE AND FIXED COST LISTED ABOVE | | | | |
| NET INCOME OVER VARIABLE & FIXED COSTS LISTED ABOVE | | | | |

Source: University of Maryland Extension, accessed 5 Nov 2014, http://extension.umd.edu/grainmarketing/crop-budgets

# In-season Corn Yield Forecasting Using a Computer Simulation Model

**Patricio Grassini, Assistant Professor**
**Francisco Morell Soler, Post-Doc Research Associate**
**Haishun Yang, Associate Professor**
**Kenneth G. Cassman, Professor**
**Roger Elmore, Professor**
**Jennifer Rees, Associate Extension Educator**
**Keith Glewen, Extension Educator**
**Charles Shapiro, Professor**
**Greg Kruger, Assistant Professor**

Crop simulation models synthesize our current understanding of crop growth and development in response to environmental conditions and management. They have the potential to serve a wide range of applications, including research, teaching, and extension education as well as decision-support for identifying promising options for changes in crop, soil, and water management in production fields. The Hybrid-Maize model simulates daily corn growth and development and final grain yield under irrigated and dryland conditions (Fig. 1). The model estimates “yield potential”, which is the yield obtained when the crop is not limited by nutrient supply, diseases, insect pressure, or weed competition-conditions that represent an “optimal management” scenario. It also assumes a uniform plant stand at the specified plant population, and no problems from flooding or hail.

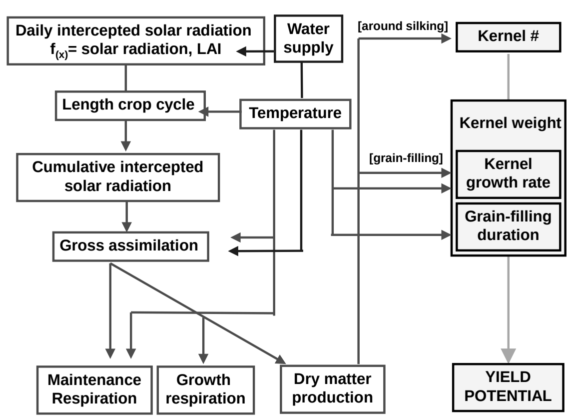



**Figure 1. Right: schematic representation of physiological processes simulated by Hybrid-Maize model. More information on Hybrid-Maize at: http://hybridmaize.unl.edu/**

Hybrid-Maize has been satisfactorily validated on its ability to predict corn yield potential under irrigated and dryland conditions (Fig. 2). Since its release in August 2004, the model is being used by researchers, extension specialists and educators, crop consultants, industry professionals, and farmers in the USA and in a number of other countries.

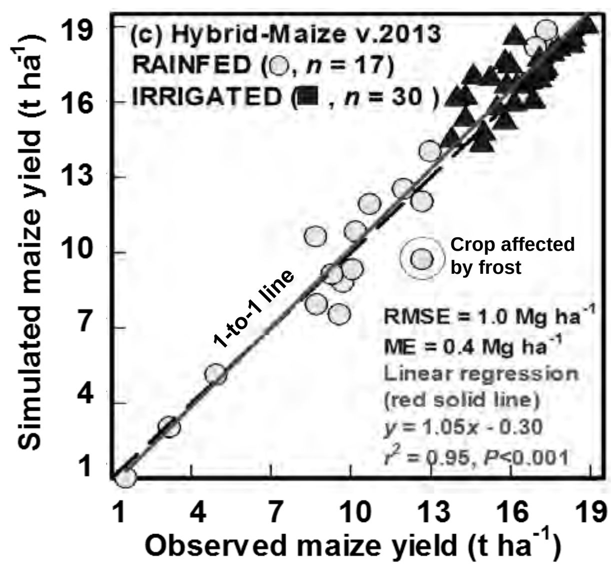



**Figure 2. Evaluation of model predicted yields versus measured yields in well-managed irrigated (blue triangles) and dryland fields (yellow circles). The 1-to-1 dashed line (i.e. perfect agreement) is shown as a reference**

Corn yield potential varies considerably from year to year in the same field as a result of the combined effects of variation in solar radiation, temperature, and water supply in irrigated and dryland cropping systems (Fig. 1). In ‘Current season prediction’ mode, Hybrid-Maize yield simulations are based on the up-to-date weather data of the current growing season, supplemented by the previously collected historical weather data for forecasting of all possible outcomes for the remainder of the season (Fig. 3). This results in a range of forecasted scenarios, which are ranked based on the predicted final yield. By comparing the range of simulated yield potential for the current year to the long-term average yield potential, it is possible to indicate if current-season corn yield potential is below-, near-, or above-average. When yield forecasts also include weather information, they can serve as an educational tool to show producers how their current crop is behaving in response to current weather. Perhaps more important, these yield forecasts, when complemented with other sources of information, personal experience and best judgment, can help producers to take farm decisions. Management decisions could include adjusting the yield goal in comparison with normal years and making subsequent adjustments in fertilizer amounts and irrigation and anticipating harvest due to early-killing frost. During grain filling, yield forecasting can provide additional information to help guide marketing decisions on marketing and provide early estimated of regional and national production to policy makers, ethanol industry, livestock sectors, insurance companies and other companies involved in grain transportation and commercialization.

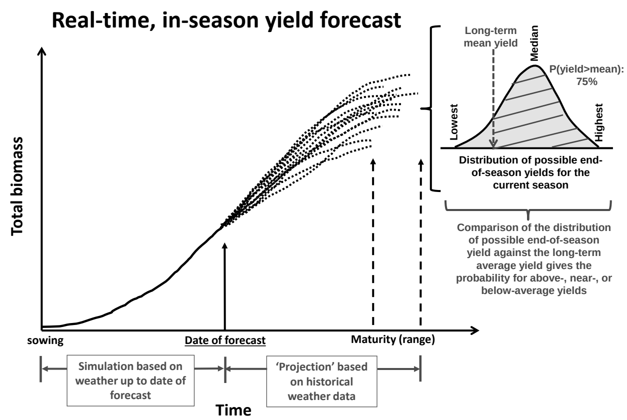



**Figure 3. Example of an in-season yield forecast. Measured weather data for the current season are used for simulating crop growth until the date of forecast (solid line). Historical weather data are used to 'project' the rest of the crop season, with as many projections (dashed lines) as years of historical weather, resulting in a range of possible end-of-season simulated yields (yellow distribution). By comparing the distribution of possible end-of-season yield against the long-term mean yield calculated for the same location based on the historical weather data (dashed blue arrow), it is possible to estimate the probability of an end-of-season yield potential higher than the historical mean yield potential. In the above example, there is a 75% probability (3 out of 4) of achieving above-average yield potential by the date of the yield forecast.**

To evaluate, in 'real-time' fashion, the impact of current weather on corn yield potential, and its spatial variability across the Corn Belt, bi-weekly simulations of 2014 end-of-season corn yield potential were performed for 25 locations in the U.S. Corn Belt, including sites in Nebraska, Kansas, Iowa, Illinois, Ohio, and Wisconsin (Fig. 4). Sites in Nebraska include North Platte, Holdrege, Clay Center, Mead, Concord, and O'Neill. Separate yield forecasts were performed for irrigated and dryland corn for those sites in Nebraska and Kansas where both irrigated and dryland productions are important. Underpinning inputs used for the simulations include weather data provided by the High Plains Regional Climate Center (HPRCC; http://www.hprcc.unl.edu/), the Illinois Water and Atmospheric Resources Monitoring Program (WARM; http://www.isws.illinois.edu/warm/datatype.asp), the Ohio State University, Ohio Agricultural Research and Development Center (OARDC) Weather Service (http://www.oardc.ohio-state.edu/newweather/), and the University of Wisconsin Extension Ag Weather (http://agwx.soils.wisc.edu/uwex_agwx/awon). Site-specific information on soil properties and typical crop management (hybrid maturity, plant populations, and historical and 2014 planting dates) were provided by local extension educators and agronomists in each state: Jennifer Rees, Keith Glewen, Charles Shapiro, Greg Krueger (University of Nebraska), Central Valley Ag agronomists, Mark Licht (Iowa State University), Ignacio Ciampitti (Kansas State University), Peter Thomison (Ohio State University), and Joe Lauer (University of Wisconsin).


**Figure 4. In-season yield forecasting reported for 25 locations across the U.S. Corn Belt in CropWatch articles published in 2014. Stars indicate the 25 sites for which in-season yield forecasting were performed using the Hybrid-Maize model with (20+ years) weather and dominant management practices and soil series at each site. Full articles can be accessed online (e.g.http://cropwatch.unl.edu/archive/-/asset_publisher/VHeSpfv0Agju/content/2014-end-of-season-corn-yield-potential-based-on-hybrid-maizes-simulations)**

As an example, we show a real-time simulation for dryland corn at Mead NE in 2014. Yield forecasts were made approximately every 7 days, beginning shortly after planting (Fig. 5). At each forecasting date, actual weather data were used in Hybrid-Maize to simulate growth until that date. From that point forward to maturity, the model used historical weather records to simulate possible growth scenarios for the remainder of the season. Early in the season, yield forecasts mainly relied on historical weather data to complete the simulation, and as a result, the median forecasted yield was close to the long-term mean yield. As the season progressed and more actual weather data were used, the range of simulated forecasted yield outcomes began to converge especially after silking. It is remarkable that, due to favorable weather conditions for dryland corn in 2014 (above-normal rainfall and below-normal temperature), the model predicted a 75% probability that the final grain yield would be equal to or greater than the long-term average by mid-June. The final simulated yield of 229 bu/ac was 35% above the long-term dryland yield potential at this site.

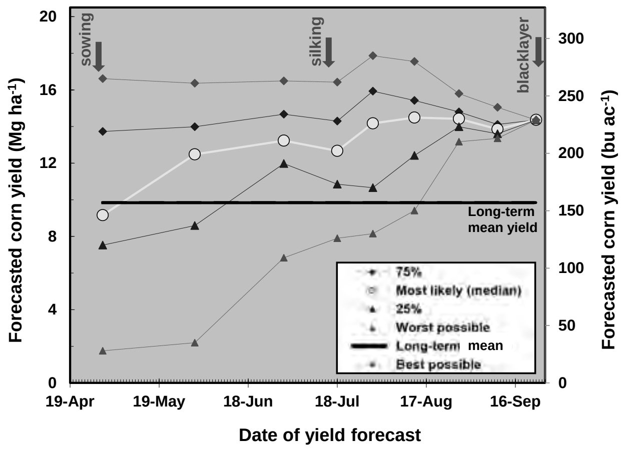



**Figure 5. In-season yield forecasting in approximate 5-d intervals (points) for dryland corn at Mead NE in 2014. Dates of planting, silking and maturity are marked by the arrows in the graphs, and the long-term mean yields is shown as a horizontal line.**

So, how do we expect 2014 producer yields to compare with Hybrid-Maize simulations? In terms of absolute yield, we expect most producers to be below the simulated yield potential because model simulations assume optimum crop management. For example, farm dryland corn yields near Mead NE ranged from 178 to 227 bu/ac in 2014 (note that the upper range was very close to the simulated yield of 229 bu/ac – see Fig. 5). Despite this, in well-managed, timely-planted fields, with even crop stands that were not damaged by hail, flooding, diseases, weeds, and insect pests, past experience indicates that producer yields follow the trend in simulated yields (i.e., to be below, near or above past years' yields). Late-season nitrogen deficiency due to excessive rainfall is one reason that may cause 2014 producer yields to be consistently below simulated yields, even in well-managed fields, especially in north-east NE, Iowa, and Illinois.

In fields with poor establishment, or affected by hail or flooding, as well as in replanted fields (as it is the case of many fields in South Central and Eastern Nebraska this year), we expect Hybrid-Maize yield simulations to be considerably higher than actual yields from such fields. Likewise, high disease or pest pressure may have negatively impacted producer yields, although their overall regional impact is unknown. For example, in south-central Nebraska, early wounding from tornadoes, wind, frost, and/or hail promoted early season systemic Goss' wilt in fields with a previous history of this disease. Likewise, incidence of northern corn leaf blight and Goss's Wilt was also reported for fields located in western Iowa starting in early August.

## References

Yang, H.S., A. Dobermann, J.L. Lindquist, D.T. Walters, T.J. Arkebauer, and K.G. Cassman. 2004. Hybrid-Maize - a maize simulation model that combines two crop modeling approaches. Field Crops Res. 87:131-154.

Yang, H.S., A. Dobermann, K.G. Cassman, D.T. Walters, 2006. Features, applications, and limitations of the Hybrid Maize simulation model. Agronomy Journal 98:737-748.

Grassini P, Yang HS, Cassman KG. 2009. Limits to maize productivity in the Western Corn-Belt: A simulation analysis for fully irrigated and rainfed conditions. Agric. Forest Meteorol. 149:1254-1265.

# Pest-Resistant Crops: A Perspective from Game Theory

**Julie A. Peterson, Extension Entomology Specialist**
**Tom Hoegemeyer, Professor of Practice**
**Roger W. Elmore, Extension Cropping Systems Agronomist**

The western corn rootworm (WCR) is just one of over 540 insect and mite species worldwide that have developed resistance to at least one type of insecticide. WCR resistance to two of the Bt proteins expressed in transgenic hybrids poses a serious threat to sustainable and profitable corn production in Nebraska (see Corn Rootworm Management Update for more information). We need innovative thinking to find solutions to this complex issue, which may include borrowing ideas from disparate fields of study, such as Game Theory.

## Game theory

Game Theory is the study of strategic decision making often using mathematical models that consider various degrees of conflict and cooperation among decision makers. One possible version of game theory is a zero-sum game where the gains and/or losses of all participants are equal. In another version called a 'normal-form game,' a matrix represents decisions by individuals or groups of people (Table 1). Each player or group of players has an option of making one of two choices. The presumption is the two people or groups don't know the decision the others are making.

## Tragedy of the commons

The 'tragedy of the commons' (Hardin, 1968) allegory essentially is a normal-form game with potential payoffs and costs for each player. Imagine a common grazing area that is open to all cattle herders in a village. The commons supports all those involved as long as the number of cattle remains below the carrying capacity of the area.

However, when the carrying capacity is reached, rational cattlemen will seek to maximize their returns by adding another animal to their herd. Unfortunately, all rational cattle herders arrive at the same conclusion and increase their herd sizes too. Everyone is locked into a mentality that compels them to increase their herd sizes without limit, despite the limitations of the common grazing resource. The result is catastrophe; the common pasture is depleted and cattle herds do not have sufficient resources. Hardin (1968, p. 1244) summarizes this by stating, "Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

Individuals or groups of individuals in these situations may find that what is in their personal best interest may not be in their neighbor's best interest. Or, thinking from another perspective, that which is in my best short-term interest, may not be in my best long-term interest. The matrix in Table 1 illustrates the decision making and the personal payoffs for the people involved in this decision-making process.

**Table 1. The tragedy of the commons illustrated: a normal-form game. Fill in the matrix during the clinic session. Score each box for yourself using a 4 to 1 scale; use 4 for the decision that is best for you and 1 for the decision that is worst for you. Use a 2 or 3 for intermediate scores. Then score 'everybody else' using the same scoring system, 4 to 1 – put yourself in their shoes. What is best and worst for both yourself and everybody else?**

| | | Everybody else | |
|---|---|---|---|
| | | Over graze | Managed grazing |
| Yourself | Over graze | / | / |
| | Managed grazing | / | / |

We propose that agriculture faces many situations similar to the tragedy of the commons. We'll illustrate our hypothesis by discussing western corn rootworm resistance development. Our thinking was stimulated by a seminar at UNL presented by David McAdams, Duke Univ. (McAdams, 2014). Unregulated exploitation leads to resource depletion. This results in a class of problems to which there is no technical solution (Hardin, 1968).

## Assumptions for stable pest resistance & A reality check

Using western corn rootworm as an example, we will examine the assumptions for stable pest resistance (Table 2). We'll fill in the table during the clinic session to answer whether these assumptions have been met in the reality of Bt western corn rootworm field populations.

## How do we control WCR?

Given the reality of Bt resistance and our inability to satisfy the assumptions for a high dose-refuge strategy, how do we manage resistance development in WCR? This will take an Integrated Pest Management (IPM) approach - the combination of multiple, diverse control strategies and adoption of new control options. Table 3 lists some of these control options, with some lines blank for you to fill in as other ideas are presented during the clinic session.

### Applications to other agricultural issues

As we mentioned earlier, agriculture faces many situations that may fit the tragedy of the commons. These may include the sustainability of high grain yields, crop monocultures, reduced tillage systems, cover crops, herbicide resistant weeds, and other pest resistance. We'll clearly need to work together to accomplish this task – stabilizing WCR resistance as well as other issues that persist in the commons. That includes all of us whether we're farmers, input suppliers, scientists, educators, Extension workers, regulators, etc. We are living, breathing, and working in the commons. Our role is to minimize or eliminate potential tragedy not only for ourselves, but also for our neighbors, our children, grandchildren, and others who follow us.

### Resources

Hardin, Garrett. 1968, The tragedy of the commons. Science, 162:1243-1248.

McAdams, David. 2014. The future of pest resistant crops – lessons from the fight against anti-biotic resistance. Seminar at the Beadle Center, Univ. of Nebraska. 27 Oct 2014.

**Table 2. Assumptions for stable pest resistance. Please fill out the real situation – Reality – in the right column during the clinic session or contact one of the authors after the session.**

| Assumptions | Reality |
|---|---|
| 1. EVERYBODY plants refuges precisely as suggested and leaves refuges UNTREATED to produce high numbers of susceptible insects. | |
| 2. Events are "High Dose," kill 99.99% of pests at average dose rate. | |
| 3. Monoculture (multiple year, continuous cropping) is the exception. | |
| 4. Random mating occurs among resistant and susceptible CRW individuals. | |
| 5. Resistance to Bt toxins is genetically recessive. | |
| 6. Significant "fitness costs" are incurred for resistant insects. | |

**Table 3. Strategies for managing WCR and resistance.**

| **Integrated pest management approaches** |
|---|
| 1. Crop rotation: still the most effective tactic for Nebraska growers! |
| 2. Bt hybrids: plant a single, effective protein or a pyramid of multiple proteins |
| 3. Liquid or granular insecticide at planting time for larval control |
| 4. Post-emergence insecticide applications for larval or adult control |
| 5. Promotion or addition of predators or pathogens that will attack corn rootworm |
| 6. |
| 7. |
| 8. |

# On-Farm Research: Reliable Data to Drive Decisions

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

Nebraska is unique in that the soil, water and climatic factors are extremely different from west to east. Therefore, from an agronomic perspective, what works in growing corn as an example in Scottsbluff County, may not be applicable in Richardson County.

***On-farm research*** can be conducted by farm operators and industry professionals to answer questions unique to a specific field or management practice. However, depending on the number of questions to be answered and the required number of treatments which need to be tested, the design of the research study may look much different.

When only one question is to be answered, such as "does starter fertilizer increase corn yield versus no starter fertilizer?", on-farm research can be conducted using the operator's equipment with the two treatments applied in alternating strips. Replication is important to manage inherent variability which is common to agronomic research. With this design, we strive for seven pairs or replications, however, statisticians suggest five as a minimum. If we were to evaluate three treatments, no starter fertilizer versus starter fertilizer type 1 versus starter fertilizer type 2, we would use what is called a randomized complete block design which we won't go into detail describing at this time. What we will emphasize is the importance of randomization and replication to make valid inferences about the treatment's impact on corn yield. These two factors separate demonstration plots from on-farm research experiments, which are designed to draw conclusions with confidence and ultimately lead to wise business decisions. You may have heard the phrase, "the yields were numerically different but were not statistically different." We use statistics to determine the probability of repeating the results obtained. Without the proper design and using the power of statistical analysis, the comparison work conducted by a farmer or industry professional may be no better than the odds of flipping a coin.

Precision agriculture technologies have greatly enhanced the ease and accuracy with which we can evaluate the profitability of many different practices. With precision agriculture technologies, inputs such as water, fertilizer, and seed can not only be distributed at different rates across a field, but also tracked and geo-referenced. This means setting up field trials can be done using prescription mapping software, and the need for flagging treatments is minimized. Using yield monitors, yield data for individual field treatments can be quickly evaluated, and the hassle of using a weigh wagon to collect grain weights for each treatment is eliminated. The time and effort required to design, implement, and analyze a sound on-farm research comparison is well worth the confidence you will gain about the profitability of various practices.

The Nebraska On-Farm Research Network has worked with farm operators from Box Butte County in Western Nebraska to Nemaha County in Eastern Nebraska and many more farm operators and counties in-between for over a decade in an effort to answer agronomic production related questions. The Network is a partnership of the University of Nebraska-Lincoln Extension and the Nebraska Corn Board, Corn Growers Association and the Nebraska Soybean Board. For more information about the Network go to: http://cropwatch.unl.edu/farmresearch In addition to conducting research on their respective farms, growers, University faculty, and industry professionals gather at three different locations across the state in February of each year to review and discuss the results. This exercise provides a rich opportunity for farmers and professionals to establish a dialogue and working relationship. This alone is seen as a value to those who participate in addition to the research information.

If conducting agronomic research in a farmer's field is desired and a multiple number of treatments are required to answer one or more questions, research can be conducted. However, it will take on a different look than the example above. When working with multiple treatments, we must still replicate and randomize in order to manage inherent field variability and possible bias. UNL faculty will also conduct small plot experiments which allow us to do many different experiments in one field. . Therefore, we will need to revert to small plot research in a farmer's field. An example of multiple treatments would be determining the effect of row spacing, seed treatment with and without an insecticide or fungicide, foliar application of an insecticide with or without a fungicide on soybean yield. As one can imagine, there are multiple combinations which need to be replicated at least four times in order to generate results which have value to the grower and industry professional. To do this, we use small plot equipment to establish, apply treatments and to conduct harvest. Agronomists have shown over the course of time this approach can and does provide results which are valid in making inferences over a field or agronomic region. On-farm small plot research is, therefore, a viable option for University and industry researchers. An example where University of Nebraska evaluated production practices over multiple environments across the soybean growing regions of Nebraska is the Soybean Management Field Days On-Farm Research Project. This effort is funded and led in-part by University of Nebraska Extension and the Nebraska Soybean Board. This field day effort started in 1999 and showcased only demonstration plots as background for the presentations made by University faculty. In 2012 it decided to expand the effort to include replicated research plots taken to harvest. The publication you have received today, 2014 Soybean Management Field Days Research Update, provides a look at the research studies conducted on four different farms at four different growing regions in Nebraska. Topics being researched include:

- Multiple production inputs – row spacing, fungicides, foliar and seed applied insecticides and nutrient management
- Irrigation management
- Herbicide applications including water quality and resistance management
- Evaluation of growth enhancement products

Results from this year and previous years can be found at: http://ardc.unl.edu/soydaysresearch.

Each plot or treatment is 35’ in length and 4 rows, 30” or 10’ wide. The number of treatments and the multiple combinations resulted in 320 plots at each of four locations. This research study would be impossible to conduct if field size strips were used.

On-farm research can be a very effective tool, as it can be localized to specific growing conditions and management resources. Farmers can use the power of precision agriculture technology which they may have purchased and is included in their farm equipment. To maximize the potential of on-farm research, proper design and thought must go into testing production treatments. Done incorrectly, it may be no better than flipping a coin. As it is often said, “It is what you think you know that you really don’t know that can really impact profitability in production agriculture.”

# Climate Information for Agricultural Decisions in Nebraska

**Tapan B. Pathak, Extension Educator in Climate Variability, University of Nebraska – Lincoln**
**Tyler Williams, Extension Educator, University of Nebraska – Lincoln**
**Martha Shulski, Associate Professor and Director of HPRCC, University of Nebraska – Lincoln**

## Introduction

Monitoring and incorporating weather and climate information into the decision making allows us to make short and long-term management strategies that could minimize climate risks to agriculture. The decisions we make based on the weather information are short-term decisions such as when to plant and harvest the crop, when to irrigate etc. In contrast, decisions made based on the climate are rather long-term strategic decisions such as seed variety selection, acreage allocation of crops etc. In this paper, several weather and climate based tools are showcased that could be used for making both short and long-term agricultural decisions.

## Useful 2 Usable (U2U) – Agclimate4u.org

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. As a part of this effort, many decision support tools are being developed through this collaborative effort of nine universities including UNL (through UNL Extension, High Plains Regional Climate Center, and National Drought Mitigation Center). Below is the brief description of several of these tools (Prokopy et al, 2014)

### *I. AgClimate View Decision Support Tool*

- This tool provides easy-to-use historical climate and crop yield data for the Corn Belt. Put growing cycles into historical context:
- Plot local temperature and precipitation variation back to 1980
- Track county crop yields and trends
- Consider crop yields in the context of temperature, precipitation and growing degree day (GDD) data

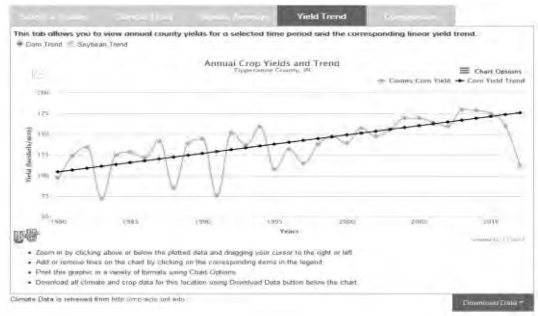



**Figure 1. Snapshot of *Agclimate View* Tool**

### *II. Corn GDD Decision Support Tool*

- Track real-time GDD accumulations and learn about climate risks for corn development. Projections and historical data can help you make decisions about:
- Climate Risks – Identify the likelihood of early and late frosts/freezes
- Activity Planning – Consider corn hybrid physiological maturity estimates, along with GDD projections when making seed purchases and other growing season decisions
- Marketing – Look at historical and projected GDD for forward pricing and crop insurance decisions

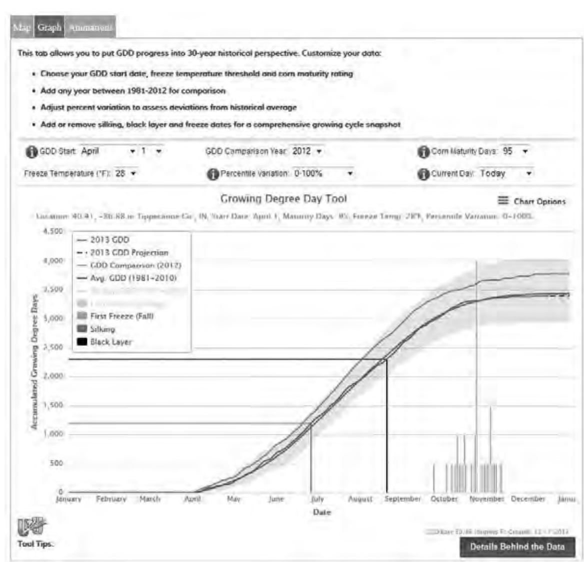



**Figure 2. Snapshot of *Corn GDD* Tool**

### III. Corn Split N Decision Support Tool

- Determine the feasibility and profitability of using post-planting nitrogen application for corn production.
- Combines historical data on crop growth, fieldwork conditions, and economics for location-specific estimates:
- Costs and savings (average/worst/best-case scenario) associated with post-season nitrogen application
- Probability of completing nitrogen applications during a user-specified time period
- Dates of crop growth stages (V2-V10)

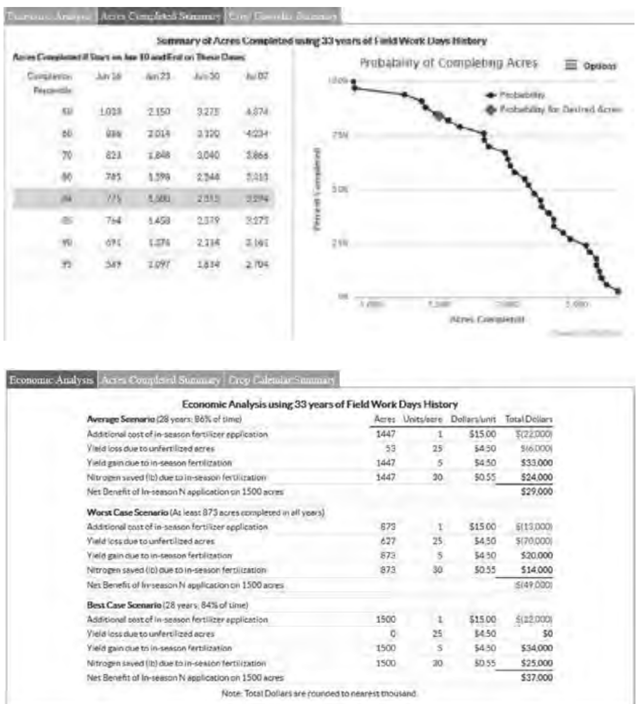



**Figure 3. Snapshot of *Corn Split N* Tool**

## AgriTools

AgriTools is a mobile webpage designed to provide location specific weather information as well as easy access to tools and apps to aid in agricultural decision making. AgriTools will feature weather data from the AWDN weather stations located throughout Nebraska. Data will include temperature, precipitation, wind, soil moisture, soil temperature, Evapotranspiration, and precipitation. The webpage will use a GPS location to interpolate data from the nearest weather stations with the ability to save locations.

Another feature to AgriTools will be the decision-aid tools using climate and weather related variables. An example of this is a quick ET calculator using crop type, crop stage, and the interpolated ET value for the location. This will provide easy access to crop water use, from the field, on your mobile device. More tools will be developed as the webpage progresses.

The third feature to AgriTools is the quick and easy accessibility to UNL developed mobile apps. Apps such as irrigation pumping efficiency calculator, irrigation cost calculator, water mark sensor calculations, pesticide monitoring and record keeping, among other useful apps. This allows you to locate these already developed apps, as well as recently released apps.

## Climate App

School of Natural Resources' High Plains Regional Climate Center released its new smartphone app to inform producer's decision-making. The Climate App's homepage currently presents five options: "Maximum Temperature (F) yesterday," "Minimum Temperature (F) yesterday," "7 Day Average Soil Temperature (4")," "1 Day Soil Temperature (4")," and "1 Day Precipitation Total." Each option links to a map with a color scale that indicates the corresponding local information. Those interested in the app simply use their phone's browser and enter the url as hprcc3.unl.edu/Ap

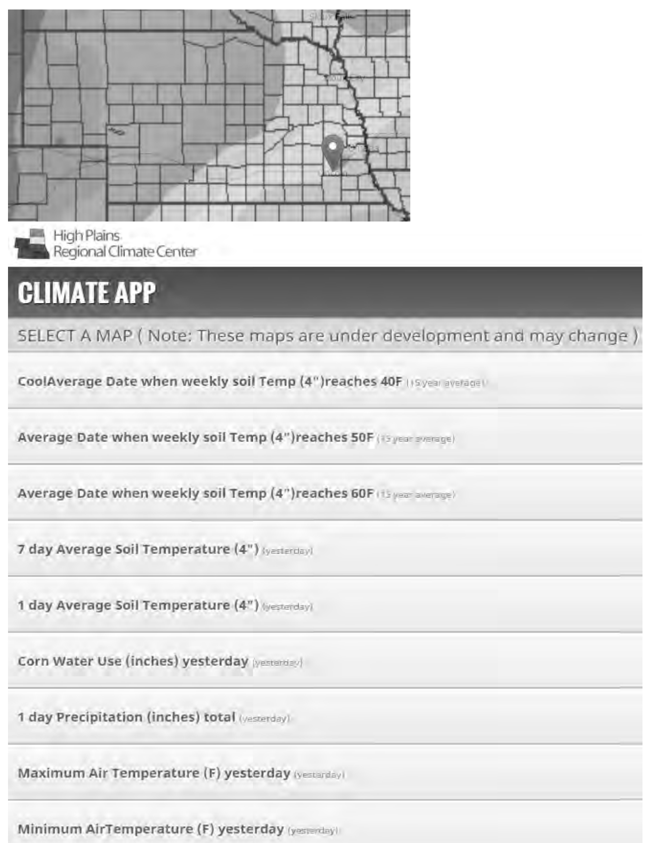



**Figure 4. Snapshot of *HPRCC Climate App***

***References:***

Prokopy et al., 2014. Agclimate4u.org factsheet. Available at https://mygeohub.org/resources/821/download/U2U_2014_DST_Factsheet_0814_FINAL.pdf

# Cover crops: What we know and don't know.

**Roger W. Elmore, Extension Cropping Systems Agronomist**
**Daren Redfearn, Extension Forage and Crop Residue Systems Specialist**
**Gary Hergert, Extension Soil and Nutrient Management Specialist**
**Chris Proctor, Post-Doctoral Research Associate**
**Humberto Blanco-Canqui, Assistant Professor, Soil Management.**

Cover crops are not new to Nebraska cropping systems. However, there is renewed interest in them from both ecological and forage production aspects encouraging new research and outreach on these complex cropping systems. Here we will define some of the key cover crop terms and provide some justification of both positive and negative aspects of including cover crops into Nebraska cropping systems.

**What is a cover crop?**

Cover crops are "crops including grasses, legumes, forbs, or other herbaceous plants established for seasonal cover and conservation purposes (NRCS, 2013)." Some potential uses for planting a cover crop - or a mixture of crops - are to reduce soil erosion, improve soil and water quality, manage pests and diseases, increase biodiversity, and improve wildlife habitat.

Specifically, cover crops primarily 'cover' cropland soil during the fall, winter, or spring when there are no annual row crops – primary crops - to provide soil cover. Using cover crops is a form of multiple cropping where two or more crops are grown in the same field in a year.

**What makes for an ideal cover crop?**

It may help if we describe a 'perfect' cover crop. From our perspective, an ideal cover crop would provide all the benefits listed in the NRCS Conservation Practice Standard listed above plus the characteristics found in the left column of Table 1. In addition, cover crops would not interfere or compete in time or space with the primary row crop for resources such as soil nutrients, water, or light – either above or below ground. This would result in minimal, if any, impact on the yield of the major crop. Also, it would germinate easily, grow rapidly, have small seeds, and wouldn't reproduce during the time it is grown as a cover crop (Florence, 2014). In addition, it would seed would be cheap and neither 'weedy' nor have hard seed. Perennial cover crops- if non-competitive to the primary crop during the summer - could fill a role in our cropping systems. It's clear that the ideal cover crop does not exist. So right from the start we realize that compromises must be made; there is no 'free lunch!'

**Cover Crops & Forage Crops**

Cover crops and forage crops have different purposes and end uses - although they may actually be the same species or mixture and managed nearly the same way. Both may be planted before or after the primary row crop. The end use or purpose may not affect either planting or most management practices. The end use is crucial to defining the purpose. Cover crops will not be grazed or harvested for forage. On the other hand, forage crops will be grazed or harvested for livestock forage.

NOTE: It is important to point out that the herbicide used on the primary crop may dictate the end use based on plant-back restrictions.

**Crop sequences and cover crops: where do they fit into Nebraska cropping systems?**

As mentioned earlier, adding cover crops to a cropping system is a form of multiple cropping. Where will cover crops fit into our cropping systems?

*Wheat – Fallow:*

This entails seeding cover crops after wheat harvest and is a form of double cropping. "Crop-fallow systems such as wheat-fallow are also highly vulnerable to wind erosion during fallow period. Addition of cover crops during this period (about 14 months) without growing crops offers promise to reduce wind erosion risks (Blanco et al., 2014, Hergert et al., 2014)

*Seed corn & silage:*

Seeding cover crops either when the male rows in seed fields are destroyed – relay intercropping – or after the seed corn or silage is harvested – double cropping - provides a relatively long period where light and other resources are used with little or no competition from the cover crop that might reduce primary-crop yields.

*Field corn and soybean: pre-harvest seeding:*

Broadcasting cover crops into standing corn or soybeans in late August to early September provides more growing season for cover crop establishment with minimal competition to the primary crop. This is a form or relay intercropping. On the other hand, competition from either the corn or soybeans in this latter part of the growing season may be intense and reduce cover crop germination, establishment, growth, and biomass production.

*Field corn and soybean: post-harvest seeding:*

Although seeding cover crops after harvest of the major crops provides more options for seeding, limited warm fall weather may preclude establishment and biomass production. This also is a form of relay intercropping.

**Potential advantages and disadvantages of cover crops**

Let's examine some assumed advantages of cover crops using science-based information from across the country to test the assumption when possible. Table 1 lists several potential advantages of cover crops in the left-most column; disadvantages appear in Table 2. We'll leave a few lines blank so you may add other advantages that may occur to you or someone else in the session. During our talk, we'll provide science-based information to help you fill in the remaining column as well as we can.

**Primary Crop Yields**

Blanco et al., (2014) in their literature review, found that out of 15 studies, cover crops increased primary crop yields in six, had no effect in six, and reduced yield in three studies. The impacts of cover crops on crop yields depend on rainfall, cover crop species (legume versus non-legumes), growing season (summer versus winter cover crops), tillage system, and length of cover crop management. In water-limited regions, cover crops may reduce primary crop yields. Some researchers have suggested that cover crops are a better fit in humid and sub humid regions than in semiarid regions where precipitation is limited and fallow periods are more common (Blanco et al., 2014).

**Table 1. Potential advantages of cover crops including forage crops. We've left a few lines blank at the bottom of the table for you to add other advantages that may occur to you or someone else in the session. During our talk, we'll provide science-based information to help you fill in the remaining column as well as we can.**

| Potential advantages of cover crops | Is this a correct assumption based on research? |
|---|---|
| Soil erosion reduction | |
| Increased water infiltration | |
| Nutrient sequestration and thus reduces nutrient needs of succeeding crop. | |
| Increase in organic matter | |
| Alleviate soil compaction – increase porosity | |
| Aids in weed management | |
| Breaks disease cycles | |
| Provides nematode control | |
| Nitrogen fixation | |
| Increases biodiversity | |
| Attracts beneficial insects | |
| Enhances mycorrhizal numbers | |
| Develops wildlife habitat | |
| Provides grazing for livestock | |
| | |
| | |
| | |
| | |

**Table 2. Potential disadvantages of cover crops including forage crops. We've left a few lines blank at the bottom of the table for you to add other advantages that may occur to you or someone else in the session. During our talk, we'll provide science-based information to help you fill in the remaining column as well as we can.**

| Potential disadvantages of cover crops | Is this a correct assumption based on research? |
|---|---|
| Water use | |
| Herbicide application limitations | |
| • Cover crops | |
| • Forage crops | |
| Increased management | |
| Increased input costs | |
| Livestock compaction | |
| N immobilization with late termination | |
| | |
| | |
| | |
| | |
| | |
| | |

**Remaining questions**

- Value of mixtures. Relative seeding single species, do mixtures increase productivity or improve soil quality? Do they reduce the impact on subsequent primary crops? Do they reduce weed competition or sequester more nutrients?
- Termination timing: this is critical especially for areas where soil moisture deficits may limit primary crop yields (Hergert et al. 2014)
- Seeding dates and rates
- Seeding depths
- Cover crop variety performance
- Seeding methods. aerial, broadcast, drill
- The implications of grazing or haying cover crops on soil
- The potential of cover crops for reducing the effects of crop residue removal (baling and grazing) or corn silage
- Cover crop research in relatively marginal soils (i.e., sandy, erosion-prone, low organic matter soils)
- On-farm and long-term studies of cover crop management across a wide range of soil types, annual rainfall, and evapotranspiration rates with different cropping systems.
- Comprehensive economic valuations of cover crops.

"Cover crop impacts are complex and site specific. Local factors such as precipitation, evapotranspiration rate, soil type, cropping system, tillage system, and site-specific management can affect the success of cover crops." Blanco et al, 2014.

Cover crops and forage-crops are a long-term investment.

**Resources**

Baas, D. G., Mutch, D. R., & Ackroyd, V.J. (2011). A state-specific online cover crop decision tool for Midwest farmers. *Journal of Extension* [Online], 49(6) Article 6TOT8. Available at:

http://www.joe.org/joe/2011december/tt8.php

Blanco-Canqui, Humberto et al. 2014. Cover crops and soil ecosystem services. In co-author review. UNL Department of Agronomy and Horticulture.

Florence, Angela. 2014. 'Cover Crop Mixture Diversity and Function' Agronomy-Horticulture 992 Seminar, 3 November 2014. UNL Department of Agronomy & Horticulture.

Hergert, Gary, David Nielsen, and Drew Lyon. 2014. UNL researchers examine use of cover crops in semi-arid conditions. Crop Watch. Univ. of Nebraska Extension. Lincoln NE.

https://cropwatch.unl.edu/archive/-/asset_publisher/VHeSpfv0Agju/content/unl-researchers-examine-use-of-cover-crops-in-semi-arid-conditions

Irmak, Suat. 2014. Long-term UNL study examines impacts of cover crops on soil, water. Crop Watch. Univ. of Nebraska Extension. Lincoln NE.

http://cropwatch.unl.edu/archive/-/asset_publisher/VHeSpfv0Agju/content/long-term-unl-study-examining-impacts-of-cover-crops?redirect=http%3A%2F%2Fcropwatch.unl.edu%2Farchive%3Fp_p_id%3D101_INSTANCE_VHeSpfv0Agju%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-1%26p_p_col_count%3D2

Liebig, M.A., H.A. Johnson, D.W. Archer, J.R. Hendrickson, K.A. Nichols, M.R. Schmer, and D.L. Tanaka. 2013. Cover Crop Chart: An intuitive educational resource for extension professionals. Journal of Extension [Online], 51(3) Article 3TOT7. Available at:

http://www.joe.org/joe/2013june/tt7.php

NRCS. 2013. Conservation Practice Standard for Cover Crops.

http://efotg.sc.egov.usda.gov/references/public/MN/340mn.pdf

Tylka, Greg. 2014. Cover crops and SCN: What’d the connection? Integrated Crop Management News, Iowa State Univ. Extension. 25 Sept 2014.

http://www.extension.iastate.edu/CropNews/2014/1106Pierson.htm

# What's New in Entomology-Eastern Nebraska

**Robert J. Wright, Extension Entomology Specialist**

## Benefits of Neonicotinoid Seed Treatments to Soybean Production

EPA analyzed the use of the nitroguanidine neonicotinoid seed treatments (e.g. imidacloprid, clothianidin, and thiamethoxam) for insect control in United States soybean production. This report (see link below) provides the analysis and EPA's conclusions based on the analysis. It discusses how the treatments are used, available alternatives, and costs.

EPA concludes that these seed treatments provide little or no overall benefits to soybean production in most situations. Published data indicate that in most cases there is no difference in soybean yield when soybean seed was treated with neonicotinoids versus not receiving any insect control treatment.

Full report at:

http://www2.epa.gov/sites/production/files/2014-10/documents/benefits_of_neonicotinoid_seed_treatments_to_soybean_production_2.pdf

## Sugarcane aphid

A new species of aphid, the sugarcane aphid, *Melanaphis sacchari*, has been found on sorghum in Texas and Louisiana in 2013. It has been expanding its range and was found in Oklahoma and southern Kansas in 2014. Growers lost up to 50 percent of grain sorghum yield in infested fields during 2013. High numbers have been found at the end of the season, producing abundant honeydew which may interfere with harvest. Existing insecticides labelled for use on sorghum appear to give variable or inadequate control of these aphids.

Unlike other common aphid species that feed on sorghum, sugarcane aphids have dark, paired, tailpipe-like structures, called cornicles, at the rear, and their tarsi (feet) are dark at high magnification. The dark cornicles and tarsi contrast distinctively with the lighter body color of the sugarcane aphid.

Sugarcane aphids differ from other aphids that attack grain sorghum:

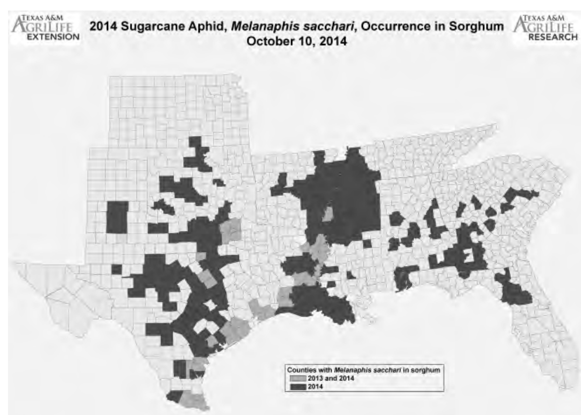
- Greenbugs have a distinctive darker green stripe down the back; sugarcane aphids do not.
- Yellow sugarcane aphids have many hairs on the body (seen with magnification).
- The legs and head of corn leaf aphids are dark.

For more information see:

http://ccag.tamu.edu/sugarcane-aphid/

Distribution of sugarcane aphid in sorghum as of October 2014.

http://agrilifeextension.tamu.edu/wp-content/uploads/2014/10/2014-sugarcane-aphid-occurrence-map.pdf.




## Methomyl Risk Mitigation Decision for Risks Due to Drinking Water Concerns

Methomyl technical and end user registrants Chemtura Corporation, E.I. DuPont de Nemours and Company (DuPont), Glades Formulating Corporation, Rotam Limited, and Sinon Corporation, have voluntarily agreed to implement label changes in order to mitigate estimated dietary risk due to drinking water exposure. To ensure timely implementation of the changes to several crops regarding number of applications and maximum seasonal rate, EPA is taking steps to make sure that the new use restrictions appear on all methomyl product labels by the end of 2014.

The mitigation measures will cancel the use of methomyl on barley, oat, and rye and restrict its use on wheat to Idaho, Oregon, and Washington. For celery, head lettuce, and peppers the number of applications will be reduced by 20% and the seasonal maximum rate will be reduced by 12% to 20%. For com, language will be added to labels that will change the timing of applications such that only two applications can occur prior to tassel push, at the 1-2 leaf stage, and applications will no longer be able to occur on bare soil.

Additionally, the number of applications for leaf lettuce, field com, popcorn, and seed com will be reduced 25% to 50%. While Florida and California were the areas of greatest concern for risks to drinking water, the registrants have agreed to implement the mitigation nationwide.

**Table 1. Agreed to Mitigation for Methomyl on Row Crops**

| Labeled Crop | Mitigation | |
|---|---|---|
| Barley | Cancel Use | |
| Oats | Cancel Use | |
| Rye | Cancel Use | |
| Wheat | Cancel Use Except in ID, OR, and WA | |
| | Number of Applications | |
| | Current* | Proposed |
| Com, Field | 10 | 5 |
| Com, Pop | 10 | 5 |
| Com, Seed | 10 | 5 |
| Com, Sweet, Field, Pop, and Seed | Timing of applications: Do not make more than two applications to com prior to tassel push. Make 1 application when com is at 1-2 leaf stage for control of early season pests; make a second application, if needed, 5-7 days later. | |

# What's New In Entomology – Panhandle

**Jeff Bradshaw, Extension Entomology Specialist**

The 2015 growing season in the Nebraska Panhandle was generally cool. Because insects are "cold blooded", their development is dependent on temperature. In fact, the emergence and development of various insects across the state and the region were delayed. In some cases it was cool enough to prevent some insects from reaching a high pest status, while in other cases damaging levels of pests were simply delayed.

### Army Cutworm

In late September and October, army cutworms lay 1,000 to 3,000 eggs directly on bare soil, such as in newly planted winter wheat or heavily grazed patches of range.  After rainfall, eggs will hatch over an extended period, leading to a variety of caterpillar sizes feeding and developing as long as temperatures are adequate. When the weather turns colder, the caterpillars burrow down into the soil to spend the winter. Come April, large larvae can sometimes be abundant in winter wheat fields. In 2011, moderate populations of the adult army cutworm moth (or "miller moth") could be found in sheltered areas during the day see

http://panhandlepests.blogspot.com/2011/06/miller-moths-continued.html

These moths contributed to a large population of larvae in 2012 and high populations in turn contributed to large populations in spring 2013. Typically, in April, when wheat breaks dormancy, is usually a good time to scout for cutworm activity. Normally a cool wet fall in 2013, and a mild winter, would produce a high survival of army cutworms.  However, excessive moisture during a short period of time, may have suppressed cutworm populations.

### Alfalfa Weevil

Alfalfa weevil populations were high this year in many alfalfa fields. These large populations took some producers by surprise. Damage during the early growth of alfalfa in April and May exists as small holes eaten in the leaves and often go unnoticed. As the larvae grow in size seriously damaged fields take on a white or gray appearance as the heavily skeletonized leaves dry out (*Figure 1*). Larvae generally damage the first cutting and adults then damage the alfalfa regrowth as this next generation emerges. Many times harvesting the first cutting takes care of the weevil due to mortality to the larval stage. In fields with extremely high populations of larvae this may not be the case. Larval survival can be large enough to hinder or stop regrowth.

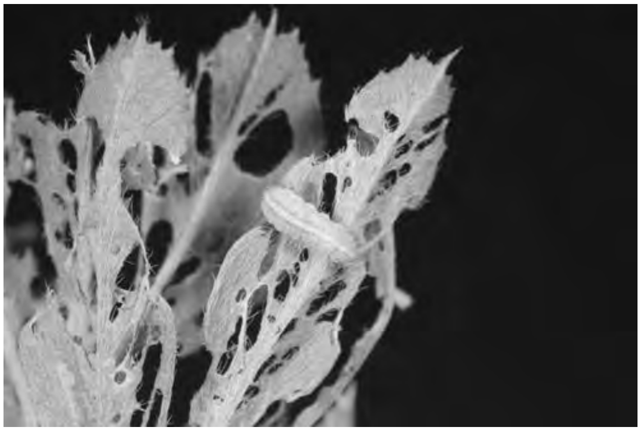


**Figure 1. Alfalfa weevil larva on alfalfa.**

In heavy infestations alfalfa growers have noticed damage in alfalfa at first cutting as well as an abundance of weevil larvae as they cut the alfalfa. During the spring of 2013 several growers had noted that the alfalfa was not starting regrowth after harvest. Upon closer inspection, it was noted that the crowns of the alfalfa stubble were loaded with larvae with counts ranging from 15 to 20 larvae per square foot.  Additionally, weevil pupae were easily seen in the fields.

Although threshold calculators exist another threshold developed by Colorado State University indicates that a treatment in alfalfa stubble should be made if an average of eight or more larvae or young adults per square foot are present in the field or more than 50% of the new growth is damaged. Pre-harvest treatment thresholds for first cutting alfalfa are if 30 to 50% of the terminals are damage or if 1.5 to 2 larvae are found per stem.

If the thresholds for treatment are reached a chemical treatment for alfalfa weevil should be applied to protect your crop. Check with your chemical supplier to find the best product for controlling alfalfa weevil. Certain products such as pyrethroids may take longer to knock down alfalfa weevil but are effective products. If possible, avoid insecticide treatment during bloom to protect pollinators. Check the pre-harvest interval for treatment and always follow the label instructions.

# What's New in Entomology: West Central Nebraska

**Julie A. Peterson, Extension Entomology Specialist**

### Western Bean Cutworm

The western bean cutworm (WBC) is a destructive insect pest that can cause severe yield loss (up to 40% and 10%, respectively) in corn and dry beans; see "Western Bean Cutworm Update" for more information. Although WBC infestations are found in western Nebraska every year, moth flights and pest pressure have been particularly high in these areas in recent years. A black light trap set up to monitor WBC and other moth populations each summer has indicated very high moth flights at North Platte, NE, particularly in 2013 and 2014 (Figure 1). Single night trap catches peaked at 670 moths on July 30, 2013 and 469 moths on July 16, 2014. These increased moth flights have resulted in high oviposition rates in some corn fields in west central and southwest Nebraska counties. Scattered reports from southwest and north central Nebraska of greater than expected damage from western bean cutworm to corn hybrids expressing the Cry1F protein have prompted investigation into the possibility of Bt resistance issues. UNL Entomologists will be exploring this issue by collecting problematic field populations and conducting bioassays. If you have experienced greater than usual damage to Cry1F Bt corn due to WBC or a lack of control of WBC using pyrethroid insecticide applications, please contact Julie Peterson.

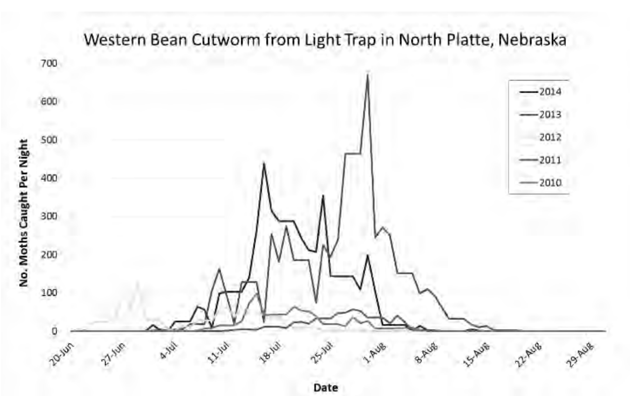



**Figure 1. North Platte light trap data for western bean cutworm populations over the past 5 years.**

### Army Cutworm & Miller Moths

Army cutworm caterpillars were reported feeding on winter wheat fields early in the 2014 season (late March through mid-April). Damaging populations were found in the northeast corner of Dundy County (near the Hayes County line), just south of North Platte in Lincoln County, and near Beaver City in Furnas County, as well as northwest Kansas. The grower from Lincoln County also reported seeing higher than usual bird activity in his fields, especially in the early morning; birds will often feed on army cutworm larvae when they are in high numbers.

Army cutworm larvae are greenish-brown to greenish-grey caterpillars, approximately ½ to 2 inches in length (Figure 2). Feeding damage from army cutworm larvae can vary from grazing leaf tips and chewing on the sides of wheat seedlings (e.g., Figure 3) to complete stand reduction. Army cutworm overwinter in the soil as larvae and emerge in the spring; therefore, they are one of the earliest caterpillar pests in wheat and alfalfa fields.

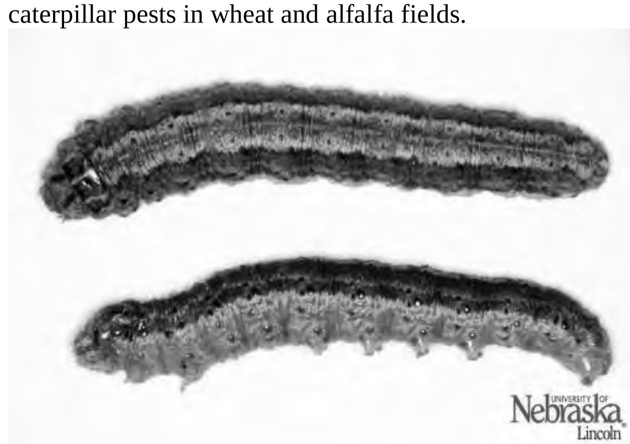



**Figure 2. Army cutworm larvae (photo: J. Kalisch).**

**Figure 3. Feeding damage to wheat (photo: J. Peterson).**

Scout for army cutworms early in the season and use a treatment threshold of four or more larvae per square foot of winter wheat or alfalfa. However, for stressed, thin stands of wheat or for newly established alfalfa stands, use a threshold of two or more larvae per square foot. New or stressed stands of alfalfa require a lower threshold because they are more prone to damage from cutworms. Army cutworms only feed at night and seek out dark sheltered areas during the day, so turn over clods of soil and residue for accurate cutworm counts when scouting fields. If army cutworm counts are above the threshold, consider an insecticide application.

In 2014, high numbers of army cutworm larvae led to high numbers of adults or miller moths, which appeared in May. The moths are generally gray or light brown with a wingspan of 1 1/2 to 2 inches. Each forewing is marked with spots, wavy lines, and other dark and light markings. The moths feed at night on the nectar of flowering shrubs and trees and congregate at resting sites during the day. Narrow cracks or crevices are preferred, but any protected area is suitable. They may enter homes, garages, barns, and sheds in search of these sites, where they may become a nuisance. With the exception of occasionally staining curtains and other surfaces with their droppings, they cause little harm. This type of moth will not cause damage to stored pantry products or clothing.

Moths emerging in Nebraska tend to remain in the area for two to three weeks, but may stay for up to six weeks or as long as local plants are flowering. The moths eventually will migrate westward to higher elevations in the Rocky Mountains, where they escape severe summer temperatures and feed on alpine flowers, their primary food source. In September the moths once again return eastward to Nebraska, where they mate and lay eggs in barren or sparsely vegetated fields, especially winter wheat, alfalfa and grasslands. The eggs hatch within a few weeks and the larvae begin to feed.

## Grasshoppers

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

### USDA-APHIS Rangeland Grasshopper Survey

A total of 2,154 sites were surveyed across 45 counties for the 2014 rangeland grasshopper surveys (Figure 4). Results showed an average of 5.2 nymphs per sq. yard and 7.3 adults per sq. yard. This was the second year in a row in which there were no county averages in the “higher risk” category (greater than or equal to 15 nymphal or adult grasshoppers per sq. yard). This means that 2014 and 2013 had the two lowest grasshopper populations in the past 11 years. Overall, the numbers suggest a relatively low egg load going into the winter. However, grasshoppers may still be problematic in some areas in 2015 if weather conditions favor early nymph survival in May and June and hinder the potential for range recovery in July and August.

### American Burying Beetle Cautionary Zone Expanded

A revised American Burying Beetle (ABB) Cautionary Zone for 2014 was established by the US Fish & Wildlife Service and Nebraska Game & Parks Commission, in collaboration with University of Nebraska-Kearney and the Rainwater Basin Joint Venture (Figure 5). This cautionary zone was determined using insect trapping and multi-year data modeling to indicate the regions within Nebraska where this endangered species may be found. Counties affected by the changes include: Antelope, Arthur, Boone, Cherry, Custer, Frontier, Garden, Gosper, Grant, Greeley, Hooker, Knox, Lincoln, Logan, McPherson, Sheridan, Thomas, Valley, and Wheeler. Counties that will remain completely within the ABB Cautionary Zone include: Blaine, Boyd, Brown, Garfield, Holt, Keya Paha, Loup, and Rock. If grasshopper control is needed within the ABB Cautionary Zone, please contact the US Fish & Wildlife Service (308-382-6468) or UNL Extension faculty. USFWS will be able to work with you to determine the local risk to ABB and provide options for grasshopper control.

## Spotted Wing Drosophila

The spotted wing *Drosophila* is an invasive fruit fly from Asia that has spread rapidly in the United States. It was first detected in California in 2008, Michigan in 2010, and Nebraska in 2013. In 2014, traps placed at several locations in and around North Platte (Lincoln County) where fruits and vegetables were being grown caught high numbers of spotted wing *Drosophila*. This insect is a pest of small fruits such as raspberry, blackberry, and strawberry, and to a lesser extent grapes and orchard fruits. Damage due to this species is worse than typical fruit flies because the female has a sharp, serrated ovipositor, allowing her to pierce the skin of undamaged fruits to lay eggs.

**For More Information See the Following NebGuides:**

- Western Bean Cutworm in Corn and Dry Beans, G2013
- Management of the Army Cutworm and Pale Western Cutworm, G93-1145
- Spring Millers, G2164
- A Guide to Grasshopper Control in Cropland, G1627
- A Guide to Grasshopper Control on Rangeland, G1630
- The Spotted Wing Drosophila, An Invasive, Small Fruit Fly in Nebraska , G2236

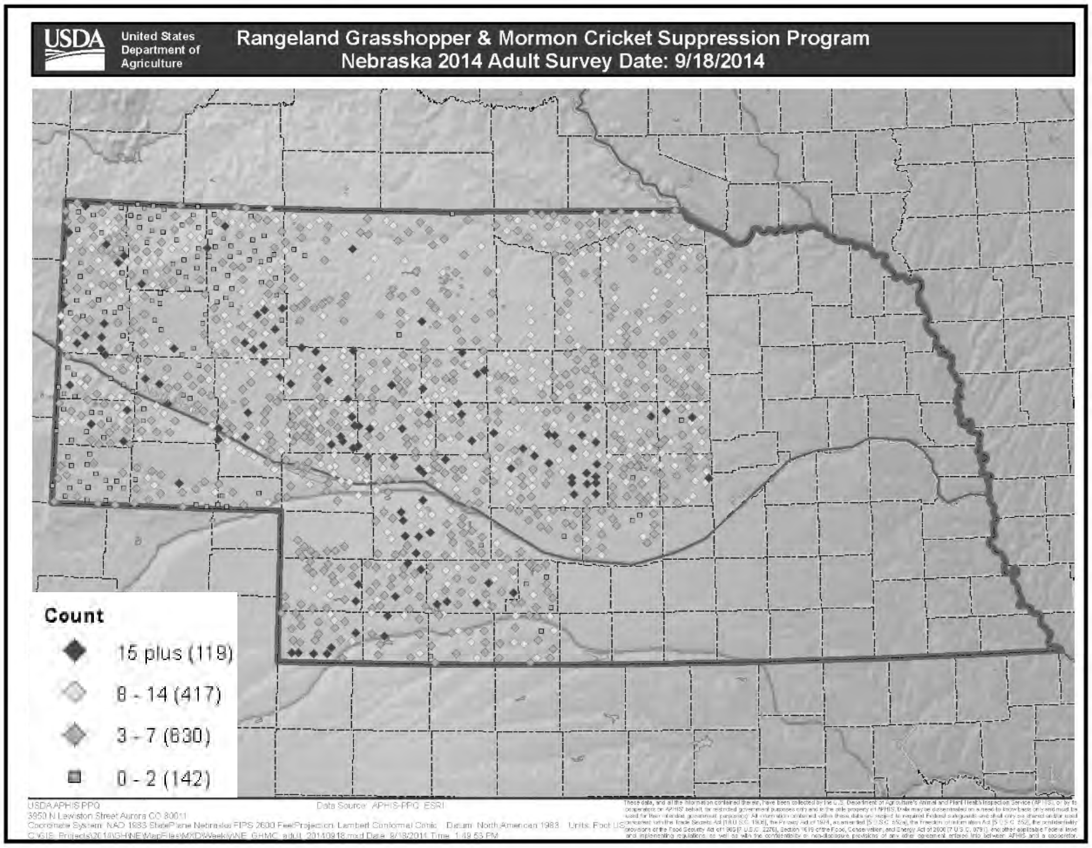



**Figure 4. Adult grasshopper surveys conducted in 2014 (courtesy of USDA-APHIS-PPQ).**

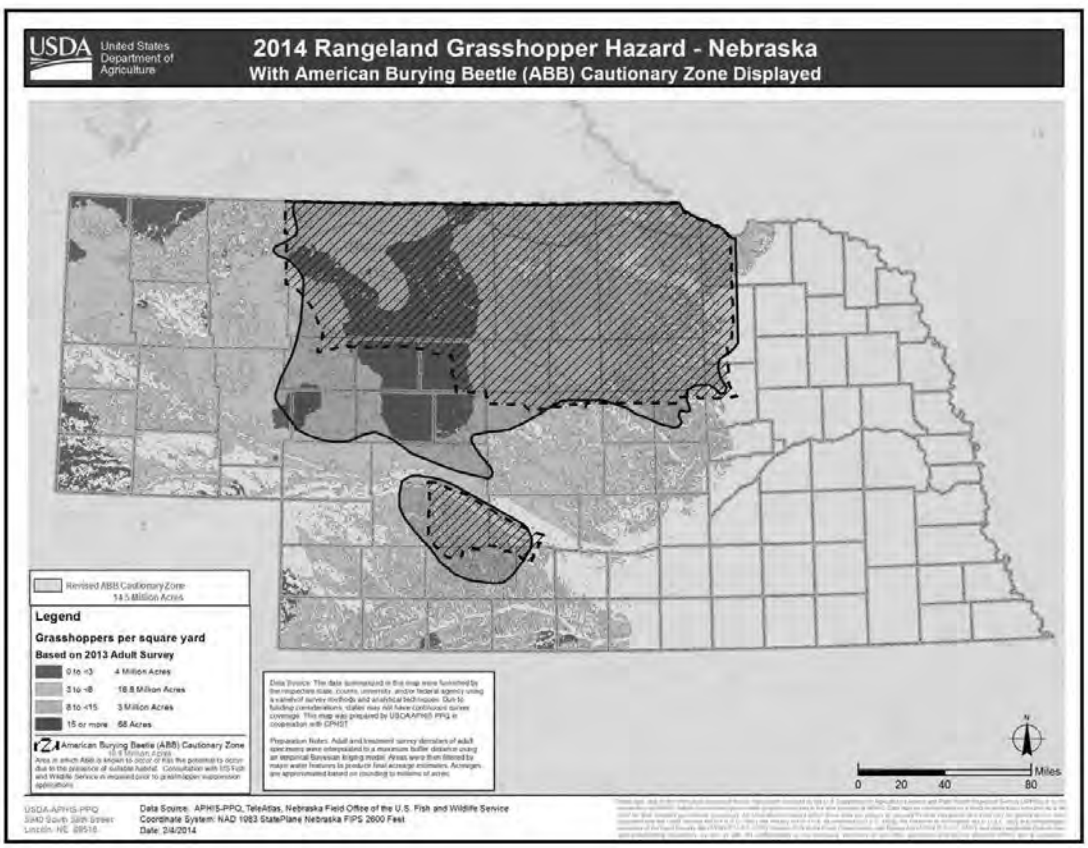



**Figure 5. Grasshopper hazard map for 2014 overlaid with ABB Cautionary Zone (courtesy of USDA-APHIS-PPQ).**

# Bt Corn Hybrid Traits

**Robert Wright and Tom Hunt, Extension Entomology Specialists**

Bt corn is now available in a great many products and with efficacy against a variety of insects. Also, a range of resistance management plans is associated with different hybrid families, some requiring an external refuge and some with the refuge seed already mixed into the bag at the appropriate rate. As you choose hybrids, be sure that your selections have the insect control and herbicide tolerance traits you desire.

Entomologists at Michigan State University and the University of Wisconsin-Madison have developed a convenient publication summarizing all available Bt corn hybrids, their traits and refuge requirements. The Handy Bt Trait Table is available online at http://www.msuent.com/assets/pdf/28**BtTraitTable2014**.pdf and is reprinted at the end of this article.

However, it is still important for you to take the following steps:

- Understand the ***terminology*** used by your seed company;
- Understand the ***biology*** of each trait, the expected level of control, and refuge requirements;
- ***Confirm that the seed you ordered the previous year*** is the seed delivered to you in spring;
- Keep good ***planting records***;
- For herbicide applications, ***Ask Twice-Spray Once***, especially if you hire a custom applicator;
- Save a representative sample of ***bag tags*** = the first thing to check if something goes wrong;
- Most important, if you see **unexpected damage or poor performance** of a trait during the field season, contact your seed dealer immediately so that the field can be visited while the problem is still visible and fresh samples can be taken.

### Insect Resistance Traits

Six species of caterpillar (European corn borer, western bean cutworm, black cutworm, corn earworm, stalk borer, and fall armyworm) are controlled or suppressed by Bt corn products. Suppressed means that while some of the pest population may be killed by the trait, a significant number will likely survive. If you are expecting a specific pest problem, choose a product that is labeled to control that specific pest, not suppress it.

Some Bt products target caterpillars, although not all products control the same group of caterpillars. Beetle-specific transgenic products target corn rootworm larvae; some products target both caterpillars and corn rootworm larvae.

Insect resistance management requirements are continuing to evolve. Currently, two basic types of refuge are required — structured and non-structured. A structured refuge refers to the 5% or 20% non-Bt corn plantings farmers are required to plant within, adjacent to, or within ½ mile of the Bt corn field. Non-structured refuge refers to the inclusion of a certain percent of non-Bt corn seed in a bag of Bt corn seed (currently 5-10%). This is often called refuge-in-a-bag (RIB), and takes the responsibility of planting a separate refuge out of the hands of the farmer.

These differences in refuge size and location can be confusing and beg the question “Why”? Differences in refuge requirements are based on the biology, behavior, and genetics of the pest, the pest’s relationship to the crop, and the relative toxicity of the toxin or toxins within the plant.

For example, refuge size depends largely on the probability of resistance developing. The initial transgenic corn hybrids resistant to European corn borer contain one gene that code for the production of one toxin that targets corn borers (e.g. Cry1Ab). This toxin interacts with a specific receptor site in the insect gut. Some of the newer transgenic hybrids contain two genes that code for two different toxins (e.g. Cry1F, Cry1Ab) that interact with two different receptor sites in the insect gut. Either one of these toxins can kill the corn borer. If an insect develops resistance to one of the toxins, it would still likely be susceptible to the other. European corn borers are less likely to develop resistance in corn fields planted with Bt corn that produces two different toxins targeting corn borers than in corn that produces only one corn borer specific toxin. Therefore, the refuge can be smaller for fields planted to corn that produces two toxins targeting corn borers. The same logic applies to hybrid with Bt proteins active against corn rootworm larvae.

### Refuge Location

Another example is the difference in refuge proximity to the Bt corn field. For lepidopteran resistant hybrids -- those resistant to corn borer larvae -- the refuge may be up to ½ mile away; however, for coleopteran resistant hybrids -- those resistant to corn rootworm larvae -- the refuge must be in or adjacent to the Bt corn field. In this case, the mobility of the adult insect is the primary reason for the difference. Before they mate, female corn borer moths fly around more than female corn rootworm beetles, so the refuge can be further away for the corn borer resistant hybrids than for the corn rootworm resistant hybrids.

The following resources will be helpful in finding information about traits and IRM requirements for different hybrids.

- The first resource to review is the IRM Grower Guide provided by each seed company for its Bt corn hybrids.
- Another resource, the Handy Bt Trait Table by Dr. Chris DiFonzo (Michigan State University) and

Dr. Eileen Cullen (University of Wisconsin, Madison), was last updated in April 2014. It provides a quick overview of current Bt corn hybrid brands, which Bt proteins are in which hybrids, which insects are controlled or suppressed, herbicide tolerance traits, and the percent refuge requirement for each hybrid.

- The National Corn Growers Association has produced an IRM Refuge Calculator at http://www.irmcalculator.com/ in cooperation with the Bt corn seed providers. This tool illustrates the appropriate refuge calculation, the quantity of standard seed bags to buy for both trait and refuge hybrids, and possible planting configurations. Companies currently providing Bt corn hybrids have supplied up-to-date information concerning their products and the associated refuge requirements. This refuge calculator does not replace or supplement the applicable company'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.

## Export approvals

As new Bt corn hybrids are commercialized they may not have export approval from all potential countries. Up to date market approval status of biotech corn hybrids can be obtained at the National Corn Growers Web Site at http://www.ncga.com/. Look under "Know Before You Grow" to learn if specific biotech corn hybrids are approved for export. http://www.ncga.com/for-farmers/know-before-you-grow

# Handy Bt Trait Table

CDD #028
**Updated**
**April 2014**

**Chris DiFonzo**, Michigan State University, East Lansing, MI
&
**Eileen Cullen**, University of Wisconsin, Madison, WI

The most up-to-date version of this bulletin is posted at: www.msuent.com

Many corn hybrids contain multiple transgenic traits and seed costs are rising. Meanwhile, refuge requirements dramatically for multi-trait corn, generally dropping from 20% to 10% or 5%, depending on the trait package and company. Some traits still require a structured refuge planted as a block or series of rows, but many hybrids are now sold as refuge-in-the-bag (RIB). Purchasing the right trait package for your pest spectrum, and understanding its refuge requirement, is critical to maximizing profitability and delaying resistance. But this process may be confusing. The table on page 2 of this bulletin summarizes, to the best of our ability, currently available Bt traits, their spectrum of control, and refuge requirements. We make every attempt to provide up-to-date information for each Bt option. However, it is still important for you to take the following steps:

*Understand the ***terminology*** used by your seed company;
*Understand the ***biology*** of each trait, the expected level of control, and refuge requirements;
****Confirm that the seed you ordered the previous year*** is the seed delivered to you in spring;
*Keep good ***planting records***;
*For herbicide applications, ***Ask Twice-Spray Once***, especially if you hire a custom applicator;
*Save a representative sample of ***bag tags*** = the first thing to check if something goes wrong;
*Most important, if you see **unexpected damage or poor performance** of a trait during the field season, contact your seed dealer immediately so that the field can be visited while the problem is still visible and fresh samples can be taken.

**Abbreviations used in the Bt Trait Table**

*Herbicide traits*
GT glyphosate tolerant
LL Liberty Link (glufosinate-tolerant)
RR2 Roundup Ready 2 (glyphosate-tolerant)

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

**NEW Cheat Sheet**
**------**
**Event names for proteins expressed in Bt plants**

| Target or Activity | Protein(s) expressed | Event | Trade name |
|---|---|---|---|
| corn borer | Cry1Ab | MON 810 | YieldGard CB |
| corn borer + glufosinate tolerance | Cry1Ab + PAT | Bt11 | Agrisure CB/LL |
| corn borer + glufosinate tolerance | Cry1F + PAT | TC1507 | Herculex 1 or CB |
| broad lep control | Vip3Aa | MIR162 | Agrisure Viptera |
| broad lep control | Cry1A.105 + Cry2Ab2 | MON89034 | Yieldgard VT Pro |
| rootworm | eCry3.1Ab | 5307 | Agrisure Duracade |
| rootworm | mCry3A | MIR604 | Agrisure RW |
| rootworm | Cry3Bb1 + CP4 EPSPS | MON88017 | YieldGard VT RW |
| rootworm + glufosinate tolerance | Cry34Ab1/Cry35Ab1 + PAT | DAS-59122-7 | Herculex RW |
| glyphosate tolerance | mEPSPS | GA21 | Roundup Ready |
| glyphosate tolerance | CP4 EPSPS | NK603 | Roundup Ready 2 |

| DiFonzo&Cullen's Handy Bt trait table Updated April 2014 | Bt protein(s) | Insects controlled (bold) or *suppressed (italics)* *Above-ground* | *In soil* | Herbicide tolerant? | Refuge %, location in the MIDWEST |
|---|---|---|---|---|---|
| **Agrisure Trait Family** | | | | | |
| Agrisure CB/LL/RW | Cry1Ab mCry3A | **ECB** *CEW FAW SB* | **RW** | LL | 20% in field/adjacent |
| Agrisure 3000GT | Cry1Ab mCry3A | **ECB** *CEW FAW SB* | **RW** | GT LL | 20% in field/adjacent |
| Agrisure Artesian 3011A | Cry1Ab mCry3A | **ECB** *CEW FAW SB* | **RW** | GT LL | 20% in field/adjacent |
| Agrisure Viptera 3110 | Cry1Ab Vip3A | **BCW CEW ECB FAW WBC SB** | --- | GT LL | 20% within ½ mile |
| Agrisure Viptera 3111 | Cry1Ab mCry3A Vip3A | **BCW CEW ECB FAW WBC SB** | **RW** | GT LL | 20% in field/adjacent |
| Agrisure 3122 E-Z Refuge | Cry1Ab Cry1F mCry3A Cry34/35Ab1 | **BCW ECB FAW WBC** *CEW SB* | **RW** | GT | 5% ***in the bag*** |
| Agrisure Viptera 3220 E-Z Refuge | Cry1Ab Cry1F Vip3A | **BCW CEW ECB FAW WBC SB** | --- | GT | 5% ***in the bag*** |
| Agrisure Duracade 5122 | Cry1Ab Cry1F mCry3A eCry3.1Ab | **BCW CEW ECB FAW WBC SB** | **RW** | GT LL | 5% ***in the bag*** |
| Agrisure Duracade 5222 | Cry1Ab Cry1F Vip3A mCry3A eCry3.1Ab | **BCW CEW ECB FAW WBC SB** | **RW** | GT LL | 5% ***in the bag*** |
| **Herculex Trait Family** | | | | | |
| Herculex 1 (HX1) | Cry1F | **BCW ECB FAW WBC** *CEW SB* | --- | LL | 20% within ½ mile |
| Herculex XTRA (HXX) | Cry1F Cry34/35Ab1 | **BCW ECB FAW WBC** *CEW SB* | **RW** | RR2 (most) | 20% in field/adjacent |
| **Optimum Trait Family** | | | | | |
| Optimum TRIsect | Cry1F mCry3A | **BCW ECB FAW WBC** *CEW SB* | **RW** | LL RR2 | 20% in field/adjacent |
| Optimum Intrasect | Cry1F Cry1Ab | **BCW ECB FAW WBC** *CEW SB* | --- | LL RR2 | 5% within ½ mile |
| Optimum Intrasect XTra | Cry1F Cry1Ab Cry34/35Ab1 | **BCW *E*CB FAW WBC** *CEW SB* | **RW** | LL RR2 | 20% in field/adjacent |
| Optimum Intrasect XTreme | Cry1F Cry1Ab mCry3A Cry34/35Ab1 | **BCW *E*CB FAW WBC** *CEW SB* | **RW** | LL RR2 | 5% in field/adjacent |
| Optimum (AM) AcreMax | Cry1F Cry1Ab | **BCW ECB FAW WBC** *CEW SB* | --- | RR2 | 5% *in the bag* |
| Optimum (AMRW) AcreMax Rootworm | Cry34/35Ab1 | --- | **RW** | RR2 | 10% *in the bag* |
| Optimum (AM1) AcreMax1 | Cry1F Cry34/35Ab1 | **BCW ECB FAW WBC** *CEW* | **RW** | LL RR2 | *10% in the bag (RW) & 20% - ½ mile (CB)* |
| Optimum (AMX) AcreMax Xtra | Cry1F Cry1Ab Cry34/35Ab1 | **BCW ECB FAW WBC** *CEW SB* | **RW** | RR2 | 10% *in the bag* |
| Optimum (AMXT) AcreMax XTreme | Cry1F Cry1Ab mCry3A Cry34/35Ab1 | **BCW ECB FAW WBC** *CEW SB* | **RW** | RR2 | 5% *in the bag* |
| **YieldGard / Genuity Trait Family** | | | | | |
| YieldGard VT Triple | Cry1Ab Cry3Bb1 | **ECB** *CEW FAW SB* | **RW** | RR2 | 20% in field/adjacent |
| Genuity VT Double PRO RIB Complete | Cry1A.105+Cry2Ab2 | **CEW ECB FAW** | --- | RR2 | 5% *in the bag* |
| Genuity VT Triple PRO RIB Complete | Cry1A.105+Cry2Ab2 Cry3Bb1 | **CEW ECB FAW** | **RW** | RR2 | 10% *in the bag* |
| Genuity SmartStax RIB Complete | Cry1A.105+Cry2Ab2 Cry1F Cry3Bb1 Cry34/35Ab1 | **BCW CEW ECB FAW SB WBC** | **RW** | LL RR2 | 5% *in the bag* |
| **Refuge Advanced Trait Family** | | | | | |
| REFUGE ADVANCED Powered by SmartStax | Cry1A.105+Cry2Ab2 Cry1F Cry3Bb1 Cry34/35Ab1 | **BCW CEW ECB FAW SB WBC** | **RW** | LL RR2 | 5% *in the bag* |

# Western Bean Cutworm Update

**Thomas E. Hunt, Extension Entomology Specialist**
**Ronald C. Seymour, Extension Educator**
**Jeff Bradshaw, Extension Entomology Specialist**
**Robert J. Wright, Extension Entomology Specialist**
**Silvana V. Paula-Moraes, UNL Entomology Dept. & Embrapa Brazil**
**Julie A. Peterson, Extension Entomology Specialist**

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

## Western Bean Cutworm in Corn and Dry Beans

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

### Life History

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

### Infestations on Corn

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

**Infestations on Dry Beans**

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

**Sampling Corn**

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

*Speed Scouting Tools: Spreadsheet & Mobile App*

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

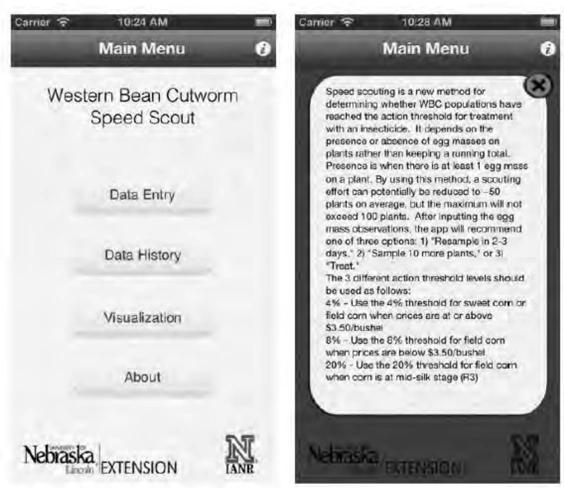



**Figure 1. Screenshots from the WBC Speed Scout mobile app**

**Sampling Dry Beans**

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

**Pest Management**

*Cultural Control*

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

*Host Plant Resistance*

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

*Biological Control*

Studies at UNL indicated that western bean cutworm eggs are susceptible to fungal infections that can reduce egg hatch by as much as 10% in dry bean and 25% in corn. An introduced egg parasitoid, *Trichogramma ostriniae*, has been shown to reduce WBC egg hatch by as much as 30% in corn and 50% in dry beans. Early instar western bean cutworms are exposed on the plant and vulnerable to predators. Thus, there are several predators that help reduce western bean cutworm infestations. Damsel bugs, ladybird beetle adults, spiders and perhaps other predators feed on both eggs and larvae up to the third instar. After the third instar of larval development, predation by birds can be beneficial. Blackbirds can cause high levels of mortality on western bean cutworm larvae found in the ear tips of corn plants, especially when the majority of ears are infested with cutworms. In addition to these natural enemies, western bean cutworm larvae are susceptible to a naturally occurring disease caused by the microsporidian, *Nosema* sp. Although these naturally occurring control methods are important in reducing western bean cutworm infestations, outbreaks that can cause economic loss in corn and dry beans are still common and may require insecticide applications for adequate control.

*Chemical Control*

Insecticide controls target the larval stage of western bean cutworms. Liquid insecticides applied by airplane or through a center pivot irrigation system typically provide acceptable control. Treatment in corn should target early instar larvae that are still active on the plant because effectiveness decreases as larvae mature and move into the ear to feed. There is some evidence that synthetic pyrethroid insecticides will force larvae out of protective areas due to the irritation properties of the active ingredient. These insecticides may be more effective should the larvae reach the silks prior to treatment. Foliar insecticides that contain *Bacillus thuringiensis* as the active ingredient do not control western bean cutworms. Current insecticide recommendations are available from your local Extension office or on the University of Nebraska–Lincoln

Department of Entomology website at *entomology.unl.edu*. **The incidence of spider mites in a field should be considered when choosing an insecticide.** Some synthetic pyrethroid insecticides may result in an increase (flare) of spider mite infestations. These products do not control the mites but will increase their dispersal within the canopy. Synthetic pyrethroids are also highly toxic to the natural enemies of spider mites, eliminating the population-regulating effect of these beneficial organisms. If spider mites are present and a synthetic pyrethroid is to be applied, the field should be sampled for the potential development of mite infestation and/or a miticide should be considered to be included in the spray mixture.

*Bt Traits*

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

**Western Bean Cutworm Populations in 2014**

UNL Extension Entomologists operate a network of black light traps across Nebraska to monitor WBC and other moth populations each summer. These traps are located in Concord (Northeast), Clay Center (Southeast), and North Platte (North Central). In 2014, North Platte had very high moth flights (cumulative 4,760 moths) compared to more moderate numbers in Clay Center and Concord (176 and 412 cumulative moths, respectively). Single night trap catches peaked at 469 moths on July 16 at North Platte, 18 moths on July 10 at Clay Center, and 81 moths on August 29 at Concord (Figure 2). Record rainfall and cool temperatures throughout the summer in northeast Nebraska resulted in a very late flight at the Concord location.

**Resistance Management Concerns**

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

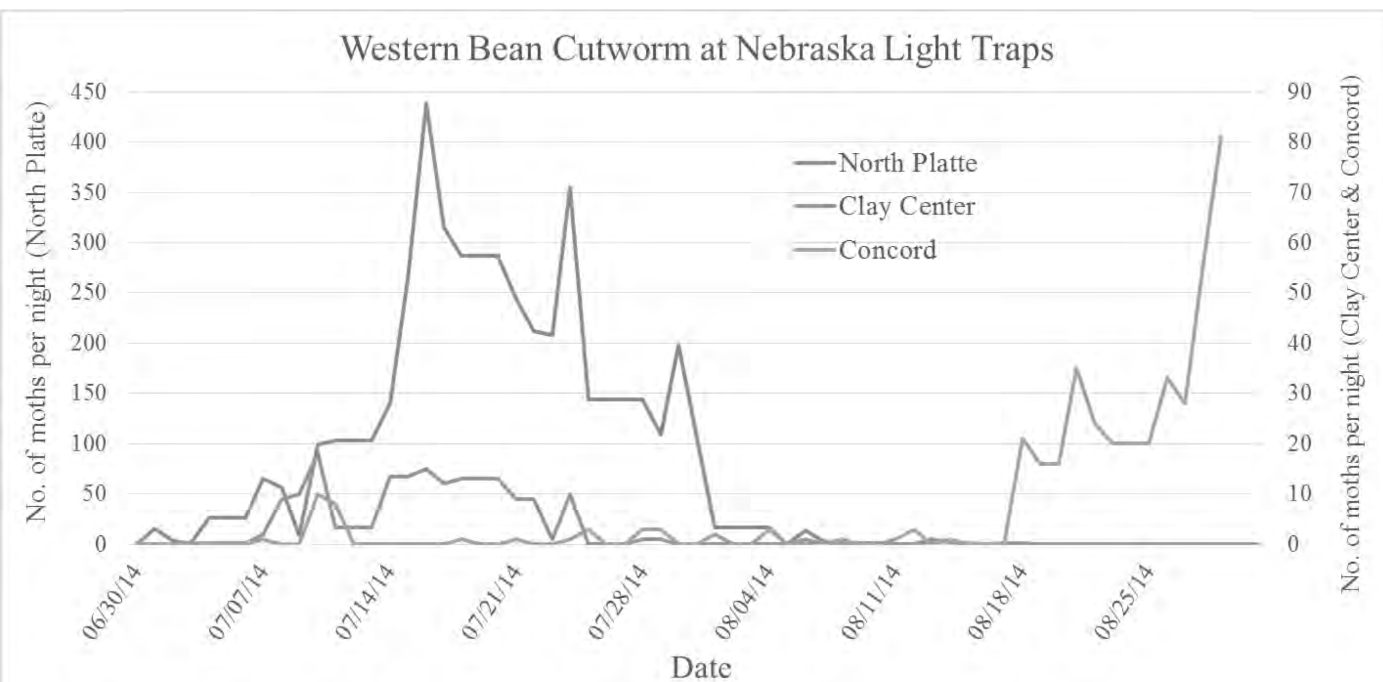



**Figure 2. Number of moths caught per night at North Platte (left axis), Clay Center (right axis), and Concord (right axis).**

# Host Plant Resistance to Insects

**Jeff Bradshaw, Extension Specialist**
**Tom Hunt, Extension Specialist**

Host plant resistance is an important tool for pest management in our cropping systems. They can help keep input costs for insect control low while conserving biological control agents. This article is a very brief overview of what host plant resistance is in respect to insect pest control.

### What is host plant resistance?

Plant resistance to arthropods (including insects) was originally define in the early 1950s as, *the consequence of heritable plant qualities that result in a plant being relatively less damaged than a plant without these qualities*. Some important things to note from this definition is that host plant resistance (HPR) is relative. That is, resistance is measured as a comparison between varieties. For example, if variety "A" constantly supports fewer grain aphids than variety "B", we say that variety "A" is resistant. As an IPM control tactic, HPR has the benefit of being compatible with the broad range of other control tactics that are available to producers. However, it is also important to note that most HPR can succumb, just like any other insect control tactic, to an insect population's ability to develop resistance against HPR.

The first insect "resistance" was documented in 1788 in wheat to the Hessian fly. While effective, this resistance wasn't a true resistance in the sense that breeders had simply selected wheat varieties that developed faster to avoid having to grow wheat when Hessian flies were present during the season. The first actual HPR was later identified in wheat to the Hessian fly in 1792 in the cultivar 'Underhill'. Perhaps the most famous historical trends provided by HPR was the "Green Revolution" during the 1960s. This event marked the introduction of high-yielding, HPR rice varieties to southeast Asian. The tremendous economic growth in much of that region today can be attributed to these HPR rice varieties. Just one rice variety, IR36, provided an estimated $1 billion of additional income to rice producers to countries in which it was deployed!

Host plant resistance is roughly divided up into three types: antibiosis, antixenosis, and tolerance. Each of these resistance types may operate separately or in combination. As a result it can be difficult to evaluate these modes separately; however, impact the pest populations in different ways as defined below.

*Antibiosis*: A type of host resistance that affects the **pest's biology** such that its abundance and subsequent crop damage is reduced compared to that of a susceptible variety. This kind of HPR usually results in an increased mortality rate of the pest or reduced longevity and reproduction of the pest. Antibiotic properties of a resistant host can also prolong the development of a pest and increase the effectiveness of other risks to the pest (e.g., improved biological control).

*Antixenosis*: A type of host resistance that affects the **pest's behavior** and is often expressed as a non-preference of the pest for a resistant plant as compared to a susceptible plant. This type of resistance usually results in a reduced pest density on a resistant plant, relative to a susceptible plant, by way of improved establishment on the susceptible plant (i.e., not by way of increased mortality, delayed development, etc. on the resistant plant).

*Tolerance*: A type of resistance in which the **resistant plant tolerates** (or recovers from) a higher infestation of a pest relative to a susceptible plant. Unlike antibiosis and antixenosis, this type of resistance does not reflect a response from the insect, but rather a response by the plant to the insect. Because tolerance does not negatively affect the insect, there is no selection pressure on the insect, so resistance developing to tolerance is not an issue.

None of these types of HPR are mutually exclusive and could act either alone or in concert. Additionally, the mechanisms underlying these types of HPR are varied with much ongoing research into the chemistries and genetics involved.

### What are the advantages and disadvantages of host plant resistance?

There are primarily three advantages of HPR. First, the cost of control is equal to the cost of seed. This is a benefit as the scale of which seed is produced usually translates into a much costly control measure for the producer. Second, there are improved ecological benefits through reduced pesticide use and reduced mortality of beneficial arthropods. Obviously, there is no personal protection equipment required with the use of HPR and no risk to the user. Also, HPR is very specific to insects or insect stages that feed on the crop plant. Therefore, there are rarely any deleterious effects on biological control activities or on the greater environment. Thirdly, in many cases an increased efficiency of biological control activity has been reported with the deployment of HPR strategies. This improved biological control is because for some HPR (antibiotsis in particular), the pest experiences reduced vigor or a decreased physiological state. This depressed population characteristics then allow greater chances for biological control agents to act on the pest.

There are also some disadvantages to HPR. First, HPR takes time to develop. For a newly emerging pest or one for which its pest status has suddenly increased, other pest control strategies are often faster to deploy. In most cases, we look to early cultural or chemical control tactics for a rapid or first response to a pest outbreak. Second, much of the biology of the pest and their interaction with host plants much be known well before an HPR strategy can be deployed. Third, there has been some evidence for some

HPR mechanisms that some of the plant defense compounds produced by resistant plants can enable some pest populations to develop a better ability to detoxify insecticides and miticides. And finally, as noted above, resistance is relative and some level of insects is often found on resistant plants. For antibiosis and antixenosis, this is typically a low number of insects and of no economic concern, although the insect population should be monitored. Tolerant plants will often have various levels of insects. They are not immune to insect injury, but can withstand many more insects before economic damage occurs, and the damage is less severe than that resulting from similar insect levels on non-tolerant plants.

# Newer Modes of Actions for Insecticides in Nebraska Field Crops

**Robert J. Wright, Extension Entomology Specialist**

For many years we have been relying on organophosphate, carbamate, and pyrethroid insecticides for control of field crop insect pests in Nebraska. With the passage of the Food Quality Protection Act by Congress in 1996, the EPA has been mandated to review registrations of many older insecticides. In many cases insecticide registrations have been cancelled, or the label has been modified to remove uses on certain crops. Many commonly used insecticides, such as methyl parathion, carbofuran and others, are no labelled for many of their past uses in Nebraska field crops.

In their place there has been increased reliance on pyrethroid insecticides, and more recently neonicotinoid insecticides as seed treatments or as foliar sprays.

Anytime we rely on a single or few modes of actions for our insecticides we run the risk of insecticide resistance development.

To minimize the risk of resistance development, it is important to use insecticides with a diversity of modes of action. There are several newer modes of actions available in insecticides labelled for insect and mite control on Nebraska field crops. This article will review several active ingredients with newer modes of action, the products that contain them, and some of the common Nebraska field crops for which they are labelled. Refer to product labels for complete information on rates, restrictions and crops labelled.

One reason the pyrethroid insecticides have been widely used is that many have a broad spectrum of activity against many different insects and mites. Some of the newer insecticides described below have a narrower spectrum of activity (e.g., primarily active against Lepidoptera), so they may not be the best choice in all situations. On the other hand, more selective products may be safer to natural enemies of pest insects, and less likely to produce pest resurgence.

The Insecticide Resistance Action Committee (IRAC) (http://www.irac-online.org/) is an industry group that works to classify the modes of action of new insecticide chemistries as they are commercialized. These IRAC codes are now being included on the first page of many product labels so you can easily identify products with different modes of action. We are also including this information in the Insecticide use section of UNL Extension Circular 130, Guide for Weed Management in Nebraska with Insecticide and Fungicide Information.

IRAC Code 4C; sulfoxaflor

**Sulfoxaflor**; Transform® WG; Dow AgroSciences. Labelled on barley, triticale, and wheat for control of greenbugs; on sugar beets for control of aphids and leafhoppers; on potatoes for control of aphids, leafhoppers and potato psyllid; on dry beans for control of aphids and plant bugs; on soybean for control of soybean aphid.

IRAC Code 5; spinosyns

**Spinosad**; Tracer, Entrust, Success; Dow AgroSciences. Labelled on for control of lepidopteran larvae on corn, soybean, sorghum, grass forages, grass grown for seed, pastures, rangeland and sod farms, barley, buckwheat, oats, rye, tricale, and wheat.

IRAC Code 10A; clofentezine; hexythiazox

**Hexythiazox**; Onager® Miticide; Gowan Company. Labelled on dry beans (west of Highway 281) for control of twospotted spider mite; on field corn for control of Banks grass mite and twospotted spider mite; on sorghum (west of Highway 281) for control of Banks grass mite and twospotted spider mite.

IRAC Code 10B

**Etoxazole**; Zeal® Miticide; Valent U.S.A. Corporation Agricultural Products. Labelled for control of Banks grass mite, twospotted spider mite on field corn, popcorn, corn grown for seed.

IRAC Code 18; diacylhydrazines

**Methoxyfenozide**; Intrepid® 2F; Dow AgroSciences. Labelled for control of European corn borer, true armyworms, western bean cutworm on field corn, popcorn, seed corn; for control of armyworms on grass forage, fodder and hay crops; for control of several lepidopterous larvae on dry beans, soybeans, alfalfa and other non-grass forage, fodder and hay crops.

IRAC Code 22A; indoxacarb

**Indoxycarb**; Steward® EC; E. I. du Pont de Nemours and Company. Labelled for control of several lepidopterous larvae on alfalfa, alfalfa grown for seed, and soybeans.

IRAC Code 23; tetronic and tetramic acid derivatives

**Spiromesifen**; Oberon®4SC; Bayer CropScience. Labelled for control of Banks grass mite and twospotted spider mite on field corn and popcorn, for control of potato/tomato psyllid, and twospotted spider mite on potato.

IRAC Code 28; diamides

**Chlorantraniliprole**; Prevathon®; E. I. du Pont de Nemours and Company. Labelled for control of several lepidopterous larvae on field corn, popcorn, seed corn, soybean, sunflower, dry beans, grass forage, fodder and hay, nongrass animal feeds including alfalfa, cereal grains including wheat, barley, sorghum, oats, and triticale.

**Flubendiamide**; Belt® SC, Bayer CropScience; Labelled for control of several lepidopterous larvae on field corn, popcorn, seed corn, soybeans, alfalfa, sorghum, sunflowers and dry beans.

For more information see:

IRAC Mode of Action Classification; http://www.irac-online.org/documents/moa-classification/?ext=pdf

Wright, R. J. 2011. Insecticide Mode of Action Classification for Nebraska Field Crops. NebGuide G2066. University of Nebraska Extension.

# Wheat stem sawfly in Nebraska – 2014 update

**Jeff Bradshaw, Entomologist**
**Susan Harvey, Entomology Research Technician**
**Chris McCullough, Graduate Research Assistant**

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).

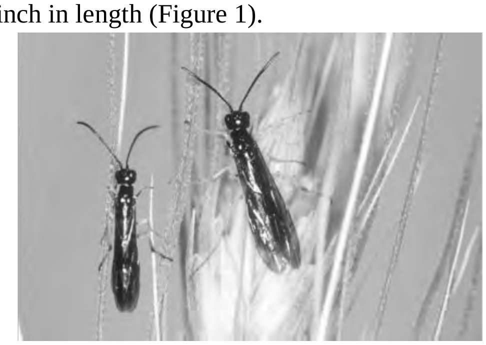


**Figure 1. Adult wheat stem sawflies (Photo: J. Kalisch, Department of Entomology)**

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

However, only one larva (Fig. 2) will survive in each stem.

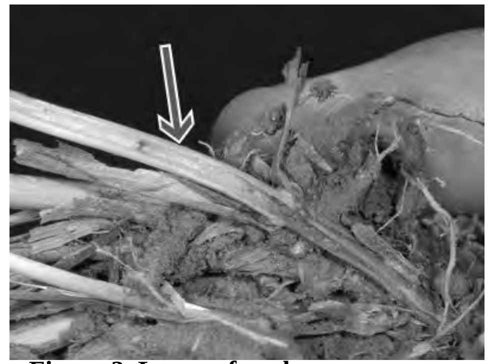


**Figure 2. Larva of a wheat stem sawfly in a wheat tiller.**

### Plant damage

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

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

### Management

**Cultural control**

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.

**2014 Report to the Nebraska Wheat Board**

A research project concerning wheat stem sawfly was supported by the Nebraska Wheat Board. The following is a report of this project. The purpose of this project is to gain a better understanding of the sawfly's emergence and movement into the wheat. Understanding the density and the location of sawflies will aid in the correct timing and location of management tactics.

**Methods**

The emergence and movement of the sawfly was measured with emergence cages, yellow sticky traps, and sweep net samples. In addition to learning about the movement of the sawfly, insights on each of the sampling methods were gained. All three sampling methods were used at three fields located near Hemingford, Gurley, and McGrew. As well as differences with location, the fields had other differences worth noting. The variety planted at McGrew and Gurley was Goodstreak, while Settler was planted at Hemingford. The McGrew field was planted in strips 250 feet wide as opposed to the large blocks at Gurley and Hemingford. This creates a different sized source for the population of emerging sawflies. This field also suffered from a heavy infestation of weeds, primarily downy brome, which may have played a role in the numbers observed there. The field near Gurley was split by an access road for oil pumping machinery as well as an area on the edge that was not planted to wheat because of a power line. Despite the differences, each field bordered the stubble from last year's wheat that contained emerging sawflies.

At each location yellow sticky traps were placed at five distances in each transect, on the edge of the wheat, 5, 10, 20, and 30m into the wheat field. These transects where then repeated 14 and 16 times at Gurley and Hemingford. There were 18 transects at McGrew, because of the nature of the field nine transects were placed on each side of the fallow. The sticky traps were checked and changed weekly. The location of each trap also served as a marker for a sweep net sample. A 20-sweep sample was taken in the direction of the rows with 10 sweeps being taken on each side of the sticky trap. Sweep net samples were taken from each location biweekly. Three sets of five emergence cages were placed in the fallow at each field to monitor emergence. Emergences cages were checked biweekly. All sawflies gathered were sexed and counted. Sampling began on May 9th and continued until sawflies were no longer caught. The last sampling date was July 1st.

**Results and Discussion**

Sawflies were first caught on May 19th at McGrew (Figure 1), May 20th at Gurley, and May 28th at Hemingford in the sweep net samples. It is worth noting that the first sawflies caught were by sweep net samples and not emergence cages or sticky traps. Peak emergence as recorded by the samples occurred in McGrew on May 29th, June 3rd at Gurley, and June 4th in Hemingford. The flight period was over June 23rd in McGrew, June 24th in Gurley and July 1st in Hemingford. The flight period lasted 35 days at both McGrew and Gurley, while it was one day shorter at Hemingford. The dates recorded only represent the time that the fields were sampled, the actual date of the events may have occurred before the sampling date.

Throughout the flight period, the sex ratio of males to females points to a greater number of males being present. The size of the ratio varies depending on the date and location of the sample in the field, but the trend is similar. Leading up to peak emergence, the ratio favors males at all distances. Following peak emergence males only maintain a ratio in their favor near the field edge.

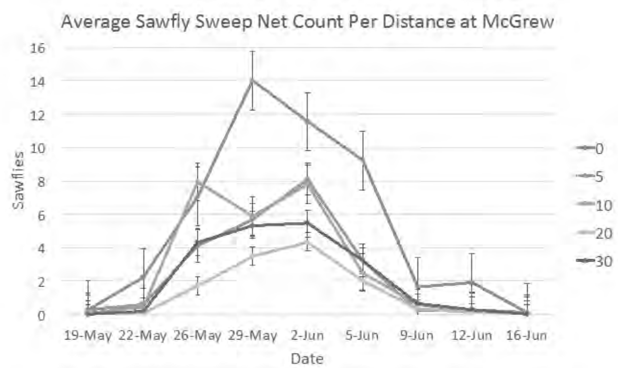



**Figure 1. Average number of wheat stem sawfly per 20 sweeps at 0, 5, 10, 20, and 30 meters from the field edge through the growing season.**

The farther in the field the sample is taken the male to female ratio is smaller or becomes reversed. When more females are caught than males, the ratio is not as great as when more males are caught. This is reflected in both the sweep net and sticky trap data. Emergence cage data reflects a different trend. The data from the emergence cages reflects a 1:2 or 1:3 ratio of males to females. The reason for the reversal of the trend can only be hypothesized. It is possible that the smaller males found a way out of the cages or simply did not move up into the collection jar. While it is possible that the data is correct, the trends observed with the other sampling methods indicate otherwise.

The last trend that was observed was a decline in adults the farther in the field a sample was taken, this is known as an edge effect. The edge effect was previously described in Montana by cutting stems and checking for the presence of a larva. With that data they were able to construct an equation to predict larval infestation levels into a wheat field. The data gathered with the adults can be used to construct a similar equation for the adult sawflies, which in turn can give an estimate to the level of infestation in the wheat. Sweeping for adults would be a faster and easier method for determining infestation than pulling and splitting stems to check for larvae. A sampling method based on adults would be subject more variability since there is normally one larva per stem even though multiple eggs may have been placed in a stem. The inverse of this presence of a larva is not a reflection of the population of the sawflies that was present, it is a reflection of the sawfly that laid its egg first and escaped parasitism. It might also reflect cannibalism of a parasitized conspecific.

Large numbers of Bracon parasitoids were found near Hemingford. Pre-harvest sampling was conducted to compliment the data that was gathered while sampling the sawfly. While similar conclusions can be made of the distribution of the parasitoids can be made, the data of interest is the population levels of the second generation of parasitoids. It is the success of the second generation of parasitoids that determine the population for the next year. The second generation has to deal with the challenges presented by harvest in either find sawfly larvae in stubs or having laid its egg low enough in a wheat stem so that it is not cut out. Sampling for adults in July is a challenge as sweep net sampling or even walking through a field can cause weakened wheat to lodge. For that reason the number of samples taken was reduced when sampling for the parasitoids.

# Corn Rootworm Management Update

**L. Meinke, Professor of Entomology, D. Wangila, Entomology Graduate Research Assistant, R. Wright, T. Hunt, J. Peterson, Extension Entomology Specialists 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 2012-2014.

## Lab Bioassays

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

### Lab Bioassays: Results

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

## Field Trials

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

### 2013 Field Trials: Key Results

<u>Cry3Bb1</u>

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

<u>mCry3A</u>

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

<u>Cry34/35</u>

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

The at-plant soil insecticide provided a significant root protection benefit only when applied to non-Bt near-isoline treatments or single traits exhibiting greater than expected relative injury (i.e., <u>Relative root protection:</u> Cry3Bb1 + insecticide: average of 3 problem fields = 81.3% control; Cry3Bb1 + insecticide: control site= 95.3% control; mCry3A + insecticide: average of 3 problem fields = 80% control; mCry3A + insecticide: control site =92.4% control. Little root protection benefit was obtained by adding soil insecticide to single trait Cry34/35 (average across 4 sites =

95.6 % control) or pyramids containing Cry34/35 (Cry34/35 + Cry3B1 average control across four sites = 95.2 %, Cry34/35 + Cry3Bb1 + insecticide: average control across four sites = 95.7 %; Cry34/35 + mCry3A: average control across four sites = 94.3%; Cry34/35 + mCry3A + soil insecticide: average control across four sites =96.5%.

**Overall Conclusions**

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

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

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

**General corn rootworm management recommendations**

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

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

2. If you must plant corn after corn:

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

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

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

**IRAC Statement**

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

Insecticide Resistance Action Committee
www.irac-online.org

Version 1.6, 04.09.2014

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

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

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

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

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

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

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

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

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

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

**Table 1. Entries included in 2013 field trials.**

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

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

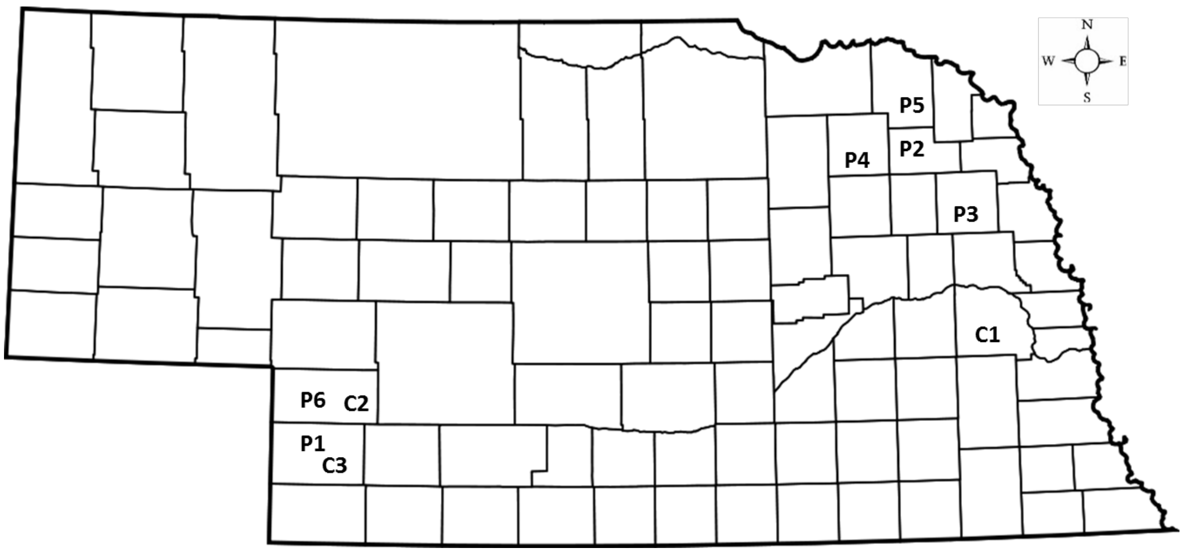



**Figure 1**: **A map of the state of Nebraska showing distribution of sites sampled in 2012. Sites beginning with P were Cry3Bb1 history/problem fields, sites beginning with C were control fields.**

NebGuide

IANR

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

Know how. Know now.

University of Nebraska Lincoln

G2082

# Soybean Stem Borers in Nebraska

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

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

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

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

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

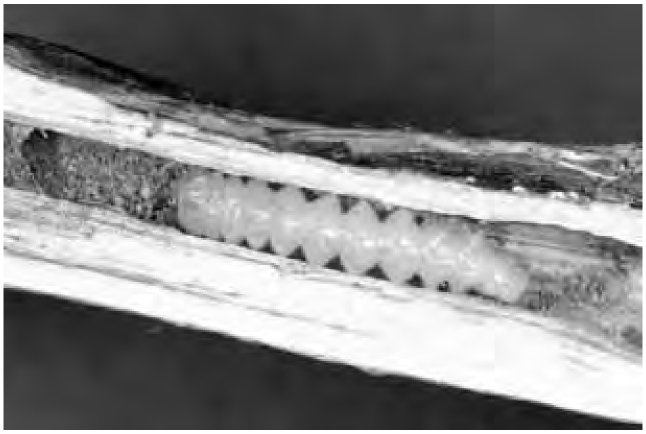


**Figure 2. Larval soybean stem borer, *Dectes texanus texanus.***

## Description and Life Cycle

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

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

## Injury Symptoms

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

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

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

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

## Management

### Cultural Controls

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

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

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

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

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

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

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

### Chemical Controls

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

## Recommendations for Harvest

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

**This publication has been peer reviewed.**

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

**File under: Insects & Pests**
**Field Crop Insects**
Issued May 2011

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

# Checkup for Pivot Efficiency

**Bill Kranz**
**Derrel Martin**

The goal of all center pivot irrigation systems is to deliver irrigation water in uniform manner based upon the management scheme of the operator. If the initial field reconnaissance has taken place correctly, the field elevation change, the flow rate, the pump outlet pressure and pumping water level all combine to match up with sprinkler requirements. Life is good.

But what should be done with systems that have been in the field for several years? It's not difficult to find some center pivots that are not functioning properly. In fact, it is much easier to find center pivots with problems than one might think. There are several aspects of poor maintenance practices that can have a very detrimental impact on water application uniformity. The first is that the extra water coming out of the sprinkler coupler or the leaky boot is more than is necessary for that location of the field. Secondly, because there is more water being delivered in these problem areas, it is quite likely that the pressure delivered to every other sprinkler on the system is less than the sprinkler design chart calls for. So what looks to be affecting a small area of the field is actually affecting the whole area. Sprinkler cost is generally less than $40, and replacing a boot is not a bank breaker either.

Another scenario we see a fair amount involves placing a sprinkler that the field manager just happened to have around so that the geyser discussed earlier is not visible. Most times the field manager has good intentions of replacing the sprinkler with the correct one. But then a week or two goes by and now the field manager has forgotten to purchase that replacement and he also needs to remember just which one of the sprinklers needs to be replaced. One field actually had 3 different types of sprinklers installed on the pivot. The long term issue with making these temporary fixes is that the sprinkler may not have the appropriate distribution pattern and in most cases the volume of water delivered in these areas is not even close to what is on the sprinkler package chart. If the sprinkler in question is near the outside edge of the center pivot, one sprinkler can cause problems for a great number of acres. Again, $30 will buy a replacement the fits the system.

A third problem that has been documented is that the current flow rate and pressure does not match the design of the sprinkler package. Consider a situation where the original design of the sprinkler package called for 750 gallons per minute (gpm) at 40 pounds per square inch (psi) at the pump outlet. Now change the situation so that the pump outlet pressure is only 30 psi. The flow rate at 30 psi is close 660 gpm and the part of the system most impacted is at the distal end of the pivot where again, a large number of acres are impacted not only by the reduced flow rate, but the water distribution pattern for the system is altered in a negative way. So the field productivity suffers every year the center pivot is operated at the reduced flow rate and pressure. Installing, maintaining and monitoring the pressure being supplied to the center pivot using a $40 pressure gauge will help identify when this sort of problem is developing.

The fourth problem is where sprinklers have exceeded their expected lifetime and just cease to function properly. For example, when sprinklers that rotate begin having issues, two things normally happen: 1) the deflection pad begins to rotate at a much faster rate; and 2) the sprinkler seizes up and stops rotating all together. In both cases, water continues to be distributed by the sprinkler. However, the water distribution uniformity delivered by the sprinkler that seizes up is much lower than it should be because the deflection pad is no longer rotating. Remember that sprinklers are designed for an expected lifetime of about 12-13,000 hours of operation. So if your sprinklers have been on your system for 15 years, there is a good chance that some of these problems have already started. The interesting thing about this problem is that the sprinklers with these problems are easy to spot from the edge of the field and are obvious if one does a walk by regularly during the irrigation season.

The fifth problem that developed in recent years is restricted to those systems that are used to irrigate corn and other tall crops. Several years back, corn hybrids grew to a final height of between 8 and 9 feet. More recent hybrids grow to a final height of 12 feet or more. Thus, tall corn means that low pressure spray sprinklers installed on drop tubes will be operating in the corn canopy for much of the irrigation season. The corn leaves intercept the water pattern which can have devastating effects on grain yield. Field data collected in western Nebraska a few years back found that corn yield half way between the sprinklers was 40 bushels per acre less than directly under the sprinklers mounted on drop tubes. The issue here was not that the sprinklers were operating in the crop canopy. The issue was that the sprinkler spacing was too wide when irrigating these new corn hybrids. Work conducted in Nebraska and Kansas suggests that the maximum spacing between sprinklers should be less than 7.5 feet if the system is used to irrigate corn. Again, it is easy to eliminate this problem. If this system was used to apply fertilizer, both water and fertilizer were not applied very uniformly.

The final problem is where the sprinklers are not installed on the center pivot in the correct positions. And yes it still happens on occasion. One new center pivot had a mixture of sprinklers installed between the 5 and 6 towers. The owner did not check the system out but the yield monitor on his combine showed that the corn yield dropped by 80 bushels per acre in the area irrigated by the 5th span. The producer was not impressed to say the least. These sorts of problems can be eliminated by comparing the sprinkler package design chart with the sprinklers that are installed on the pivot. Unless one avails themselves of some of the sprinkler replacement issues described earlier in this article, verifying the sprinkler package should only need to happen once in the lifetime of the sprinkler package. The printout gives coupler number, sprinkler nozzle size, and distance from the pivot point. Most printouts are placed in the pivot control panels. If not, contact the business who installed the sprinkler package and request a copy of the printout.

Most of the items described above are quite easy to remedy. The fix is normally not very expensive, often less than $100, and does not require very much time. However, failure to keep in touch with your center pivot can result in reduced yields that have a significant impact on your bottom line. So evaluate your center pivot to determine if you have one or more of these issues. If you do, fix the problem now before it has a chance to cheat you out of income.

# University of Nebraska–Lincoln Extension
# Irrigation Water Apps
# Developed to help agriculturalists better manage irrigation water resources

## CropWater App

**The University of Nebraska–Lincoln Extension Crop Water App was developed at the request of Nebraska Agricultural Water Management Network (NAWMN) participants. This app provides an easy way to estimate soil water status based on Watermark sensors. Users have the option to input readings for sensors installed at depths of 1, 2, 3 and 4 feet. With these sensor readings, the CropWater App will estimate the amount of water used from the soil profile, as well as what is still available. You can view historic sensor readings and graphs and can also pin your GPS location for the fields. A new feature is the last irrigation calculator which allows users to input crop growth stage and sensor values and will help determine how much irrigation or rainfall is needed.**

iOS/Apple store link:
http://go.unl.edu/tkht

Android store link:
http://go.unl.edu/hkg

YouTube instructional video link:
http://youtu.be/EhToqgbG1kY

## Water Meter Calculator App

**The UNL Extension Water Meter Calculator App will help you calculate the number of inches of irrigation water applied over a given time and can apply it to your yearly and multi-year allocation caps. The app will calculate the amount of water applied to each respective field over the given time period.**

iOS/Apple store link:
http://go.unl.edu/zn2g

Android store link:
http://go.unl.edu/4a8h

YouTube instructional video link:
http://youtu.be/ygIXBQoE5ZU

IANR

University of Nebraska Lincoln EXTENSION

# University of Nebraska–Lincoln Extension
# Irrigation Water Apps
# Developed to help agriculturalists better manage irrigation water resources

## IrrigateCost App

**This UNL Extension Agriculture Irrigation Costs App computes the annualized costs of owning and operating an irrigation system. A number of management decisions are based on the annualized costs of owning and operating an irrigation system. Before developing land for irrigation, the first decision should be to determine whether the irrigation system will be economically feasible. In other words, will the net income from increased yields achieved by irrigation development exceed the added costs of owning and operating the system over its expected life? The IrrigateCost app models center pivot and gated pipe irrigation systems and the most commonly used energy sources. The app is also useful for determining a fair lease agreement when using a pivot to water a neighbor's field.**

iOS/Apple store link:
http://go.unl.edu/dzvn

Android store link:
http://go.unl.edu/w0m9

YouTube instructional video link:
http://youtu.be/6Z0ooqipvYI

## IrrigatePump App

**The Irrigation Pumping Plant Efficiency Calculator developed by UNL Extension calculates pumping plant's efficiency powered by diesel, electricity, gasoline, natural gas, or propane. It also can estimate potential savings of system upgrades or adjustments. This app is based upon the Nebraska Pumping Plant Performance Criteria (NPPPC), a standard used by irrigation design engineers worldwide. Defining the original criteria involved manufacturers, Nebraska Tractor Test data, and field evaluations of pumping installations.**

iOS/Apple store link:
http://go.unl.edu/fx9x

Android store link:
http://go.unl.edu/dtxu

YouTube instructional video link:
http://youtu.be/be3N9rQ4Xuk

# Applying Pesticides Safely

**Clyde L. Ogg, Pesticide Safety Educator and Ben Beckman, Extension Assistant**

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

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

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

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

- *Pesticide Laws and Regulations G479*
- *Worker Protection Standard for Agricultural Pesticides G1219*
- *Nebraska Pesticide Container and Secondary Containment Rules G2033*
- *Understanding the Pesticide Label G1955*
- *Spray Drift of Pesticides G1773*
- *No Drift Zone: Driftwatch Brochure*
- *Protective Clothing and Equipment for Pesticide Applicators G758*
- *Pesticide Safety: Choosing the Right Gloves G1961*
- *Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications G2083*
- *Pesticides and the Endangered Species Protection Program G1893*
- *Protecting Pesticide Sensitive Crops G2179*
- *Bee Aware: Protecting Pollinators from Pesticides EC301*
- *Rinsing Pesticide Containers G1736*
- *Cleaning Pesticide Application Equipment G1770*
- *Managing Pesticide Spills G2038*
- *Managing the Risk of Pesticide Poisoning & Understanding the Signs & Symptoms EC2505*
- *Safe Transport, Storage, and Disposal of Pesticides EC2507*

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

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

http://facebook.com/UNLPSEP
Facebook

http://twitter.com/UNL_PSEP
Twitter

http://youtube.com/UNLExtensionPSEP
YouTube

NebGuide

University of Nebraska Lincoln

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

Know how. Know now.

G479
(Revised April 2013)

# Pesticide Laws and Regulations

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

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

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

## FIFRA

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

### General Provisions

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

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

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

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

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

## Nebraska Pesticide Act and Regulations

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

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

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

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

**Pesticide Applicator Licensing**

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

To become certified as a private applicator, individuals can:

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

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

**Commercial and Noncommercial Pesticide Applicator Categories**

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

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

**Direct Supervision**

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

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

**Recordkeeping Requirements — Commercial and Noncommercial Applicators**

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

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

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

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

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

**Recordkeeping Requirements — Private Applicators**

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

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

**Spot treatments — Recordkeeping**

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

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

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

**Access to RUP Application Records**

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

**Recordkeeping Requirements — Distributors/Dealers**

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

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

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

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

**Violations and Penalties**

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

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

**Resources**

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

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

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

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

**This publication has been peer reviewed.**

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

**Index: Pesticides, General Regulations**

1979, 2002-2007, Revised April 2013

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

G1219
(Revised September 2012)

# Worker Protection Standard for Agricultural Pesticides

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

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

The U.S. Environmental Protection Agency (EPA) issued the Worker Protection Standard (WPS) to protect employees working on agricultural establishments from exposure to agricultural pesticides, both general and restricted use. Similar to OSHA (Occupational Safety and Health Administration), WPS strives to provide employees with a safe workplace, with the obligation for safety falling on the employer. WPS requires employers to protect two types of agricultural employees: *agricultural workers* and *pesticide handlers* (see definitions below). WPS is part of the pesticide label and is enforceable when a pesticide with a label that references WPS is used to produce an agricultural crop or commodity.

An EPA manual, *How to Comply with the Worker Protection Standard for Agricultural Pesticides–What Employers Need to Know* provides detailed information about WPS. Employers will find this manual to be a valuable resource for compliance. The manual is available in paperback or CD format from the Nebraska Department of Agriculture (NDA) at no cost, or can be viewed online at *www.epa.gov/agriculture/htc.html*.

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

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

## WPS Labeling

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

## Who Are the Affected Employers?

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

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

Most provisions of the Worker Protection Standard are protections that employers must provide to their employees and, in some instances, to themselves. The task being performed will determine whether or not an employee is a worker or handler, and will determine the amount of protection the employer must provide. Owners of agricultural establishments and their immediate families are exempt from many, but not all, of the WPS requirements (refer to the *How to Comply with the Worker Protection Standard for Agricultural Pesticides–What Employers Need to Know* manual, listed in the Resources section, for details).

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

1. **Wear appropriate personal protective equipment (PPE)**
The personal protective equipment and other work attire required for each pesticide are listed on the pesticide label for the tasks being performed. The required equipment for a specific pesticide is listed under the *Hazards to Humans* section on the label. These requirements may be different for applicators and mixer/handlers. If an applicator is using a closed system or working in an enclosed cab, some protective equipment exceptions are allowed unless expressly prohibited by the product labeling. Required equipment must be within the cab, however, to protect the person if the rig were to break down. Always use the PPE listed on the label. Refer to the *How to Comply* manual for additional details.
2. **Restrictions during pesticide applications**
During the application of pesticides, handlers and/or their employers must make sure that:
   - All label requirements are followed,
   - Pesticides are applied so that they do not contact anyone either directly or through drift, and
   - Everyone is kept out of treated areas during the treatment.

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

### Basic Duties of Employers of Pesticide Handlers and Agricultural Workers

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

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

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

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

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

**Decontamination supplies.** Employers must provide supplies so that workers and handlers can wash pesticide**s** or their residue**s** from their hands and bodies. Accessible decontamination supplies must be located within a quarter mile of all workers and handlers and must include:

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

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

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

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

### Additional Duties for Employers of Workers

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

**Restrictions after applications.** Employers must notify workers about pesticide applications on the establishment and the product's REI if workers will be on or within a quarter mile of the treated area. In most cases, employers may choose between oral warnings or posted warning signs concerning the REI. In either case, employers must tell workers which warning method is being used. Some pesticide labels may require both oral and posted sign warnings. All notifications regarding greenhouse applications must be posted.

**Posted warning signs.** Warning signs must be:

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

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

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

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

### Additional Duties for Employers of Handlers

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

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

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

**Personal protective equipment.** Employers must provide handlers with the personal protective equipment required by the pesticide labeling for each task. They also must provide handlers with a pesticide-free work area for storing personal clothing, as well as for changing into and out of personal protective equipment for each task. Employers must not allow any handler to wear or take home any used personal protective equipment. They must make sure PPE is worn and used correctly, and make sure respirators fit correctly.

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

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

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

**PPE cleaning and maintenance.** The employer must make sure that:

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

**Replacing respirator purifying elements.** Dust/mist filters must be replaced when breathing becomes difficult, if the filter is damaged or torn, when the respirator label or pesticide label requires it, or at the end of each day's work period in the absence of any other instructions. Cartridges or canisters designed to remove vapors must be replaced when odor, taste, or irritation is noticed; when the respirator label or pesticide label requires it; or at the end of each day's work period in the absence of any other instructions.

**Disposal of PPE.** Discard coveralls and other clothing that are heavily contaminated with an undiluted pesticide having a DANGER or WARNING signal word, according to directions on the pesticide label. Federal, state, and local laws must be followed when disposing of PPE that cannot be cleaned correctly.

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

### Employer/Commercial Applicator Information Exchange

To protect the agricultural owner/operator and his or her family, a commercial applicator must inform an agricultural owner/operator before a pesticide is applied on the agricultural establishment. The commercial applicator must provide the owner/operator with the following information.

- Location and description of area to be treated
- Time and date of application
- Product name, EPA registration number, active ingredients, and REI
- Whether postings at the treated area and/or oral warnings are required
- Entry restrictions and other safety requirements for workers or other people

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

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

**Emergency medical assistance.** When there is a possibility that a handler or worker has been poisoned or injured by a pesticide, an employer must promptly provide transportation to an appropriate medical facility. Information about the medical facility must be posted at a central location. In addition, the employer must provide the victim and medical personnel with the following information.

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

### Exemptions

The WPS does not cover pesticides applied:

- On pastures, rangeland, or livestock;
- On the harvested portions of plants or on harvested timber;
- For control of vertebrate pests, such as rodents;
- On plants grown in home gardens and home greenhouses;
- On plants that are in golf courses (except those areas set aside for plant production) or right-of-way areas;
- On public or private lawns, although sod farms are covered by the WPS;
- On plants intended only for decorative or ornamental use, such as trees and shrubs in lawns;
- For mosquito abatement, or similar wide area public pest control;
- For structural pest control, such as termite control; or
- For research uses of unregistered pesticides.

### Agricultural Owner Exemptions

Owners of agricultural establishments and members of their immediate family are exempt from some of the WPS requirements while performing tasks related to the production of agricultural plants on their own establishment. The following WPS requirements **do not** need to be met by owners or members of their immediate family but must be provided to any worker or handler they may hire.

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

### Exceptions to REIs

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

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

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

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

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

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

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

### Crop Advisor Exemptions

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

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

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

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

#### Resources

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

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

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

**This publication was peer reviewed.**

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

**Index: Pesticides, General Regulations**
1994, Revised September 2012

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

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

G2033

# 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:

**Container Disposal**
***Nonrefillable Container. DO NOT*** reuse or refill this container. Triple rinse or pressure rinse container (or equivalent) promptly after emptying; then offer for recycling, if available, or reconditioning, if appropriate, or puncture and dispose of in a sanitary lanldfill, or by incineration, or by other procedures approved by state and local authorities.

**Figure 1. Example of label language on a nonrefillable container**

- Meet basic Department of Transportation (DOT) requirements in the Code of Federal Regulations (49 CFR 173.24).

Packaging for all other products (Restricted Use Products (RUP) and/or toxicity categories I or II) must meet the nonrefillable container requirements. Nonrefillables must:

- Meet certain requirements for DOT construction, design, and marking (for example, five-gallon or smaller containers should be capable of 99.99 percent residue removal; three-gallon or smaller containers require special lids).
- Be vented so product does not surge and pours in a continuous stream (for example, not "glug"); there also should be minimal dripping outside the container.

Labels for nonrefillables identify them as nonrefillable containers with a "Do not use" statement. The label also contains cleaning/rinsing and disposal instructions, recycling instructions, and a lot number identifying the batch.

### Refillable Containers

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

**STORAGE AND DISPOSAL**

**Container Disposal**

***Refillable Container.*** Refill this container with pesticide only. DO NOT reuse this container for any other purpose. Triple rinsing the container before final disposal is the responsibility of the person disposing of the container. Cleaning before refilling is the responsibility of the refiller.

**Figure 2. Example of label language on a refillable container**

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

Requirements for refillable containers are discussed below.

1) *Stationary tanks* are containers that are fixed in place for 30 or more days at the facilities of independent refillers and hold 500 gallons (liquid) or 4,000 pounds (dry) pesticides. The tanks require:
   - A serial number or other identifying code
   - Sufficient strength and durability
   - Vents that limit evaporation
   - No external sight gauges
   - A lockable inlet/outlet valve
   - Secondary containment if holding an agricultural pesticide
   - Anchorage or elevation to prevent flotation if holding an agricultural pesticide

2) Registrants are responsible for making sure *portable refillable containers (mini bulks, shuttles, totes, etc.)* meet DOT standards and bear a DOT transport marking and serial number. They also must be tamper resistant or have one-way valves. These changes will result in many older containers being recycled. Tri-Rinse, Inc. and many other agro chemical manufacturers or distributors offer programs to properly collect and destroy old mini-bulk containers that can no longer be used under the PCC Rule. Many of these programs will continue for years as old containers are being taken out of circulation and replaced by new, compliant containers. In Nebraska, Tri-Rinse will collect containers annually, bi-annually, or as requested. For more information, see *www.tri-rinse.com/*.

3) *Repackaging* requirements for any refiller or registrant include:
   - A written contract between the independent refiller and the registrant
   - Responsibility for product integrity
   - No regulatory limits on size of refillable containers, although in their contract, registrants might establish a specific size limitation
   - Acquiring from the registrant 1) procedures to clean refillables 2) descriptions of acceptable containers that meet stationary tank and portable refillable requirements. Refillers must have these documents on file.

4) Important requirements that refillers need to implement during the repackaging process include:
   - Identifying the previous pesticide that was in the refillable container and visually inspecting the container to ensure it is safe and has the required marks and openings
   - Cleaning containers unless the tamper resistant or one-way valve is intact and the container is being refilled with the same product (or if a new product meets other limited circumstances)
   - Ensuring that the container is included in the registrant's description of acceptable containers
   - Properly labeling the product, including the EPA establishment number and net contents
   - Recording product repackaging information, such as date of repackaging and container serial number

Examples of label language for refillables include a "refillable container" statement and instructions for cleaning the container before recycling or disposal (not before being refilled).

**Secondary Containment/Load-out Facilities**

Large containers of bulk liquid fertilizers or pesticides pose some unique challenges, such as the potential for spillage or leakage into groundwater or surface water. To address these issues, there are secondary containment and load-out facility standards covered by the EPA containment rules and Title 198, *Rules and Regulations Pertaining to Agricultural Chemical Containment*. According to Title 198, secondary containment is "a device or structure designed, constructed, and maintained to hold or confine a release of a liquid pesticide or liquid fertilizer from a storage facility." Simply stated, this means using a larger container to hold a smaller container in order to prevent leakage *(Figure 3)*.

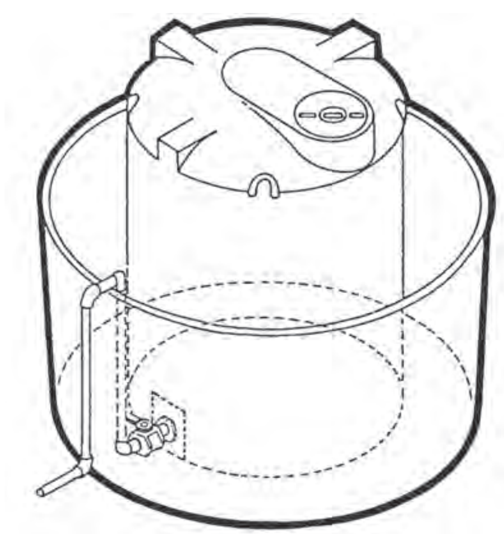


**Figure 3. Secondary containment**

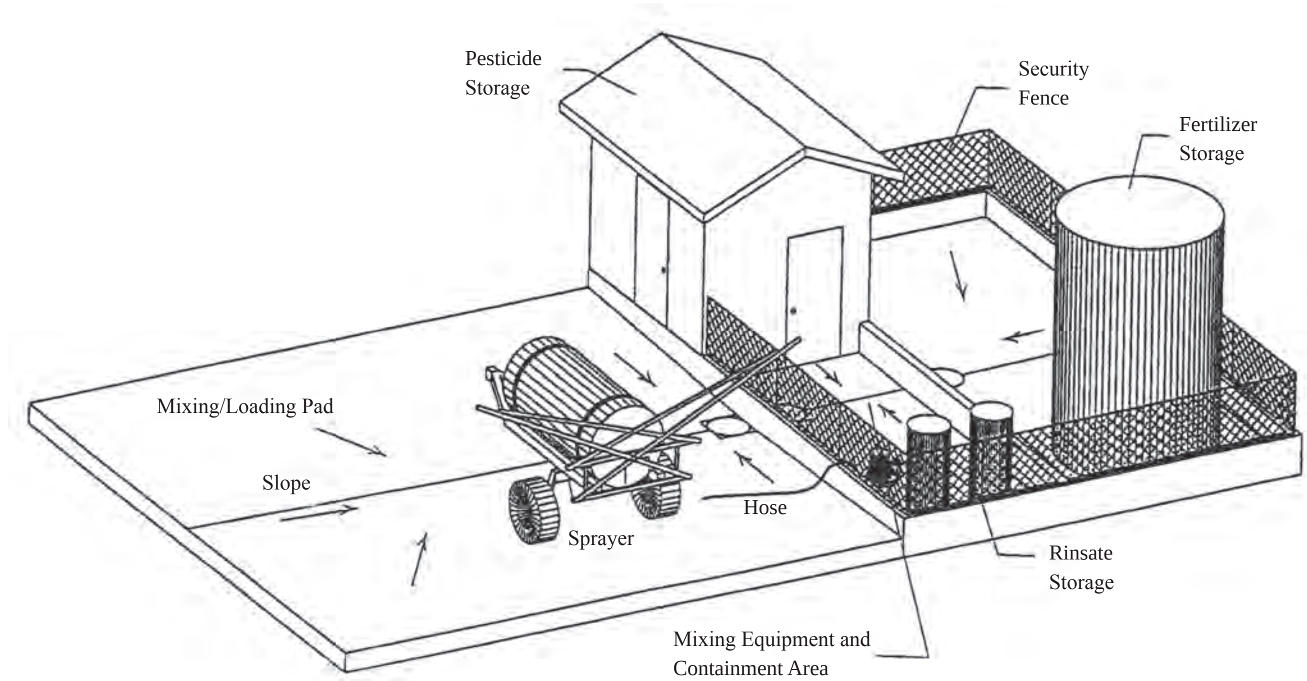



**Figure 4. A load-out pad**

Also, a load-out facility *(Figure 4)* is defined as "a location, other than the field of application, used for the loading, unloading, handling, or mixing of pesticides or fertilizers or a location used for the rinsing or washing of delivery or application equipment which is designed, constructed, and maintained to hold or confine a release of a liquid pesticide or liquid fertilizer." For more detailed information about rules pertaining to size, capacity, enclosed or not enclosed, and other aspects of secondary containment and load-out facilities, see the full Title 198 rule at *http://www.deq.state.ne.us/RuleAndR.nsf/Pages/198-TOC.*

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

According to the NDEQ, secondary containment and/or load-out facilities are required if the storage capacity of a liquid pesticide exceeds 500 gallons. Also, custom applicators must be aware that load-out facilities are required if using liquid pesticides in original containers greater than 3 gallons or if using mixtures of liquid fertilizers or pesticides in containers greater than 100 gallons.

Liquid fertilizer storage requirements differ from liquid pesticide storage requirements in that liquid fertilizers require secondary containment if:

- One container exceeds 2,000 gallons
- Two or more containers have a combined capacity greater than 3,000 gallons, or
- Liquid fertilizers are stored anytime between Nov. 1 and March 15 in quantities that occupy over 25 percent of the container capacity for containers larger than 500 gallons.

Secondary containment is not required if the contents of one or more containers (up to 6,000 gallons total) are stored at the application site between March 15 and Oct. 1 for no more than 21 consecutive days. Note that this exception is specific to application sites, and some containers, such as those used in chemigation, do not qualify for this exemption. Containers must also follow other rules including maintaining a minimum distance from wells and surface water. For more information about containment rules and/or exceptions, consult the NDEQ publications *Are Environmental Regulations becoming a Pest*? or *Fertilizer and Pesticide Containment in Nebraska* (see *Resources*).

While Title 198 does not require either registration or a permit, you must have a construction plan and management program for secondary containment and load-out facilities. The construction plans must be certified by a Nebraska registered professional engineer. These plans remain with the owner and must be made available to NDEQ upon request.

Containment standards follow existing NDEQ regulations. For guidance contact the NDEQ at (402) 471-2186 or visit them at *http://www.deq.state.ne.us/.*

## Resources


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

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

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

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

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


**This publication has been peer reviewed.**

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

**Index: Pesticides, General Regulations**

Issued August 2010

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

NebGuide

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

Know how. Know now.

G1955

# 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;

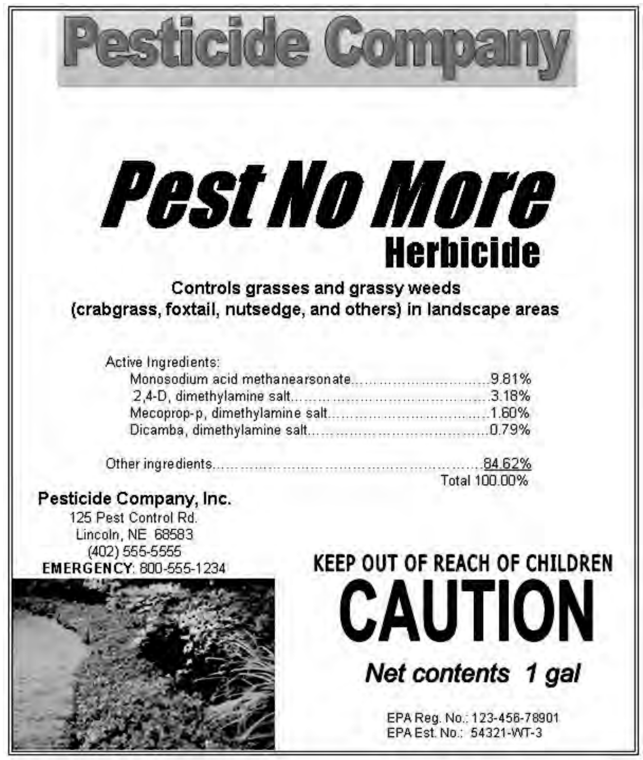



**Figure 1. An example of what a pesticide label might look like.**

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

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

### Brand, Trade, or Product Name

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

### Ingredient Statement

Every pesticide label must include the product's active and inert ingredients with the percentage of each by weight. Only the active ingredients must be listed out by name (chemical and/or common name). Inert ingredients, also referred to as "Other ingredients" on consumer pesticide labels, don't have to be listed out by name but must also show their percentage by weight. *Net contents* are listed on the front of the product and indicate the total amount of product in the container (fluid ounces, pints, quarts, ounces, pounds, etc.).

### Use Classification Statement

Each pesticide is categorized as either a General Use Pesticide (GUP) or a Restricted Use Pesticide (RUP). In general, GUPs are less toxic than RUPs. Thus, to purchase, apply, or supervise the use of RUPs, the applicator must be trained and certified *(Figure 2)*.

**RESTRICTED USE PESTICIDE**

**May injure (Phytotoxic) susceptible, non-target plants. For retail sale to and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification. Commercial certified applicators must also ensure that all persons involved in these activities are informed of the precautionary statements.**

**Figure 2. An example of a restricted-use pesticide statement.**

### Type of Pesticide

Most labels state the type of pesticide on the front. For example, the label may say *Herbicide*, indicating it controls weeds or *Insecticide*, indicating it will control insects.

### Manufacturer

The name and address of the manufacturer, formulator, or registrant (e.g. Pesticide Company, Inc. in *Figure 1*) of the product is required to be on the label. If the registrant is not the manufacturer, then contact information will be preceded by statements like, "packed for," "distributed by," or "sold by."

### Emergency Telephone Number

Often the label will show a telephone number to use in case of emergencies (poisoning, spill, fire). This is especially common on consumer labels.

### Registration and Establishment Numbers

The *Registration Number* (EPA Reg. No.) is proof that the product and the label was approved by the EPA. The *Establishment Number* (EPA Est. No.) identifies the specific facility that manufactured the product. This allows an individual product to be traced back to the manufacturing facility.

**Table I. Signal-level words.**

| *Signal Word* | *Category* | *Toxicity** |
|---|---|---|
| Danger or Danger-Poison | Class I — highly toxic | Corrosive or irritant properties, a few drops to 1 teaspoon |
| Warning | Class II — moderately toxic | 1 teaspoon to 1 ounce |
| Caution | Class III — slightly toxic | 1 ounce to 1 pint/ 1 pound |
| Caution or none | Class IV — very slight hazard | Over 1 pint or 1 pound |

*The lethal dose is less than those listed for a child or person under 150 lbs. and more for a person over 150 lbs.

### Signal Words

Pesticide labels must include a signal word prominently displayed on the front unless they have a Class IV toxicity level. Signal words identify the relative toxicity of a particular product. The signal words, in order of increasing toxicity, are Caution, Warning and Danger *(Table I)*.

### Precautionary Statements

These statements guide the applicator to take proper precautions to protect humans or animals that could be exposed. Sometimes these statements are listed under the heading *Hazards to Humans and Domestic Animals*. Every pesticide label must include the statement: "Keep Out of Reach of Children." Some example *Precautionary Statements* include: "Harmful if inhaled." and "Remove contaminated clothing and wash before reuse."

Often the *Route of Entry* and *Protective Clothing and Equipment (PPE) Statements* are located under the *Precautionary Statement* on a label. The *Route of Entry Statement* identifies the way(s) in which a particular pesticide may enter the body and gives specific actions to prevent exposure. The main routes of exposure are dermal (skin and eyes), oral, and respiratory.

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

### Statement of Practical Treatment

Also called *First Aid* on many consumer labels, the *Statement of Practical Treatment* tells what to do in case of product exposure. This information should be read before using the product, again in the event of an emergency, and be available for all emergencies in order to reference specific information. Statements like, "Move individual to fresh air" and "Get medical attention" are two examples of information found in the *Statement of Practical Treatment* section.

### Environmental Hazards Statement

This statement details possible hazards to the environment including soil, water, air, wildlife, fish, and nontarget plants. There may be special warning statements like "This product is highly toxic to bees," "Do not contaminate water when disposing of equipment washwaters," and "Do not allow drift to contact nontarget plants or trees."

### Physical or Chemical Hazards

Descriptions of any possible fire, chemical, or explosion hazards specific to this product are listed in this section of the label. For example, "Spray solutions of this product should be mixed, stored, and applied, using only stainless steel, aluminum, fiberglass, plastic, or plastic-lined steel containers" and "This gas mixture could flash or explode causing serious personal injury if ignited by open flame, spark, welder's torch, lighted cigarette, or other ignition source" are both statements that can be found under the *Physical and Chemical Hazards* section of the label.

### Agricultural Use Requirements

This section *(Figure 3)* will only be on pesticide labels where the *Worker Protection Standard* (WPS) must be followed. The WPS includes specific safety measures for agriculture workers and handlers of agricultural pesticides.

**Agricultural Use Requirements**

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

Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 4 hours.

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

- Coveralls
- Chemical resistant gloves made of any waterproof material
- Shoes plus socks

**Figure 3. An example of an "agricultural use" label section.**

The *Re-entry Statement* or *Restricted Entry Interval* (REI) is often contained in the information pertaining to WPS. The REI indicates how much time must pass after the application before workers are allowed back in to the treated area with no personal protective equipment (PPE). (See NebGuide G1219, *Worker Protection Standard for Agricultural Pesticides*.)

Some pesticide applications fall under *Non-agricultural Use Requirements* (lawns, golf courses, aquatic areas, rights-of-way, etc.) and no specific re-entry time is indicated. Often the label on these products advises people and pets to not enter the area until the application has dried or dust has settled *(Figure 3)*.

### Storage and Disposal Statement

Each pesticide label has general storage and disposal instructions. Proper storage of any pesticide is important. Keep pesticides stored in a secure location, away from food and feed supplies, and in the original containers. When disposing of pesticide containers, **triple- or pressure-rinse and puncture containers to avoid re-use**. State and local laws may include additional requirements, especially for proper pesticide disposal procedures. (See Exension Circular EC2507, *Safe Transport, Storage, and Disposal of Pesticides*.) Two very common statements found on the label under this section are: "Do not contaminate water, food, or feed by storage or disposal," and "Store in original containers only."

### Directions for Use

These directions instruct the applicator how to properly apply the pesticide and achieve the best results. The *Directions for Use* provide information for things such as the rate of application, the sites the product is intended to protect (e.g. aquatic, non-crop sites, wildlife habitat areas, crop sites, greenhouses, etc.), which pests it controls, mixing directions, and other specific directions related to applying the pesticide.

In cases where the product is intended for use on crops or vegetables, the *Pre-harvest Interval* (PHI) will be listed that indicates how much time must pass between the application and harvest to avoid pesticide residues. The consequences of not following the PHI can vary, but toxicity to livestock or inability to sell harvested grain are two possible results. On some labels, the *Re-entry Statement* may also be listed under this section.

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

**This publication has been peer reviewed.**



**Index: Pesticides**
**General Safety**
Issued July 2009

NebGuide

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

Know how. Know now.

G1773
(Revised November 2013)

# 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.

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

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

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

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

### Droplet Size Categories

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

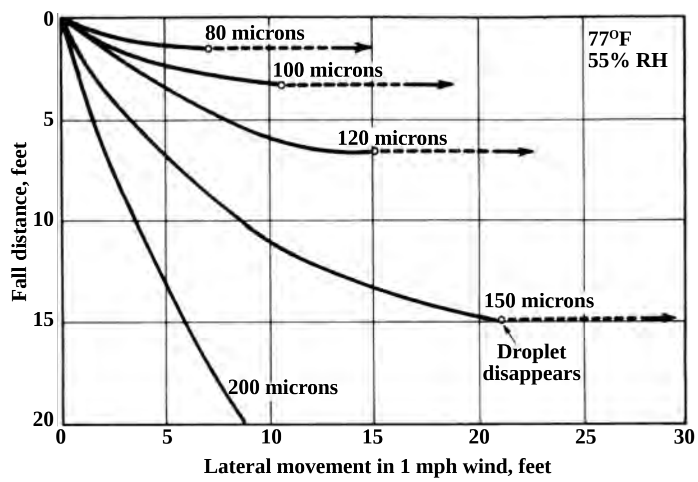



**Figure 1. Lateral movement of water droplets. (Hofman and Solseg, 2004)**

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

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

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

| *Category* | *Symbol* | *Color Code* | *Approximate VMD Range (microns)* |
|---|---|---|---|
| Extremely Fine | XF | **Purple** | ~50 |
| Very Fine | VF | **Red** | <136 |
| Fine | F | **Orange** | 136-177 |
| Medium | M | **Yellow** | 177-218 |
| Coarse | C | **Blue** | 218-349 |
| Very Coarse | VC | **Green** | 349-428 |
| Extremely Coarse | EC | **White** | 428-622 |
| Ultra Coarse | UC | **Black** | >622 |

## Altering Droplet Size

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

The following section covers ways to alter droplet size.

### Nozzle Type

Spray droplets are produced from nozzles in different ways.

- A *flat-fan nozzle* forces the liquid under pressure through an elliptical orifice and the liquid spreads out into a thin sheet that breaks up into different-sized droplets. This type includes the venturi-type that relies on a pressure-against-orifice effect to atomize the spray.
- A *flood nozzle* deflects a liquid stream off a plate that causes droplets to form.
- A *whirl chamber nozzle* swirls the liquid out an orifice with a circular motion and aids the droplet formation with a spinning force.
- An *air inclusion nozzle* has one orifice to meter liquid flow and another larger orifice to form the pattern. Between these two orifices is a venturi or jet that draws air into the nozzle body. There, air mixes with the liquid and forms a spray pattern at a lower pressure. The coarse spray contains large, air-filled droplets and few drift-susceptible droplets.

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

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

| *Nozzle Type* | *Volume Median Diameter, microns* |
|---|---|
| Hollow Cone | 330 (*Coarse*) |
| Drift Guard | 440 (*Extremely Coarse*) |
| Turbo TeeJet® | 500 (*Extremely Coarse*) |

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

### Spray Pressure

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

### Orifice Size and Carrier Volume

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

### Nozzle Spray Angle

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

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

| *Nozzle Spray Angle Degrees* | *Volume Median Diameter, microns* | | |
|---|---|---|---|
| | *15 PSI* | *40 PSI* | *60 PSI* |
| 40 | 900 (*UC*) | 810 (*UC*) | 780 (*UC*) |
| 65 | 600 (*EC*) | 550 (*EC*) | 530 (*EC*) |
| 80 | 540 (*EC*) | 470 (*EC*) | 450 (*EC*) |
| 110 | 410 (*VC*) | 380 (*VC*) | 360 (*VC*) |

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

## Spray Volume

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

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

| | *Volume Median Diameter, microns* | | |
|---|---|---|---|
| *Nozzle Type* | *0.3 GPM* | *0.4 GPM* | *0.5 GPM* |
| Extended Range Flat Fan | 270 (*C*) | 300 (*C*) | 330 (*C*) |
| Drift Guard | 400 (*VC*) | 425 (*EC*) | 450 (*EC*) |
| Turbo TeeJet | 450 (*EC*) | 480 (*EC*) | 510 (*EC*) |

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

# Other Drift Factors

## Boom Height

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

**Table VI. Suggested minimum spray heights above spray contact surface.**

| | *Spray Height, inches* | | | |
|---|---|---|---|---|
| | *20-inch Nozzle Spacing* | | *30-inch Nozzle Spacing* | |
| *Spray Angle Degrees* | *30% overlap* | *100% overlap* | *30% overlap* | *100% overlap* |
| 65 | 22-24 | -NR- | -NR- | -NR- |
| 73 | 20-22 | -NR- | 29-31 | -NR- |
| 80 | 17-19 | 26-28 | 26-28 | -NR- |
| 110 | 10-12 | 15-17 | 14-18 | 25-27 |

NR — Not recommended if height is above 30 inches

## Nozzle Spacing

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

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

## Wind Speed

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

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

| | *Drift* | |
|---|---|---|
| *Droplet Diameter* | *1 mph Winds* | *5 mph Winds* |
| Microns | *feet* | |
| 100 (Mist) (*VF*) | 15 | 77 |
| 400 (Coarse Spray) (*VC*) | 3 | 15 |

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

## Wind Direction

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

## Air Stability

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

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

## Relative Humidity and Temperature

Low relative humidity and/or high temperature conditions cause faster evaporation of spray droplets and a higher potential for drift. During evaporation, the spray solution loses more water than pesticide, creating smaller droplets with a greater concentration of pesticide. The quantity of spray that evaporates from the target surface is related to the quantity of spray deposited on that surface. Smaller droplets, being more prone to drift and evaporation, have less chance of actually being deposited on the target surface than do large droplets. Therefore, hot and dry weather conditions lead to less spray deposition and more drift, due to evaporation of the spray carrier solution.

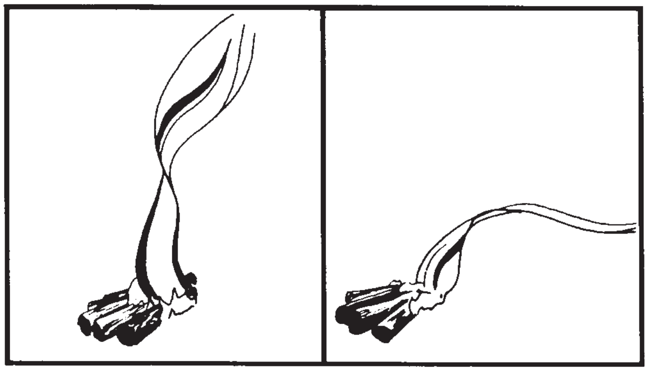



**Figure 2. Smoke rising with wind velocity below 5 mph.**

Evaporation increases the potential for drift so spray during lower temperature and higher humidity conditions. Pesticides differ in their evaporation rate. Use formulations and adjuvants that reduce evaporation. Some pesticide labels specify relative humidity and temperature conditions for product use. Generally, if the relative humidity is above 70 percent, conditions are ideal for spraying. A relative humidity below 50 percent is critical enough to warrant special attention.

### Spray Thickeners

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

## Best Management Practices to Avoid Pesticide Drift

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

1. Select low or nonvolatile pesticides.
2. Read and follow the pesticide label. Instructions on the pesticide label are given to ensure the safe and effective use of pesticides with minimal risk to the environment. Each pesticide is registered for use on specific sites or locations. Many drift complaints involve application procedures in violation of the label.
3. Use spray additives within label guidelines. This will result in better pesticide effectiveness and less potential for drift.
4. Use nozzles with larger orifice sizes. This will produce larger droplets and increase the number of tank refills, but may improve coverage and effectiveness while reducing the potential for drift.
5. Avoid high spray boom pressures; high spray pressure creates finer droplets. Consider 45 PSI the maximum for conventional broadcast ground spraying.
6. Use drift-reduction nozzles that produce larger droplets when operated at low pressures. When using venturi nozzles, higher pressures will be required to maintain an effective pattern. As the pressure is increased with these nozzles, the drift potential will increase, but not as much as with other types of nozzles.
7. Use wide-angle nozzles, low boom heights, and keep the boom stable. Drive perpendicular to terraces rather than parallel to avoid moving the boom ends high above the target surface or digging into the ground.
8. Drift is minimal when wind velocity is between 3 mph and 10 mph. Do not spray when temperature inversions are likely or when wind is high or blowing toward sensitive crops, gardens, dwellings, livestock, or water sources.
9. Use shielded booms. When banding, use shroud covers.
10. When possible, use lower application speeds. As application speed increases, there are often unintended effects on other application parameters that may increase drift.

### References

Elliot, J.G. and B.J. Wilson, editors. 1983. The influence of weather on the efficiency and safety of pesticide application. The drift of herbicides. Occasional Publ. No. 3. BCPC Publs., Croydon, England.

Grisso, R., P. Hipkins, S. Askew, L. Hipkins, and D. McCall. 2013. Nozzles: Selection and Sizing. Virginia Cooperative Extension, Publication 442-032.

Hansen, G., F.E. Oliver, and N.E. Otto. 1983. Herbicide manual, a water resources technical publication. U.S. Government Printing Office, Denver, Colo.

Hartley, G.S. and I.J. Graham-Bryce. 1980. Physical principles of pesticide behavior. Vol. 1 Academic Press Inc., New York, N.Y.

Haskel, P.T., editor. 1985. Pesticide application: principles and practice. Oxford University Press, New York, N.Y.

Hofman, V. and E. Solseg. 2004. Spray equipment and calibration. North Dakota State University Extension AE-73. North Dakota State University, Fargo, ND.

Matthews, G.A. 1979. Pesticide Application Methods. Longman, Inc., New York, N.Y.

Pearson, S. 1989. Don't get my drift. In: Grounds Maintenance 25(1): 32, 36, 38.

Ross, Merrill A. and Carole A. Lembi. 1985. Applied Weed Science. Burgess Publishing Company, Minneapolis, Minn.

Spraying Systems Company. 1990. TeeJet Catalog 42, Agricultural Spray Products. Wheaton, Ill.

Spraying Systems Company. 2007. TeeJet Catalog 50, Agricultural Spray Products. Wheaton, Ill.

**This publication has been peer reviewed.**



**Index: Pesticides, General Equipment**

2007, Revised November 2013



# NO DRIFT ZONE

**driftwatch**
Pesticide Sensitive Crops and Habitats Registry

www.driftwatch.org

# Sign Up!

*Register or learn more:*

**driftwatch**
*Pesticide Sensitive Crops and Habitats Registry*

***www.driftwatch.org***

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.

NEBRASKA DEPARTMENT OF AGRICULTURE

NebGuide
Published by University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
Know how. Know now.
2015 Proceedings : Crop Production Clinics 78
University of Nebraska Lincoln
G758
(Revised August 2012)

# Protective Clothing and Equipment for Pesticide Applicators

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

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

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

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

## Manage Your Risk

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

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

## What is Toxicity?

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

Pesticides can enter the human body in three ways:

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

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

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

| *Group* | *Signal Word* | *Toxicity Rating* | *Lethal Dose for a 150 lb Human*[a] |
|---|---|---|---|
| **I** | Danger[b] | Highly toxic | Few drops to 1 teaspoon |
| **II** | Warning | Moderately toxic | 1 teaspoon to 1 tablespoon |
| **III** | Caution | Slightly toxic | 1 tablespoon to 1 pint |
| **IV** | Caution (signal word not always required) | Relatively non-toxic | More than a pint |

[a]The lethal dose is less than those listed for a child, or a person under 150 lb and more for a person over 150 lb.
[b]The skull and crossbones symbol and the word "Poison" are sometimes printed with the "Danger" signal word.

## Read the Pesticide Product Label

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

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

## Use Personal Protective Equipment

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

### Choose the Right PPE

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

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

### Use Protective Clothing

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

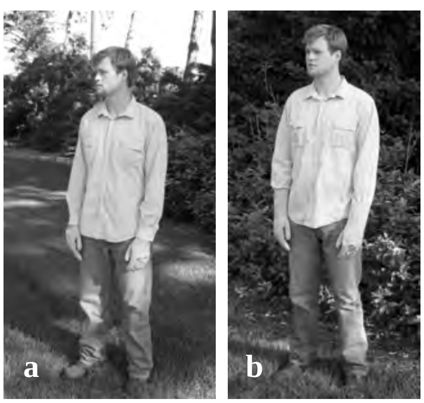


**Figure 1. Wear a long-sleeved shirt, long pants, shoes plus socks, and chemical resistant gloves when applying pesticides. We recommend wearing gloves inside sleeves (1a), but wearing gloves outside sleeves may work equally well (1b).**

Shoes and socks also should be worn. Avoid sandals, flip-flops, and cloth or canvas shoes to minimize exposing your feet to liquid pesticides. Leather shoes are suitable while using most pesticides; however, leather will absorb liquids. Therefore, wear chemical-resistant boots while working with highly toxic liquid pesticides (signal word: DANGER) and when there may be prolonged exposure to any pesticide spray. Applicators who mix and load liquid concentrates, especially highly toxic ones, also should wear chemical-resistant aprons.

### Protect Your Head, Eyes, and Hands

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

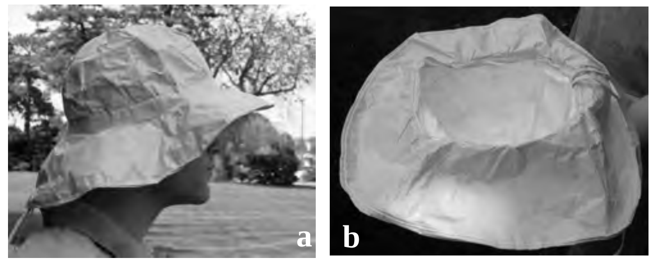


**Figure 2. Example of protective hat that can be worn when applying pesticides.**

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


**Figure 3. Different types of safety goggles and glasses.**

- open vents for impact protection only; not recommended for use with pesticides;
- indirect vents for protection from pesticide and other chemical splashes; and
- non-vented for protection from gases, mists, and fumes.

Other labels may require a full face shield.


**Figure 4. Chemical resistant gloves (top row, left to right): natural rubber, disposable nitrile, reusable nitrile and (bottom row, left to right) neoprene, butyl rubber, Viton, and barrier laminate.**

Chemical-resistant gloves (*Figure 4*) often are needed for mixing, loading, and applying pesticides. Unlined, liquid-proof neoprene, butyl, PVC, Viton®, barrier laminate, or nitrile gloves with tops that extend well up on the forearm are best. Most of these gloves are available in reusable pairs that can be cleaned after each


**Figure 5. Disposable nitrile gloves in 4, 8, and 12 mil weights.**

**Use and Care of a Respirator**

Always read and follow the label guidelines to see what type of respiratory protection is required for the pesticide you'll be using. OSHA (Occupational Safety and Health Administration) requires that when using a respirator, you must have a medical evaluation prior to fit testing. In addition, you will need to be properly trained in respirator use.

- Use respirators approved by the National Institute of Occupational Safety and Health (NIOSH).
- Read and follow the manufacturer's instructions for use and care of the respirator. Filters, cartridges, and canisters must be designed for the type of contaminant expected. For example, a particulate filter is appropriate for dusts and mists. An organic vapor cartridge is necessary for protection against organic vapors, such as pesticides. Other examples include mercury vapor cartridges or acid gas cartridges. Manufacturers also offer combination cartridges when protection against multiple types of contaminants is needed.
- Cartridges and canisters have a limited useful life and must be replaced at proper intervals.
- Inspect and fit test respirators before use to ensure a snug seal against the face. Users with facial hair may not be able to obtain an adequate seal; a clean shave along the seal line is usually necessary.
- Exposed respirator parts must be cleaned after each use, and cartridges should be stored in an airtight container in a clean location. For more information about fit testing and cleaning respirators, see NebGuide 2083, *Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications* at *http://www.ianrpubs.unl.edu/live/g2083/build/g2083.pdf*.

mixing/loading task or pesticide application. Others, such as nitrile gloves, are available in single-use disposable versions in a variety of mil weights (*Figure 5*).

Avoid lined gloves because the lining can absorb the pesticides and is hard to clean. Latex gloves, commonly used by medical personnel, do not provide adequate dermal protection because they are not chemical-resistant. Never wear cotton, leather, or canvas gloves unless the label specifically requires them, as with certain fumigants. Some fumigants penetrate rubber, neoprene, and leather, and if trapped inside a glove can cause severe skin irritation or be absorbed through the skin.

In most cases, we recommend wearing gloves under your sleeves to keep the pesticide from running down the sleeves and into the gloves. When working with your hands above your head, roll glove tops into cuffs to prevent the pesticide from running down the gloves to your forearms. As an extra safety measure, you can duct tape around where the glove and sleeve meet. Remember, the most important thing is to wear gloves! For more information about types of gloves, see NebGuide 1961, *Pesticide Safety: Choosing the Right Gloves*, at *http://www.ianrpubs.unl.edu/sendIt/g1961.pdf*.

## Protect Your Lungs

Your lungs and the lining of your respiratory system readily absorb pesticide dusts and vapors from the air. Respiratory protection, therefore, is essential whenever the label calls for it and is recommended during mixing and loading, even if not required by the label. Respiratory protection also is recommended whenever an applicator will be exposed to intensive concentrations of pesticide dusts, fumes, or vapors. The type of respirator an applicator uses will be determined by the type and toxicity of the pesticide, application site, and other factors.

Particulate respirators (dust masks) are acceptable when applying pesticide dusts and granules, and for protection against large droplets suspended in air. They are not recommended for protection against vapors. Always read the pesticide label for product-specific recommendations. In all cases, the selected respirator should bear a mark indicating it is "NIOSH approved." (NIOSH refers to the National Institute of Occupational Safety and Health.) One-strap dust masks typically available at hardware stores generally are not NIOSH approved and will not provide adequate respiratory protection. Discard particulate respirators after each use and do not attempt to reuse a disposable respirator.

Most air purifying respirators consist of a tight-fitting mask with disposable cartridges or canisters (*Figures 6* and *7*). The respirator design may be a half-mask (covers the nose, mouth, and chin) or full-face (covers the entire face). An air-purifying respirator equipped with suitable cartridges/canisters is needed for protection against vapors. An air-purifying respirator also can provide protection against dusts/mists if the appropriate cartridge/canister is selected. Canisters typically have a longer use life than cartridges because they have more absorption capacity. A full-face respirator provides greater protection than a half-mask and also protects the eyes.

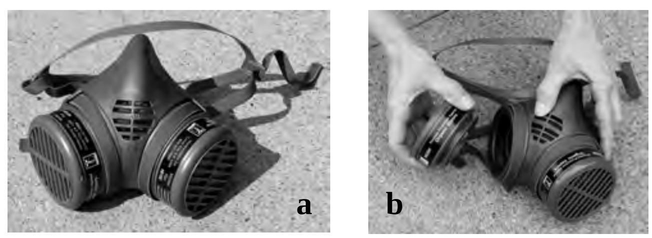



**Figure 6. Half-face cartridge respirator with cartridges attached (6a) and cartridge detached (6b).**

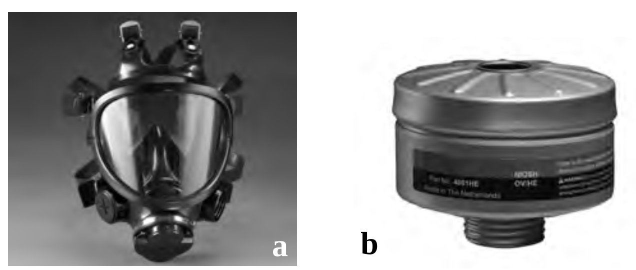



**Figure 7a. Full-face canister respirator (no canister) (Photo courtesy of 3M); 7b. Close-up of canister. (Photo courtesy of North by Honeywell)**

If the oxygen supply is likely to be low or the application will result in heavy concentrations of highly toxic pesticides, such as fumigants, a self-contained breathing apparatus (SCBA) (*Figure 8*) or supplied-air respirator (*Figure 9*) will be needed. The air pack is an SCBA commonly used for

**Figure 8. Self-contained breathing apparatus. (Photo courtesy of MSA.)**

fumigation. Air packs typically supply 25-30 minutes of air and consist of a full-face mask attached to a tank of air carried on the applicator's back. The supply time may be considerably shorter if the respiration rate increases due to overexertion. A warning bell can be set to signal depletion of the air supply.

**Figure 9. Supplied air respirator. (Photo courtesy of MSA.)**

Air-supplied respirators provide air from an outside source that is pumped to the applicator through an airline. A major advantage of an airline is that the air supply does not expire in a short time. However, the airline must be towed throughout the facility being treated; air pump failure or a constriction of the airline can shut off the air supply. Also, the air pump must be located in a fumigant-free area. In combination with an SCBA, an air-supplied respirator offers an unlimited work period with backup respiratory protection provided by the SCBA if the outside air supply is cut off for any reason.

## Caring for Protective Clothing

Applicators who routinely work with pesticides should wear clean clothing daily, and reserve at least one set of clothing for pesticide work if possible. Launder pesticide-contaminated clothing and store work clothing separately.

Clothing that has become wet from pesticides should be removed immediately. Fast action will reduce your exposure to the pesticide. Discard clothing (including shoes and boots) saturated with any concentrate or any diluted spray of highly toxic pesticides (signal word: "Danger"). Waterproof and chemical-resistant hats, gloves, boots, and goggles should be washed daily and hung to dry. Test reusable gloves for leaks by filling them with water and gently squeezing the top. If water comes out, replace the gloves.

### Laundering Clothing Soiled With Pesticide

- Wear uncontaminated clothes during pesticide applications. Remove these clothes upon finishing the job and change into clean clothes before going home for the day. Or wear chemically resistant, disposable (non-reusable) coveralls over your clothing.
- At the end of the job or application, remove your contaminated clothing and wash immediately. If this is not possible, wash separately from family laundry.
- Dispose of clothing heavily soiled with pesticide according to label instructions. This includes pesticide saturated shoes and boots.
- Wear chemical-resistant gloves when handling pesticide contaminated clothing.
- Wash pesticide contaminated clothing daily.
- Wash only a few items at a time. Do not mix with regular laundry.
- Use liquid detergent, highest water level, and hot water.
- Use wash cycle for heavily soiled clothes.
- After washing, remove clothing from the machine and run the washer through another cycle with hot water and detergent before laundering other clothing.
- Line dry if possible, or use regular dryer setting.

### Emergency Phone Numbers

**The Poison Control Center**
For aid in human poisoning cases
**(800) 222-1222**
**Nebraska Department of Environmental Quality**
To report chemical spills 8 a.m. to 5 p.m. M-F
**(402) 471-2186; (877) 253-2603**
**Nebraska State Patrol (after hours)**
To report chemicals spills after hours
**(800) 525-5555; (402) 471-4545**

## Washing Up

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

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

## Be Prepared for an Emergency

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

**This publication has been peer reviewed.**

### Disclaimer

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

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

**Index: Pesticides, General Safety**
1985, 2002, 2006, Revised August 2012

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

G1961

# 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


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

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

**Table I. Types and characteristics of personal protective material.**
(for use when the personal protective equipment section on pesticide label lists a chemical resistance category)

| ***Selection Category Listed on Pesticide Label*** | ***Types of Personal Protective Material*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Barrier Laminate* | *Butyl Rubber ≥ 14 mils* | *Nitrile Rubber ≥ 14 mils* | *Neoprene Rubber ≥ 14 mils* | *Natural Rubber* ≥ 14 mils* | *Polyethylene* | *Polyvinyl Chloride (PVC) ≥ 14 mils* | *Viton ≥ 14 mils* |
| A (dry and water-based formulation) | NA | NA | NA | NA | high | NA | NA | NA |
| B (acetate) | high | high | slight | slight | none | slight | slight | slight |
| C (alcohol) | high | high | high | high | moderate | moderate | high | high |
| D (halogenated hydrocarbons) | high | high | moderate | moderate | none | none | none | slight |
| E (ketones, such as acetone) | high | slight | high | high | slight | none | moderate | high |
| F (ketone and aromatic petroleum distillates mixture) | high | high | high | moderate | slight | none | slight | high |
| G (aliphatic petroleum distillates, such as kerosene, petroleum oil, or mineral oil) | high | slight | slight | slight | none | none | none | high |
| H (aromatic petroleum distillates, such as xylene) | high | slight | slight | slight | none | none | none | high |

*includes natural rubber blends and laminates.

**High:** Highly chemical-resistant. Clean or replace PPE at end of each day's work period. Rinse off pesticides at rest breaks.
**Moderate:** Moderately chemical-resistant. Clean or replace PPE within an hour or two of contact.
**Slight:** Slightly chemical-resistant. Clean or replace PPE within 10 minutes of contact.
**None:** No chemical resistance. Do not wear this type of material as PPE when contact is possible.
**NA:** Not Applicable. Provides high resistance but exceeds level of protection required for these formulations.
**Reference:** Environmental Protection Agency, *Labeling Review Manual,* Chapter 10: Worker Protection Labeling, EPA Chemical Resistance Category Selection Chart, *http://www.epa.gov/oppfead1/labeling/lrm/chap-10.htm#VIA*

liners must be discarded after each use to avoid potential exposure to pesticides that may have been absorbed into the cotton material. You also should avoid gloves with integrated linings or gloves made entirely of cotton. These materials absorb pesticides, are hard to clean, and increase your chance of pesticide exposure.

The EPA has developed a rating chart defining chemical resistance of various materials used in glove construction. These ratings vary from no chemical resistance — materials that should never be used during pesticide applications — to highly chemical-resistant materials that with proper care and cleaning can be reused and still provide good protection. A chemical resistance category (designated with letters A-H) may be listed on the label. It is based on the solvents within pesticides rather than the pesticides themselves. The category refers to how long a glove of a certain material and thickness can be worn while handling a specific pesticide. This is also dependent upon the pesticide's formulation. For example, the amount of time you can wear a certain glove when using a dry formulation may differ from the same pesticide in a liquid formulation.

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

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

**Disposable vs. Reusable**

The majority of information in this guide addresses gloves that have 14 mil (mil = 0.001 inch) or greater thickness (often referred to as reusable). These gloves are available in a variety of sizes, cuff lengths, and thicknesses. Like other protective equipment, the number of times these gloves can be reused depends on the age and condition of the material and hours of use. Gloves have to be replaced after eight hours of continuous use, for example, but could be used several times if used in shorter intervals. After sufficient use or extended storage, glove material can become brittle and less impervious to chemicals. Also, any glove, regardless of thickness, should be discarded if it becomes torn or damaged. Do not use gloves more than one season.

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

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

In general, disposable gloves may be preferable to reusable because they can be discarded after one use and require much less maintenance. However, because reusable gloves are thicker, always consider the type of pesticide being used and the length of time needed to make the application. Thicknesses of 14 mil or more may be a better choice in some circumstances.

Reusable gloves must be washed and carefully removed after use to prevent contamination of your skin or areas such as a tractor cab interior. Reusable gloves must be stored properly and checked for leaks before using again, but disposable gloves can be thrown away — according to the label — after completing a pesticide application.

### Glove Size

Depending upon the manufacturer and material, disposable and reusable gloves are available in standard or long-cuff lengths. Determine the best glove size by measuring the circumference around the palm of your hand. For example, if the circumference is 8 inches, a medium probably would be the best choice.

Available glove sizes are found in the table below:

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

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

### Glove Thickness

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

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

### Proper Use

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

If applying fumigants, be especially cautious; read the label directions for gloves. Some fumigants can penetrate materials such as rubber and neoprene, and may result in severe skin irritation if trapped and absorbed by the skin. Many labels for pelletized fumigants, such as aluminum phosphide, may require dry cotton gloves. These gloves allow air flow so that fumigant gasses won't get trapped against and burn skin.

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

### Proper Cleaning and Removal

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

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

To properly remove disposable gloves:

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

To properly remove reusable gloves:

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

After removal of either disposable or reusable gloves, always wash your hands with warm water and soap before resuming daily activities. This will ensure that you do not transfer pesticide residue from your hands into your home, vehicle, or other areas where it could potentially expose you, your family, or other people or animals to pesticides.

**Storage and Disposal**

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

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

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

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

**This publication has been peer reviewed.**

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

**Index: Pesticides, General**
**Safety**
Issued August 2009

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

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

G2083

# Maintaining and Fit Testing Cartridge Respirators for Pesticide Applications

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

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

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

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

## Your New Respirator

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

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

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

## Fit Testing

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


**Figure 1. Examples of respirator packaging and instruction manual.**

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

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

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

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

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

There are three common ways to test the seal. Before testing, adjust the respirator so you think you have a good fit. To begin, place the respirator on your face, then pull the top (halo-shaped in some models) plastic strap and adjust it over and on top of your head. Next, connect the straps that go behind your neck, and pull the loose ends of the straps to adjust for comfort and fit. When you feel you have a tight seal, test to ensure your respirator is fitted properly *(Figure 2).*

### Positive Seal Check

To perform the positive seal check *(Figure 3)*, cover the exhalation valve in front of the respirator and gently exhale. If you can do this without feeling a rush of air around the faceplate, you have a good seal.

### Negative Seal Check

To perform the negative seal check *(Figure 4)*, cover the intake portion of each of the two cartridges with your hands and inhale gently. Note that you also can do this test without

**Figure 3. Positive seal.**

**Figure 4. Negative seal.**

**Figure 5. Ampule test.**

## Prior to Fit Testing

1. Remove respirator and cartridges from their packaging.

2. Place the mask in front of you with the cartridge holes facing toward you.

3. Attach each cartridge by lining it up with one of the holes, inserting it, and turning it counterclockwise until it locks firmly in place.

4. Perform the fit test and seal check.

the cartridges by simply covering the inlet holes and testing the seal. If you have a good seal, you should not be able to pull any air through the seal against your face. If you can pull air, check carefully around the seal for damages or obstructions. If you find breaks or damaged portions of the seal, replace the respirator. If you are able to clear obstructions and make additional adjustments to strengthen the seal, simply retest the unit. In some cases, if you can't find a solution, you will need to replace the respirator seal or the entire unit.

**Ampule Test**

An ampule is a small, sealed vial that can be purchased from many online suppliers. Ampule testing for respirator fit is one example of several procedures that may be required by OSHA. In the ampule test *(Figure 5)*, you break an ampule designed for this purpose and see if you can detect an odor (often smelling like concentrated banana) through the respirator. If you detect an odor, you know that your seal isn't adequate and you'll have to make additional adjustments. Make sure to test the ampule across all portions of the respirator seal. You also should consider simulating common working motions such as moving your head up and down and side to side to test field operability.

### Maintaining Your Respirator

When finished with your respirator, clean and store it properly after each use so that it's in good condition for the next use.

After removing your respirator, remove the cartridges. They generally unthread, bend, or snap out of the faceplate. If the cartridge seating is damaged during removal, do not attempt to repair or bend it back in place — simply replace the cartridge. Store cartridges in either the original respirator packaging or a resealable zipper storage bag when not in use. The best type of storage container is one with an airtight seal. Cartridges absorb pesticides and other organic vapors when exposed to air. You can extend their life span by storing them properly whenever they are not in use. The respirator package or resealable zipper storage bag provides ideal storage because it offers an airtight seal that will help preserve the cartridges by keeping organic vapors out. It is also a good idea to mark the storage container with the purchase date of the cartridges and a running tally of the total number of hours used *(Figure 6)*.

After removing and storing the cartridges, wash the faceplate with soapy water and either air or towel dry before storing it in a clean, dry container with a good seal such as a resealable zipper storage bag or a tight-sealing plastic storage container until the next use. Store the respirator in a way that preserves the shape and integrity of the respirator, protecting it from distortion, contamination, and extreme temperatures.

**Figure 6. Store your respirator in its original packaging or a resealable zipper storage bag or plastic storage container.**

**Figure 7. After each use and before storing your respirator, the faceplate should be washed with soapy water, hung to dry, and checked for wear or damage.**

Also, be sure to inspect the respirator for any holes, damage, or wear, and replace it if necessary *(Figure 7)*.

### Replacing Your Cartridges

A respirator cartridge has a limited life span, which is greatly affected by the conditions of use, such as the temperature, humidity, work efforts of the user, and the chemical concentration and type of chemicals for which the cartridge is used. Many respirator manufacturers have online calculators in which you can enter this information to determine cartridge life. Consult the manufacturer's website for such software. Keep a log of respirator usage to know how long the cartridges have been used. For more information and a sample log, see the UNL Safe Operating Procedure "Respiratory Protection — Air Purifying Respirators: Cartridge Change Schedules" at *http://ehs.unl.edu/sop/RPP_SOP_Cartridge_Change_Log.pdf*.

Proper storage will help preserve cartridges for as long as possible, but eventually you will need to replace them.


**Figure 8. Cartridges are color coded according to the particulates they filter.**

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

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

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

**This publication has been peer reviewed.**

**Disclaimer**

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*.

**Index: Pesticides, General Safety**

Issued June 2011

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

NebGuide

University of Nebraska Lincoln

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

G1893
(Revised October 2014)

# Pesticides and the Endangered Species Protection Program

**Clyde L. Ogg, Extension Pesticide Safety Educator; Erin C. Bauer, Extension Associate; Jan R. Hygnstrom, Extension Project Manager; and Emilee A. Dorn, Extension Assistant**

This NebGuide discusses the Endangered Species Protection Program and its role in the use of pesticides.

## Background

The Endangered Species Act (ESA) is designed to protect animal and plant species in danger of becoming extinct, as well as the ecosystems in which they live. According to the ESA, federal agencies are required to "use their legal authorities to promote the conservation purposes of the ESA and to consult with the U.S. Fish and Wildlife Service and National Marine Fisheries Service, as appropriate, to ensure that effects of actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of listed species" (U.S. Fish & Wildlife Service, 2013). The overall goal of the ESA is to help populations of species recover so they no longer are threatened or endangered. An endangered species is one in danger of becoming extinct in all or most of its range. Threatened species have a high probability of becoming endangered in the near future if assistance is not given.

The U.S. Environmental Protection Agency (EPA) requires and is responsible for registration of pesticides. The EPA reviews information and data and determines whether a pesticide product may be registered for a particular use. Because some pesticides may harm certain threatened or endangered species, the EPA requires a review of potential impacts.

The Endangered Species Protection Program (ESPP) is one of the ways that the EPA meets the requirements of the ESA. A primary goal of the ESPP is to manage federally registered pesticides to avoid jeopardizing protected species while avoiding any unnecessary limitations on the use of many pesticides important to American agriculture for the production of food, fiber, wood, and other commodities.

## Pesticide Labeling

A key component of the ESPP is directing pesticide users, through labeling on applicable pesticide products, to follow use limitations found in Endangered Species Protection Bulletins. When referenced on a pesticide label, the limitations on pesticide use given in the bulletins are mandatory and enforceable.

Bulletins are available through EPA's "Bulletins Live!" (*Figure 1*) database program at *http://www.epa.gov/espp/bulletins.htm*, which is searchable by state and county. Click the "Bulletins Live!" link and select the state and county where the pesticide application will take place. You also may click

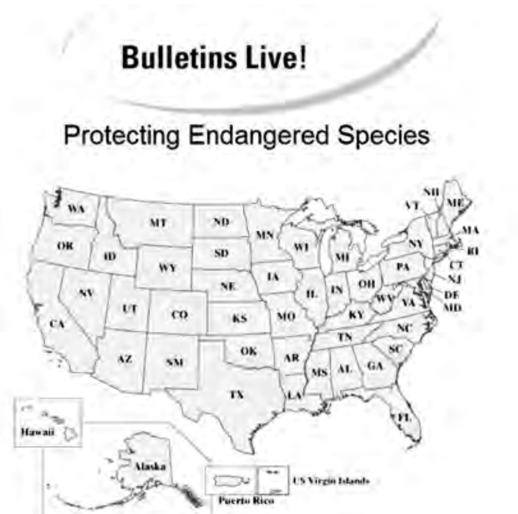



**Figure 1. Bulletins Live! map on U.S. EPA website.**

"NE" on the map, and choose the county where the application will take place from the pull-down menu. Next, select the month of the pesticide application and follow the steps given in the bulletin. Bulletins also are available by calling the toll-free Endangered Species Hotline at 1-800-447-3813. Those applying pesticides can check for information in a bulletin up to six months prior to making a pesticide application.

Bulletins contain a description of the endangered or threatened species to be protected, the name of the pesticide's active ingredient that could cause harm, use limitations of the pesticide that ensure the species' protection, county maps where the bulletin applies, and the valid month(s) in which the bulletin is applicable.

## Species-Based Approach

A pesticide is included in the ESPP if it poses a potential threat to a federally listed plant or animal species. The EPA consults with the U.S. Fish and Wildlife Service to make this determination. Discussed here are examples of Endangered and Threatened (E&T) animal or plant species that may appear in Endangered Species Protection Bulletins for Nebraska. While all E&T species require special attention, this publication covers only 10 of Nebraska's species, to explain how pesticides may affect plants, insects, fish, and birds. For a complete listing of all Nebraska E&T species, visit the Nebraska Game and Parks Commission's (NGPC) Rare Species website at *http://rarespecies.nebraska.gov*.

## Endangered and Threatened Plants

Herbicide applications, drift, and overspray may weaken or kill fragile populations of plants. In addition, pollinators such as bees, butterflies, moths, and flies are important to the survival of many plants. Be careful when applying pesticides that could affect pollinators.

**Hayden's (blowout) penstemon** (*Penstemon haydenii, Figure 2,* federal and state endangered) is unique to the Sandhills region of Nebraska and Carbon County, Wyoming. Blowout penstemon is a "pioneer" plant that begins growth in a sand blowout site before most other plant species, anchoring the sandy soil and reducing wind erosion. In 1968, about 7,000 plants grew on less than 25 total acres scattered throughout the Sandhills. Since then, seeds have been collected and raised in greenhouses, with seedlings introduced to blowouts. About 20,000 plants existed in 2008 due to recovery efforts, primarily in Box Butte, Cherry, Garden, Hooker, and Thomas counties, with populations in Grant and Morrill counties, as well. In 2013, 32 blowout penstemon populations were found in the Sandhills region of Nebraska (10 native sites and 22 introduced populations). Most of the known plants are on private land. To sustain the populations, continual transplanting and maintenance of blowout sites may be necessary.

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

**Western prairie fringed orchid** (*Platanthera praeclara, Figure 3,* federal and state threatened) requires a relatively high and constant level of soil moisture, maintained by groundwater that is near the surface. Known populations are in 64 sites in wet prairies and meadows in the eastern two-thirds of Nebraska. According to the Nebraska Natural Legacy Project, the western prairie fringed orchid is one of Nebraska's rarest plants, with estimates of 2,000 to 5,000 plants in the state. It relies on the sphinx moth for pollination and seed production, so insecticides and other threats to these insects threaten the orchid as well. Loss of these native pollinators may be impacting pollination and genetic diversity in the western prairie fringed orchid. Other threats include invasive species, annual mid-summer haying, loss of habitat, and herbicide sprays.

**Figure 3. Western prairie fringed orchid (photo credit: NGPC).**

**Colorado butterfly plant** (*Gaura neomexicana* ssp. *coloradensis, Figure 4,* federal and state threatened) is found in moist areas of floodplains within a small area of southeastern Wyoming, north-central Colorado, and western Nebraska. The only known populations in Nebraska are located in the floodplain of Lodgepole Creek in Kimball County and the Oliver Reservoir State Recreation Area. The U.S. Fish and Wildlife Service estimates fewer than 50,000 reproducing individuals in its entire range, with only 10 of the 14 current populations considered stable or increasing in numbers. In 2008, Nebraska populations were estimated at less than 200 plants; a field survey of the two areas of Nebraska counted 12 plants. Threats to this species include invasion of habitat by Canada thistle and herbicide spraying.

**Figure 4. Colorado butterfly plant (photo credit: NGPC).**

**Ute ladies'-tresses** (*Spiranthes diluvialis, Figure 5,* federal threatened, state endangered) is a perennial terrestrial orchid. It grows in scattered sites in Colorado, Wyoming, Utah, Montana, Washington, Idaho, and Nevada. Nebraska is at the eastern edge of the species' known range. In Nebraska, they have been found only in Sioux County on private land in a two-mile stretch of the Niobrara River Valley, in subirrigated wet meadows. Ute ladies'-tresses could occur in other river and stream valleys in far western Nebraska, but have not been found during surveys. Only about 60,000 individual plants remain in the U.S. A 2010 survey in Nebraska found 831 flowering plants.

**Figure 5. Ute ladies'-tresses (photo credit: Bekee Hotze, U.S. Fish and Wildlife Service).**

**Small white lady's slipper** (*Cypripedium candidum, Figure 6,* state threatened) is a perennial orchid of the northeastern U.S. Historically, the orchid probably was found throughout eastern Nebraska and much of central Nebraska. Historic collection records account for the orchid in 17 Nebraska counties. The present range consists of the eastern Sandhills and the Loup River Valley. All known Nebraska populations have less than 200 plants each, with total population estimates of 1,000 to 2,000 plants in the state. Nebraska's known populations occur primarily in native, subirrigated wet meadows, which are commonly hayed. Populations of orchids also can occur in road ditches adjacent to native wet meadows. Threats include invasive species, annual mid-summer haying, loss of habitat, and herbicide sprays.

**Figure 6. Small white lady's slipper (photo credit: Tom Barnes, University of Kentucky).**

## Endangered and Threatened Insects

Applications of insecticides in areas occupied by E&T insects could result in the loss of local populations. Direct contact with the spray or insecticide carried by particle drift, vapor drift, or runoff could affect these insects.

**Salt Creek tiger beetle** (*Cicindela nevadica lincolniana, Figure 7*, federal and state endangered) is a predatory insect, about ½ inch long, that captures smaller or similar-sized insects by grasping prey with its mouthparts. The beetle spends two years as a larva in an underground burrow, capturing insects that wander by the opening. The adult beetle lives on the surface for only about six weeks, from mid-June through July.

**Figure 7. Salt Creek tiger beetle (photo credit: UNL Department of Entomology Image Library).**

Found only in Lancaster and Saunders counties of Nebraska, Salt Creek tiger beetles live in the moist, muddy areas of saline wetlands and stream edges associated with Salt Creek, Little Salt Creek, and Rock Creek. In 2012, researchers counted 374 beetles during an intensive field survey.

Applications of insecticides in areas occupied by Salt Creek tiger beetle could result in the loss of local populations or the entire subspecies. Both the adult and larvae are susceptible to insecticides. They may be killed through direct contact with insecticides, or they could die from secondary poisoning — eating insects that had been sprayed with an insecticide. Insecticides may reduce the numbers of insects that serve as food for this beetle, as well.

**American burying beetle** (*Nicrophorus americanus, Figure 8*, federal and state endangered) feeds on carrion — dead birds, fish, mammals, and other organisms. It now is found only in six states, including Nebraska. This beetle is the largest North American carrion beetle and may reach up to 2 inches in length. This species is nocturnal, seeking out and burying carrion to feed its young.

**Figure 8. American burying beetle (photo credit: NGPC).**

Availability of carrion and soil moisture, rather than vegetation type, appears to determine the habitat of the American burying beetle. This insect seems to require a soil type that allows for burial of carrion. The species occurs in areas least disturbed by human influence, including the Sandhills and an area southeast of North Platte. Locations include grassland prairie, forest edges, and wet meadows.

Perhaps fewer than 1,000 American burying beetles live east of the Mississippi River. In Nebraska, an estimated 3,000 beetles live in Lincoln County, with the population extending into Gosper, Frontier, and Dawson counties. A northern population of perhaps 30,000 is in the Sandhills of Nebraska, extending into South Dakota. Factors that may play a role in the population decline include habitat fragmentation that lowers the availability of preferred carrion, competition for carrion by other predators, and artificial lighting that decreases the populations of nocturnal insects. Contact with insecticides can cause direct mortality or lower reproduction rates. Applications of pesticides to control grasshoppers may affect populations.

## Endangered and Threatened Fish

Pesticide applications or runoff could enter streams, ponds, or rivers and harm fish populations. Fish are particularly susceptible to pesticides during their larval development. In addition, most small native fish depend on aquatic insects for survival. Applications of insecticides could affect the fish populations indirectly due to the loss of insects as a food source. Reduce the risk of having pesticides enter surface water by establishing adequate buffer strips and using sound agricultural practices to reduce erosion and runoff.

**Topeka shiner** (*Notropis topeka, Figure 9*, federal and state endangered) is a small minnow, less than 3 inches long. Food consists of insects, algae and other plant material, and fish eggs. The Topeka shiner is known to occur in portions of South Dakota, Minnesota, Kansas, Iowa, Missouri, and Nebraska. It is found in small prairie (or former prairie) streams in pools containing clear, clean water in areas of Cherry County, and the North Loup River. It also is found in Taylor Creek and its tributaries in Madison County. Most streams with Topeka shiner flow year-round, but some are small enough to stop flowing during dry summer months. When this happens, water levels must be maintained by groundwater seepage for the fish to survive. The estimated population in Nebraska is less than 200 fish.

**Figure 9. Topeka shiner (photo credit: Konrad Schmidt, Minnesota Department of Natural Resources).**

## Endangered and Threatened Birds

Pesticides in stormwater runoff could enter streams, ponds, or rivers and harm or kill fish and invertebrates such as aquatic insects, crustaceans, and mollusks upon which some shorebirds feed. Fish and invertebrates can accumulate toxins in their bodies; a bird that eats them may have a buildup of toxins as well.

**Interior least tern** (*Sternula antillarum athalassos, Figure 10*, federal and state endangered) is 8 to 9 inches long with a 20-inch wingspread. Males and females are similar in appearance. Immature birds also look similar but have considerably browner upperparts and the black on the head is more diffuse.

**Figure 10. Interior least tern (photo credit: NGPC).**

Interior least terns leave their wintering grounds in Central and South America and arrive in Nebraska from mid-May to early June. This tern nests on midstream river sandbars, sand and gravel mines, and lakeshore housing developments across the state (primarily along the Platte, Missouri, Elkhorn, Loup, and Niobrara River drainages). Nests are inconspicuous, consisting of a small depression on sand or similar substrate.

Interior least terns typically lay two or three brown spotted eggs.

Adult interior least terns eat small fish. Water quality must be high enough to support a reproducing fish population. During the breeding season, least terns may feed within a few hundred yards of, to miles from the nesting area. Typically, all interior least terns have migrated out of Nebraska by the end of August.

The decline of interior least terns is principally attributed to habitat loss, but human disturbance at nesting sites, pollution, and disease also negatively affect this species in Nebraska and elsewhere.

**Piping plover** (*Charadrius melodus, Figure 11*, federal and state threatened) is a robin-sized shorebird. A common relative, the killdeer, is larger, more darkly colored, and has two dark breast bands.

**Figure 11. Piping Plover (photo credit: NGPC).**

Piping plovers breed in Nebraska from early April through August. Nesting habitat includes extensive, sparsely vegetated areas of sand adjacent to water, including sandbars, sand and gravel beaches, reservoir shorelines, and sand and gravel mines along rivers. Nests are shallow, typically lined with small pebbles, shells, or other material. Females lay a clutch of four eggs. Piping plovers feed on small insects, worms, and other invertebrates they collect from the surface of wet sand along the shoreline of rivers, ponds, and lakes. Reduced availability of food due to pollution or other variables can affect survival and reproductive success. The piping plover commonly is found in the same breeding areas as the interior least tern, and has been negatively affected by many of the same variables as the interior least tern.

## National Pollutant Discharge Elimination System Permits

When making pesticide applications to, over, or near waters of the state for nonagricultural uses (rights-of-way, mosquito control, algae control, etc.), a National Pollutant Discharge Elimination System (NPDES) permit may be required. In these cases, you must consider if state-listed E&T species could be adversely affected. The NGPC has developed a document with standard procedures to follow, *E&T Species Standard Procedures for NPDES Pesticide Permit.* If you cannot follow these procedures, you must consult with the NGPC Planning and Programming Division prior to the pesticide application. Paperwork must be submitted, and at least 30 days are required for the review. Information on a consultation with NGPC is available at *http://outdoornebraska.ne.gov/wildlife/programs/nongame/consultation.asp*.

## Summary

Endangered and threatened species require special attention due to their vulnerability. Always read pesticide labels carefully. If directed to do so by the label, follow use limitations found in Endangered Species Protection Bulletins, accessed either online or through the toll-free telephone number. When applying nonagricultural pesticides to, over, or near waters of the state, a National Pollutant Discharge Elimination System may be required. If so, Nebraska Game and Parks Commission has additional standards that must be followed.

## Resources

Contact the following individuals, offices, or websites for additional information.

**Nebraska Department of Agriculture**

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

Nebraska Department of Agriculture List of Threatened and Endangered Species *http://www.nda.nebraska.gov/pesticide/endangered.html*

**Nebraska Department of Environmental Quality**

NPDES Press Release *http://www.deq.state.ne.us/Press.nsf/pages/PR111011* or *http://pested.unl.edu/NPDES*

**Nebraska Game and Parks Commission**

Nebraska Game and Parks Commission, Lincoln, NE (402) 471-0641 *http://rarespecies.nebraska.gov/*

NGPC Endangered and Threatened Species Consultation Information *http://outdoornebraska.ne.gov/wildlife/programs/nongame/consultation.asp.*

NGPC Environmental Analyst Supervisor, Michelle Koch, Lincoln, NE (402) 471-5438

NGPC E&T Species Standard Procedures for NPDES Pesticide Permit *http://outdoornebraska.ne.gov/wildlife/programs/nongame/pdf/E&T%20Species%20Standard%20Procedures%20for%20Pesticide%20Permit_04112012.pdf*

**USDA Natural Resource Conservation Service (NRCS)**

Field Office Technical Guide listing of Nebraska Endangered and Threatened Species with descriptions and locations (2011). *http://efotg.sc.egov.usda.gov//references/public/NE/Subsection_II_TOC_ENDANGERED_AND_THREATENED_SPECIES_LISTS.pdf*

**U.S. Environmental Protection Agency**

Dick Wiechman, Environmental Protection Agency Region 7, Nebraska Field Office, Lincoln, NE (402) 437-5080

EPA endangered species hotline (800) 447-3813

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

**U.S. Fish & Wildlife Service**

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

U.S. Fish & Wildlife Service. 2013. ESA Basics at *http://www.fws.gov/endangered/esa-library/pdf/ESA_basics.pdf*

**This publication has been peer reviewed.**

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

**Index: Environmental & Natural Resources Conservation**

2008, Revised October 2014

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

NebGuide

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

Know how. Know now.

G2179

# Protecting Pesticide Sensitive Crops

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

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

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

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

## Use Pesticides Carefully

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

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

## Be Proactive

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

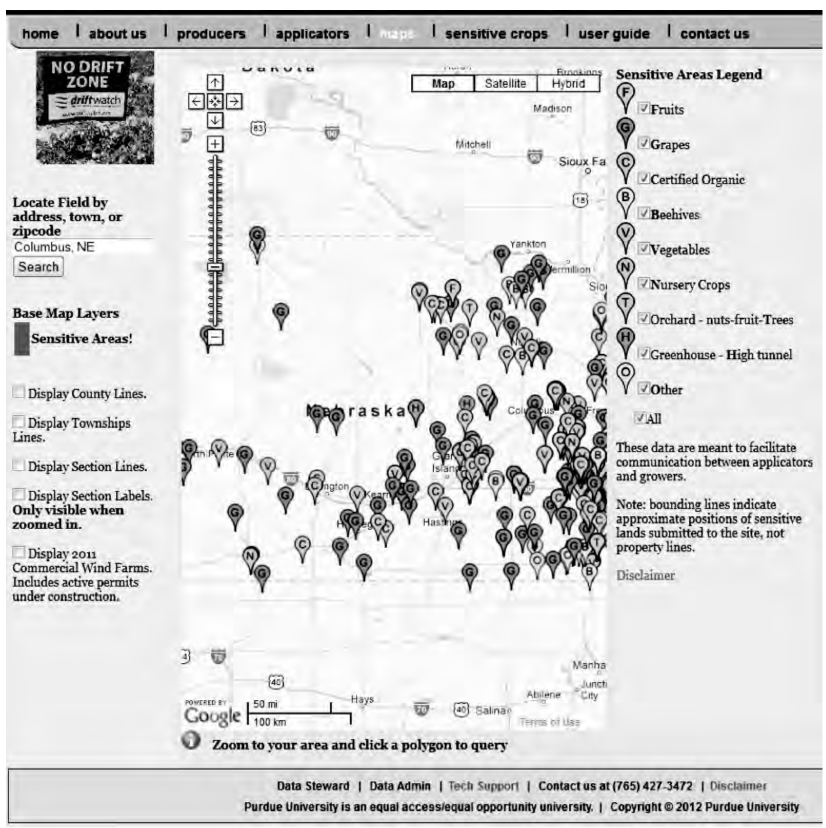



**Figure 2. Nebraska Driftwatch encourages commercial producers to register locations of sensitive crops and bee hives.**

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

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

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

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

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

### Strategies to Protect Sensitive Crops

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

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

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

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

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

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

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

Wind and boom height are two of the biggest problems when it comes to drift. By using a rate controller that changes output pressure, and lowering boom height, you can effectively help reduce drift. For more details about pesticide drift and how to prevent it, see *Spray Drift of Pesticides* (NebGuide G1773).

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

If several pieces of spray application equipment are available, dedicate one to phenoxy herbicides or one to the specific crop to be treated. If not, extra careful cleaning following each application of a phenoxy herbicide is necessary to avoid subsequent crop damage. Mixing two quarts of ammonia and letting it stand in the sprayer overnight is especially effective for cleaning residue from growth regulator herbicides such as 2,4-D (phenoxy) or dicamba. Certain herbicides, such as glyphosate, if left in the tank, will absorb growth regulator herbicides that are added later and result in crop injury when applied. For more details about cleaning pesticide application equipment see *Cleaning Pesticide Equipment* (NebGuide G1770).

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

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

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

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

### Pesticides Can Move Off the Application Site

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

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

Spray drift can be reduced by doing the following:

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

Volatilization can be reduced by doing the following:

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

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

### Growth Regulator Herbicides

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

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

**Figure 4. Grape leaf injured by 2,4-D *(Bruce Bordelon, Purdue University).***

### Symptoms of Phenoxy (2,4-D) Injury

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

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

### Other Growth Regulators

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

### Other Herbicide Injury

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

### Summary

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

### Additional Information

**University of Nebraska Extension Publications**
*http://www.ianrpubs.unl.edu/epublic/pages/index.jsp*

- *Spray Drift of Pesticides*, G1773
- *Nozzles - Selection and Sizing*, G955
- *How to Spray a Field to Prevent Overlap and Reduce Drift Injury*, G1570
- *Cleaning Pesticide Equipment*, G1770
- *Guide for Weed Management*, EC130
- *Protecting Surface Water Quality,* EC730
- *Safe Transport, Storage, and Disposal of Pesticides,* EC2507
- *Understanding the Pesticide Label,* G1955

**University of Nebraska–Lincoln Extension Pesticide Safety Education Program**

- Pesticide Container Recycling: *http://pested.unl.edu/recycling*
- Pesticide Disposal: *http://pested.unl.edu/Hazardous*

**NDA's Pesticide Program:** *http://www.agr.ne.gov/pesticide/*

- Nebraska Driftwatch
- Integrated Pest Management
- Applicator Certification and Training
- Nebraska Pesticide Act and Enforcement

**National Pesticide Information Center**, for objective, science-based information about pesticides and pesticide-related topics: (800) 858-7378, *www.npic.orst.edu*

**The U.S. Environmental Protection Agency Office of Pesticide Programs** *www.epa.gov/pesticides/*

**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.

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

**Index: Pesticides, General**
**Herbicides**

Issued October 2012

University of Nebraska Lincoln EXTENSION

Know how. Know now.

EC301

# 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 to bees, butterflies, moths, flies, hummingbirds, and some bats can be important pollinators.

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


**Figure 1. Honey bee**

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

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

Honey bees (*Figure 1*) are hairy, yellow, and black or brown banded social insects that are about ½-inch long on average and live in hives. Each individual has distinct duties, either

IANR

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

as a worker (serving as a nursemaid, housekeeper, or forager) or a reproductive bee (drone or queen).

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

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

## Considerations for Pollinator Protection

### Plant Growth Stage

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

### Relative Toxicity of the Chemical

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

RISK = TOXICITY X EXPOSURE

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

### Choice of Formulation

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

### Using Treated Seed

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

**Table I. Selected representative trade names, pesticide AIs, bee toxicities, toxicity ratings, and pesticide types.[1]**

| *Representative Trade Names* | *Pesticide Active Ingredient (AI)* | *Bee Toxicity ($LD_{50}$ as µg/bee)* | *Toxicity Rating* | *Pesticide type* |
|---|---|---|---|---|
| **Gaucho** | Imidacloprid | 0.0039 | Highly toxic | I |
| **Cruiser Platinum** | Thiamethoxam | 0.005 | Highly toxic | F |
| **Lorsban Vulcan Nufos 4E** | Chlorpyrifos | 0.01 | Highly toxic | I |
| **Brigade Capture** | Bifenthrin | 0.0146 | Highly toxic | I |
| **Ambush Pounce** | Permethrin | 0.024 | Highly toxic | I |
| **Aztec** | Cyfluthrin | 0.037 | Highly toxic | I |
| **Dimethoate** | Dimethoate | 0.056 | Highly toxic | I |
| **Methyl** | Methyl parathion | 0.111 | Highly toxic | I |
| **Avid Zoro** | Abamectin | 0.41 | Highly toxic | M |
| **Carbaryl Sevin** | Carbaryl | 1 | Highly toxic | I |
| **Acramite** | Bifenazate | 7.8 | Moderately toxic | M |
| **Captan** | Captan | 10 | Moderately toxic | F |
| **Javelin Dipel** | *Bacillus thuringiensis*[2] | 23.2 | Relatively nontoxic | I |
| **Tilt Bumper Fitness** | Propiconazole | 25 | Relatively nontoxic | F |
| **Quilt** | Propiconazole + Azoxystrobin | 25<br>200 | Relatively nontoxic | F |
| **Atrazine AAtrex** | Atrazine | 97 | Relatively nontoxic | H |
| **Headline** | Pyraclostrobin | 100 | Relatively nontoxic | F |
| **Kanemite Shuttle** | Acequinocyl | 100 | Relatively nontoxic | M |
| **2,4-D Ester** | 2,4-D 2-EHE | 100 | Relatively nontoxic | H |
| **Roundup** | Glyphosate | 100 | Relatively nontoxic | H |
| **Parallel Stalwart** | Metolachlor | 110 | Relatively nontoxic | H |
| **Stratego** | Trifloxystrobin + Propiconazole | 200<br>25 | Relatively nontoxic | F |
| **Quadris Dynasty** | Azoxystrobin | 200 | Relatively nontoxic | F |

[1]The USDA Windows Pesticide Screening Tool (Win-PST) is an environmental risk screening tool that includes bee toxicity data available for each active ingredient in the database. The tool is available for download from *http://go.usa.gov/Kok*.
[2] *Bacillus thuringiensis* (*Bt*) Reregistration Eligibility Decision (RED), U.S. EPA. Data can be found at *http://www.epa.gov/oppsrrd1/REDs/0247.pdf*

### Residual Action

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

### Drift

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

### Temperature

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

### Distance from Treated Areas

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

### Time of Application

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

### Communication and Cooperation

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

## How Growers and Applicators Can Reduce Risks of Honey Bee Injury

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

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

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

**Maintain forage areas for bees.** Intensive agriculture often increases bee dependence on cultivated crops for forage. Establishing plants in wild or uncultivated areas for honey bees to forage will reduce bee dependence on crop plants that may require pesticide treatments. Plants recommended for uncultivated areas include sweet clover, white Dutch clover, alfalfa, purple vetch, birdsfoot trefoil, and partridge

**Figure 2. Partridge pea planted in an uncultivated area serves as bee forage.**

pea (*Figure 2*). Many trees and shrubs are beneficial to bees as well. The most attractive species include linden, black locust, honey locust, Russian olive, wild plums, elderberries, red maples, willows, and honeysuckle. However, when establishing foraging areas with trees and shrubs, avoid planting honey locust, Russian olive, or honeysuckle. Although attractive to honey bees, these species can become invasive and outcompete native plant species. Soil conservation, natural resource, and game managers usually are eager to help establish plantings that benefit honey bees because these areas also conserve soil and provide valuable habitat for plant and wildlife conservation programs. These individuals can be a good resource for selecting trees that are both attractive to bees and healthy for the environment.

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

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

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

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

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

Figure 3. Notify beekeepers when you will be applying a product that is toxic to bees.

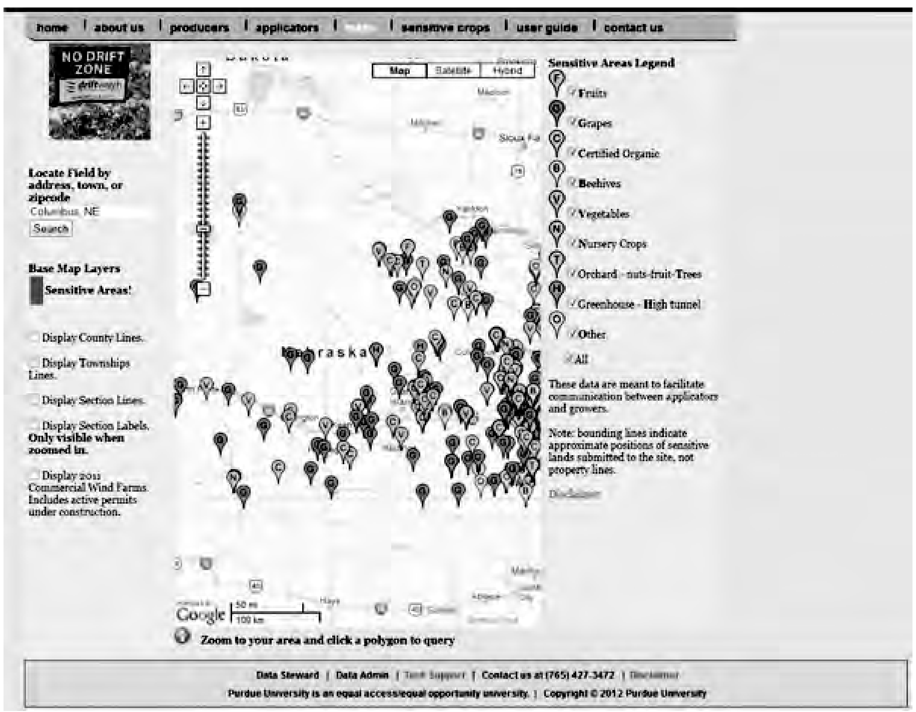



Figure 4. DriftWatch encourages commercial producers to register locations of beehives.

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

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

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

## Steps Beekeepers Can Take to Protect Their Colonies

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

**Know the risks.** Many crop pests can be controlled without endangering bees. Attend crop pest management training sessions to learn the latest about crop pests and control measures used by growers and applicators. These sessions also provide an opportunity to establish communication links with growers and pesticide applicators.

**Figure 5. Hives shouldn't be placed near crops likely to be sprayed with pesticides.**

**Maintain positive working relationships with applicators.** Risk management decisions can best be made when both parties understand each other's needs. Establish a communication link prior to the spray season rather than during peak activity periods when all parties are busy.

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

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

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

1. When products with short residual activity are to be applied, briefly confine bees to their hive with wet burlap. This measure is only feasible if a small number of colonies are involved and if the confinement period is brief and early in the morning. *Caution! This measure can result in the colony overheating and should be used with care.* Fine mesh moving nets are also available and can be purchased by beekeepers if the need arises.
2. Temporarily disrupt foraging activity by removing colony covers and offsetting boxes. This will result in a temporary reduction in foraging. Most honey bees will remain in the hive to protect their stores and to maintain temperature and humidity in the exposed hive. After a few hours to one day, colonies will adjust to the change and resume foraging. This approach is safer than confining colonies but is not recommended if bees are located in or adjacent to areas that will be treated.
3. When highly toxic products with extended residual activity are applied to flowering crops, move honey bees to another location at least four miles from the treated area. Moving populous colonies during hot weather can result in considerable bee mortality and should be avoided if possible. Moves should be made early in the morning or evening when temperatures are cool and the bees are the least active. In general, moving colonies isn't practical for most beekeepers. It requires that hives be kept on pallets and moved using a forklift. Migratory beekeepers may be some of the few with such equipment.

**Report colony injury**. Beekeepers are often reluctant to report bee injury incidents for a number of reasons, one of which is because they may be relying on the landowner/applicator to provide a place to put their hives. However, EPA is unable to adequately evaluate product use and risk assessment without bee injury incident information. The best way for EPA to collect this necessary information is through an incident reporting form, available at *http://pi.ace.orst.edu/erep/*.

## Final Thoughts

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

With good environmental stewardship, you can help protect the bees that are essential pollinators for Nebraska crops. Applicators and beekeepers should work together to ensure successful pest control while reducing the risks to honey bees. This includes registering beehives on DriftWatch, having a good communication network, using pesticides that are least toxic to bees, and timing applications when bees are not actively foraging. Bees are a valuable agricultural resource that are worthy of our respect and protection.

## Resources

DriftWatch:
*http://www.driftwatch.org*

UNL Extension PSEP YouTube Channel:
*http://www.youtube.com/user/UNLExtensionPSEP*

**This publication has been peer reviewed.**

### 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.

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

2015 Proceedings : Crop Production Clinics 108

NebGuide

University of Nebraska Lincoln

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

Know how. Know now.

G1736
(Revised April 2013)

# 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 Saves Money

It is very easy to leave 6 ounces or more of pesticide product in a 2.5-gallon container. Six ounces is about 2 percent. If you do not rinse, you either apply 2 percent less product, which can affect performance of the pesticide, or incur 2 percent more cost for the application. Neither option is good.

If you delay rinsing your used pesticide containers, it is more difficult to remove product from the containers. Because it is more difficult, more time is required and time is money. Removing pesticide product from containers that were not rinsed immediately may also require additional dilutents. These added chemicals are costly and some may even cause injury if applied to the target site.

## Rinsing Helps Protect the Environment

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

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

## Types of Pesticide Containers

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

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

## Triple-Rinsing

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

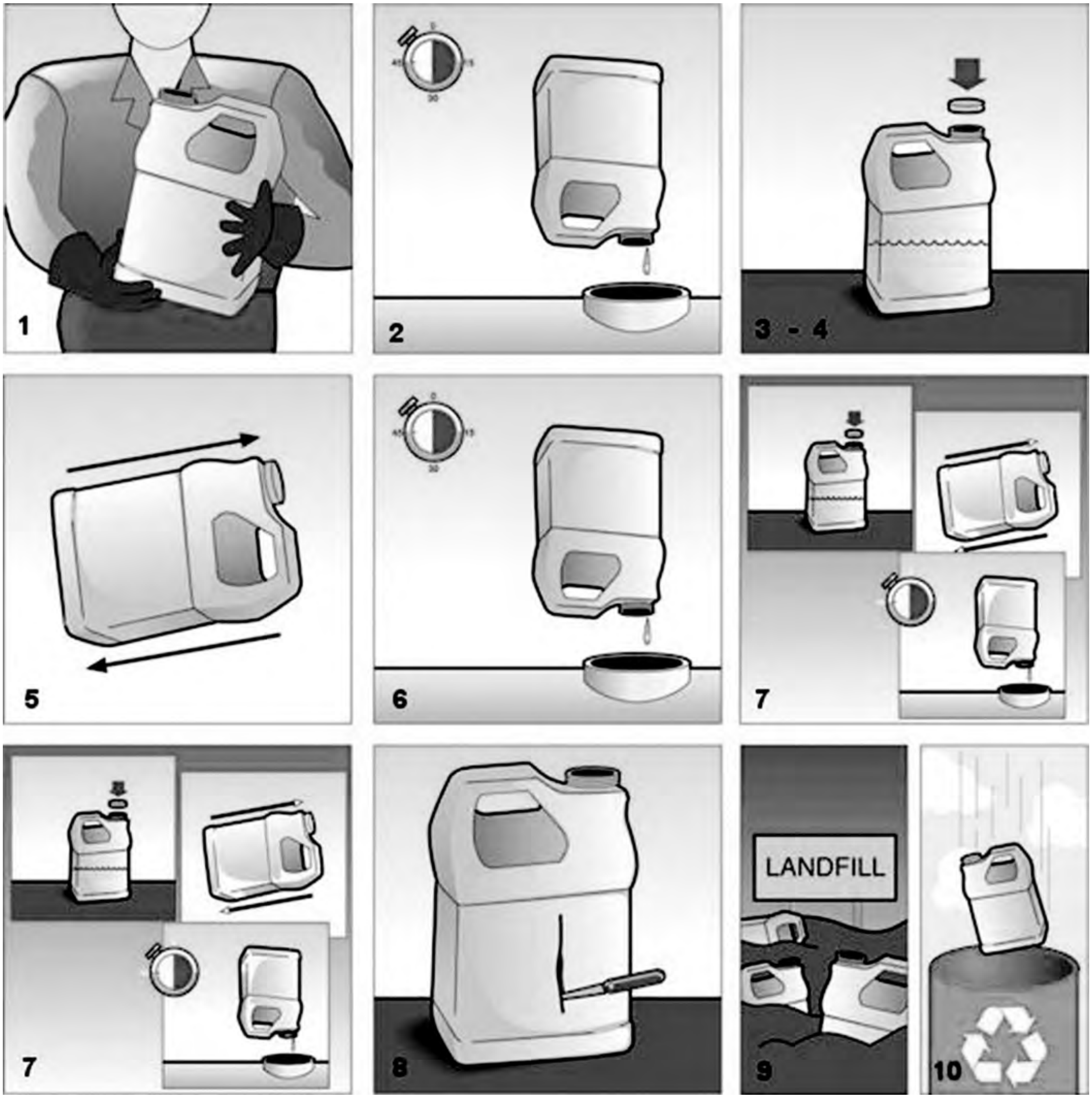



**Figure 1. Triple-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.**

**How to triple-rinse** *(Figure 1)***:**

1. Wear the same personal protective equipment while rinsing containers as the pesticide label requires for handling and mixing.
2. Remove the cap from the pesticide container. Empty all pesticide into the spray tank, allowing the container to drain for 30 seconds. Begin rinsing immediately or the product may be difficult to remove. If you are unable to rinse the container immediately, replace the cap until you can.
3. Fill the container 10 percent to 20 percent full of water or rinse solution (i.e., fertilizer solution).
4. Replace the cap on the container.
5. Swirl the liquid within the container to rinse all inside surfaces.
6. Remove the cap from the container. Pour the rinsate from the pesticide container to the spray tank and allow it to drain for 30 seconds or more.
7. Repeat steps 3 through 6 **two more times**.
8. Puncture or crush the container so it cannot be reused.

9. Replace the cap and dispose of pesticide container according to label directions.
10. If recycling, remember that caps and containers are made from different materials; therefore, caps cannot be recycled.

**How to triple-rinse drums:**

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

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

## Pressure-Rinsing

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

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

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

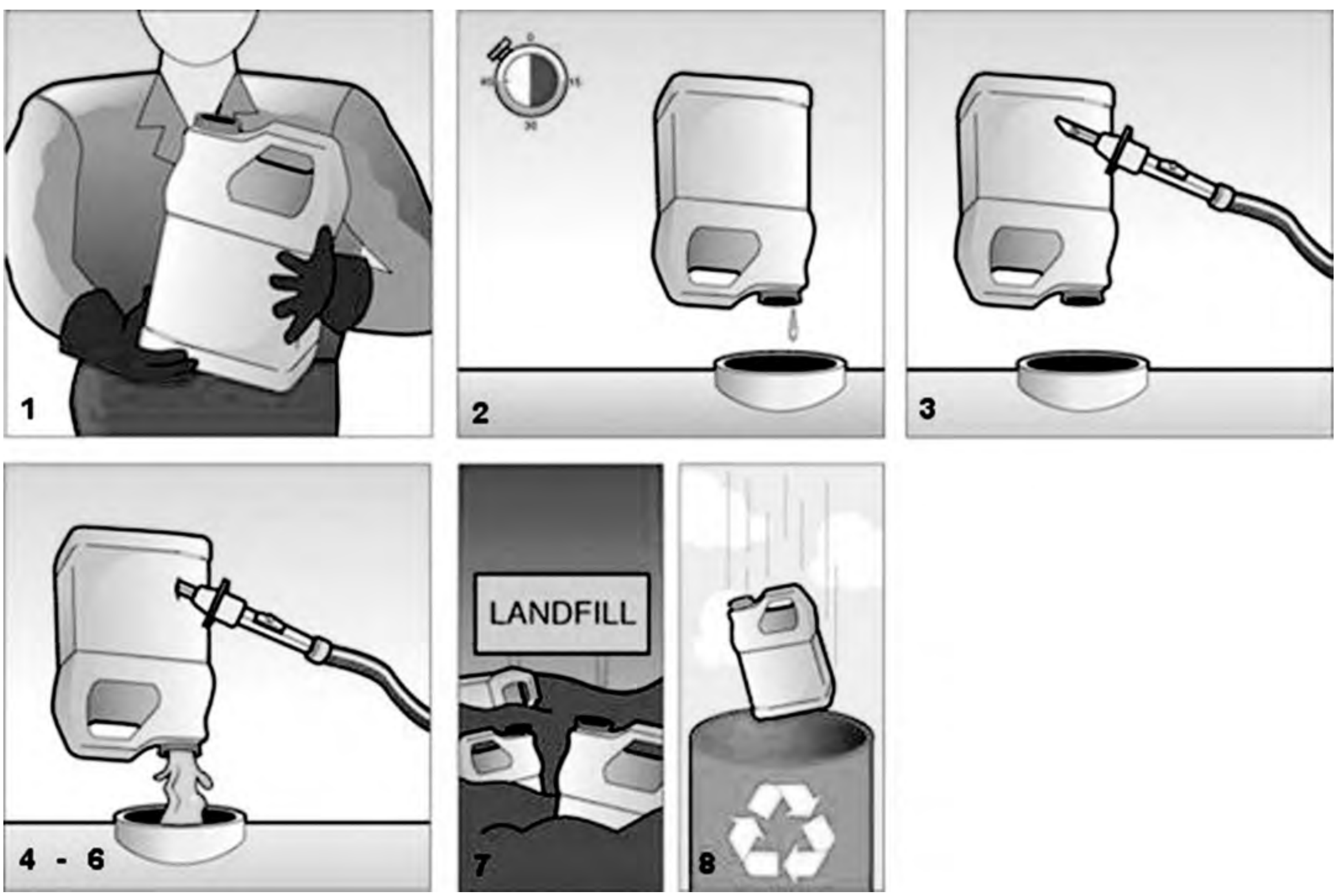



**Figure 2. Pressure-rinsing procedure for plastic pesticide containers. Used with permission from Fred Whitford, Purdue University. Scott Dallas and John Metzinger, illustrators.**

to drain for 30 seconds. Begin the rinsing procedure immediately or the product may be difficult to remove. If you are not able to rinse the container immediately, replace the cap until you are able to rinse the container.

3. Insert the pressure-rinsing nozzle, which should be equipped with a flow control, by puncturing a hole through the lower side of the pesticide container.
4. Hold the pesticide container upside down over the spray tank opening, turn on the flow of water, and allow the rinsate to run into the spray tank.
5. Rinse for the length of time recommended by the manufacturer (usually 30 seconds or more). Rotate or rock the nozzle to rinse all inside surfaces.
6. Rinse the cap separately in a bucket of water and pour this rinse water into the spray tank.
7. Replace the cap and dispose of pesticide container according to label directions.
8. If recycling, remember that caps and containers are made from different materials; therefore, caps cannot be recycled.

## Storing Empty Pesticide Containers

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

## Container Recycling

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

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

## Remember

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

**This publication has been peer reviewed.**

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

**Index: Pesticides, General**
**Safety**
2007, Revised April 2013

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

University of Nebraska–Lincoln Extension educational programs abide with the nondiscrimination policies of the University of Nebraska–Lincoln and the United States Department of Agriculture.

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

G1770
(Revised August 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.

**Figure 1. Cleaning a sprayer (Photo credit: USDA).**

The area may be the same as the mixing and loading location. It should be impervious to water and have a wash rack or cement apron with a sump to catch contaminated wash water and pesticides. If such a facility is not available, catch or contain the rinsate and spray the rinse water or the cleaning solution on a site and in a manner consistent with the labeled use of the pesticide product.

If concentrated spray material is spilled on the outside of the sprayer during loading or mixing, wash the outside of the sprayer immediately. Screens and strainers also should be cleaned or replaced frequently as they can be a major source of contamination. Self-cleaning strainers do a good job of straining and do not require cleaning. Residues also can accumulate in checked or cracked hoses. Inspect the inside of hoses and replace if necessary. Pay special attention to the following areas as they may be missed or difficult to clean:

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

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

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

**Rinsates**

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

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

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

The rinsate **cannot** be added to a pesticide mixture if:

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

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

**Equipment Cleanup**

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

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

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

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

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

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

**Equipment Storage**

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

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

### Removing Herbicide Residues from the Sprayer

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

This procedure is recommended for all herbicides unless the label specifies a different cleanout procedure. With sensitive crops, the best method to avoid herbicide injury from residual in the tank is to use a separate sprayer for the crops. When some herbicides, such as glyphosate, are left in the tank for a period of time, they can absorb products such as dicamba (Banvel®/Clarity®/Sterling) from the spray tank, which can result in crop injury.

1. Add one-half tank of fresh water and flush tanks, lines, booms, and nozzles for at least five minutes using a combination of agitation and spraying. Rinsate sprayed through the booms is best sprayed onto cropland for which the pesticide is labeled to avoid accumulation of pesticide-contaminated rinsate. Thoroughly rinse the inside surfaces of the tank, paying particular attention to the surfaces around the tank-fill access, baffles, and tank plumbing fixtures. The use of a 360-degree nozzle, such as the TeeJet Model 27500E-TEF rinsing nozzle, permanently installed to the spray system, can automate the cleaning of tops and sides of the tanks. Several nozzles may need to be carefully positioned to clean tanks with baffles. Pressure sprayers are useful for removing caked-on internal and external residues. Hot water can increase penetration of dried residues, but adding a hot-water rinse may cause unacceptable health hazards due to the vapors produced. Carefully review labeled safety precautions for the agrichemicals and cleaning products used.
2. Fill the tank with fresh water and the recommended cleaning solutions or a commercially available tank cleaner and agitate the solution for 15 minutes. To make a cleaning solution, add one of the following to 50 gallons of water:
   - 2 quarts of household ammonia (let stand in sprayer overnight for growth regulator herbicides such as 2,4-D or Dicamba), or
   - 4 pounds of trisodium phosphate cleaner detergent.

   Operate the spray booms long enough to ensure that all nozzles and boom lines are filled with the cleaning solution. Let the solution stand in the system for several hours, preferably overnight. Agitate and spray the solution onto areas suitable for the rinsate solution.
3. Add more water and rinse the system again by using a combination of agitation and spraying. Remove nozzles, screens, and strainers and clean separately in a bucket of cleaning agent and water.
4. Rinse and flush the system once again with clean water.

**This publication was peer reviewed.**



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

**Index: Pesticides, General**
**Safety**

Issued August 2013

NebGuide

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

Know how. Know now.

G2038

# 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.**

### Read the Label

Product labels and MSDS contain emergency information and procedures that may be specific to each product. Read labels carefully and make sure they are easily accessible for quick reference in an emergency.

### Resources

Nebraska Pesticide Applicator Certification Core Manual, 2007.

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

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

## When and How to Report a Pesticide Spill

Evaluating which spill situations require reporting is the first step in proper response. The following statement helps assess when to report a spill: "Report a spill if there is any potential harm to human health or the environment ... a spill is not reportable when it does not result in pesticide lost to the environment ... such as when it occurs on a concrete floor or in an enclosed area."

Follow these steps when a spill occurs:

1. Call First Responders/EMT for human injuries, and medical or fire emergencies **(911)**, OR The Poison Center for aid in human poisoning cases, **(800) 222-1222**.
2. Control the spill.
3. Contain the spill.
4. Call CHEMTREC (Pesticide Accident Hotline) or the local fire department for help involving spills, leaks, fires; be prepared to report the actual amount of concentrated chemical/fertilizer spilled, **(800) 424-9300**.
5. Call the Nebraska State Patrol to report chemical spills or releases and motor vehicle accidents on state/public roadways, **(800) 525-5555**; OR the Nebraska Department of Environmental Quality to report all other spills, **(402) 471-2186,** and receive guidance.
6. Clean up the spill according to recommendations from appropriate agencies.

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

***Nonemergency Telephone Numbers***

- National Pesticide Information Center for questions about pesticides and safety, **(800) 858-7378**.
- Chemical Referral Center (weekdays only) for referrals to manufacturers on health and safety related to chemicals, **(800) 262-8200.**
- Individual chemical manufacturer numbers on the pesticide label.

**This publication has been peer reviewed.**

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

**Index: Pesticides, General**
**Safety**
Issued September 2010

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

Nebraska Lincoln EXTENSION

Know how. Know **now.**

EC2505
(Revised October 2012)

# 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

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

University of Nebraska–Lincoln Extension educational programs abide with the nondiscrimination policies of the University of Nebraska–Lincoln and the United States Department of Agriculture.



IANR

# 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**
**Pierce J. Hansen, Extension Assistant**

The potential for accidents with pesticides is real. Accidental exposure or overexposure to pesticides can have serious consequences. While most pesticides can be used with relatively little risk when label directions are followed, some are extremely toxic and require special precautions.

In 2010, the Poison Control Centers received 91,940 calls (3.3 percent of all human exposures) related to pesticide exposures. That year, pesticides were responsible for about 3 percent of all accidental exposures to children 5 years and younger and almost 6 percent for adults. In addition, pesticides were the cause of about 4 percent of children's deaths reported to the Poison Control Centers.

## Routes of Exposure

Pesticides can enter the human body three ways: 1) ***dermal exposure***, by absorption through the skin or eyes; 2) ***oral exposure***, through the mouth; and 3) through ***inhalation or respiratory exposure***, by breathing into the lungs.

**Dermal exposure** results in absorption immediately after a pesticide contacts the skin or eyes. Absorption will continue as long as the pesticide remains in contact with the skin or eyes. The rate at which dermal absorption occurs is different for each part of the body (*Figure 1*). The relative absorption rates are determined by comparing each respective absorption rate with the forearm absorption rate, given a rate of 1.

It is easy to transfer pesticide residues from one part of the body to another. For example, residues can be inadvertently moved from the palm of a hand that has an absorption rate of 1.3, to a sweaty forehead (4.2) or to the genital area (11.8). When this occurs, the applicator increases the potential for pesticide poisoning.

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

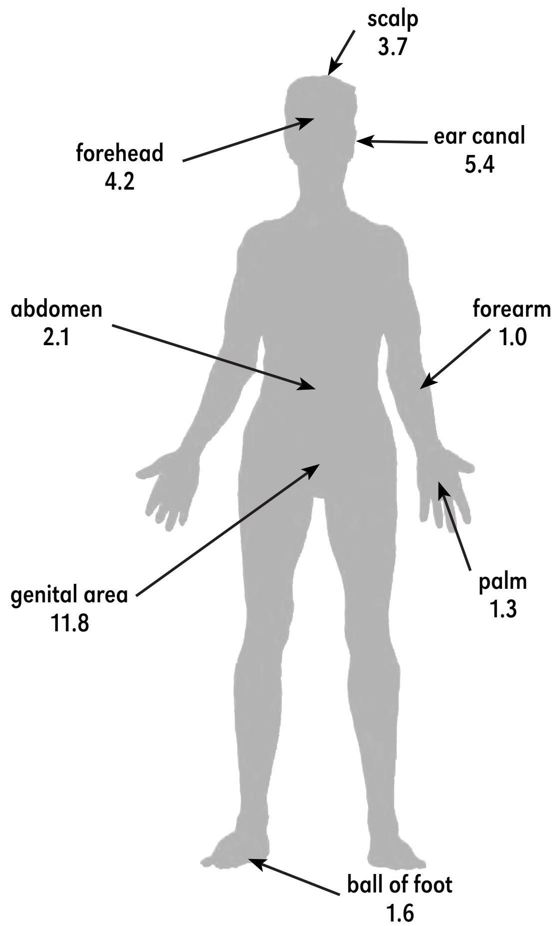



**Figure 1. Absorption rates of the different parts of the body based on the absorption rate of the forearm.**

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

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

Follow these guidelines to reduce the risk of pesticide exposure:

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

## Pesticide Toxicity

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

***Measuring toxicity***. The $LD_{50}$ (lethal dose, 50 percent) describes the dose of a pesticide that will kill half of a group of test animals (rats, mice, or rabbits) from a single exposure or dose by a dermal, oral, or inhalation route. The $LD_{50}$ is the dose per unit of body weight, such as milligrams per kilogram (mg/kg). A pesticide with a lower $LD_{50}$ is more toxic than a pesticide with a higher number because it takes less of the pesticide to kill half of the test animals. For example, a pesticide with an $LD_{50}$ of 10 mg/kg is much more toxic than a pesticide with an $LD_{50}$ of 1,000 mg/kg.

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

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

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

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

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

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

| GROUP | SIGNAL WORD | TOXICITY RATING | ORAL LETHAL DOSE for a 150-pound Human[a] |
|---|---|---|---|
| I | Danger[b] | Highly toxic | Few drops to 1 tsp |
| II | Warning | Moderately toxic | 1 tsp to 1 Tbsp |
| III | Caution | Slightly toxic | 1 Tbsp to a pint |
| IV | Caution (signal word not always required) | Relatively nontoxic | More than a pint |

[a]The lethal dose is less than those listed for a child or for a person under 150 lb, and more for a person over 150 lb.
[b]The skull and crossbones symbol and the word “Poison” sometimes are printed with the signal word “Danger.”

## Signal Words

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

## Read the Pesticide Label

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

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

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

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

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

## Manage Your Risk

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

**Risk = Toxicity *x* Exposure.**

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

## Recognizing Signs and Symptoms of Poisoning

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

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

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

## Recognizing Common Pesticide Poisonings

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

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

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

## Insecticides

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

### Organophosphate and Carbamate Insecticides

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

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

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

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

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

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

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

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

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

## Organochlorine Insecticides

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

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

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

## Pyrethroid Insecticides

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

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

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

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

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

## Biological Insecticides

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

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

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

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

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

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

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

## Inorganic Insecticides

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

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

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

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

### Other Insecticides

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

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

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

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

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

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

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

## Insect Growth Regulators

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

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

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

## Mosquito Repellents

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

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

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

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

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

## Fumigants

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

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

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

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

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

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

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

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

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

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

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

## Rodenticides

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

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

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

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

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

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

## Wood Preservatives

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

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

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

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

## Herbicides

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

### Bipyridyl Herbicides

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

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

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

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

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

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

### Chlorophenoxy Herbicides

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

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

### Arsenical Herbicides

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

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

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

### Other Herbicides

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

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

## Fungicides

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

## Other Pesticides and Synergists

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

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

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

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

## What if a Pesticide Poisoning Occurs?

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

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

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

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

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

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

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

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

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

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

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

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

## References

*2010 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 28th Annual Report.* 2010. 515 King Street, Suite 510, Alexandria, VA 22314. *http://www.aapcc.org/dnn/Portals/0/2010%20NPDS%20Annual%20Report.pdf*

*Crop Protection Handbook.* 2006. Meister Publishing Company. Willoughby, Ohio.

*Handbook of Pesticide Toxicology*. 1991. Wayland J. Hayes Jr. and Edward R. Laws Jr., Editors. Academic Press, Inc. San Diego, California.

*National Pesticide Information Center.* 2011. Oregon State University. *http://npic.orst.edu/*

*Pesticide Education Resources* website. 2012. University of Nebraska–Lincoln Extension. *http://pested.unl.edu/*

*Recognition and Management of Pesticide Poisonings*. 1999. Donald P. Morgan. Fifth Edition. Document No. EPA735-R98-003. Supt. of Documents, U.S. Government Printing Office, Washington, D.C. 20402-9325. *http://npic.orst.edu/rmpp.htm*

*Rotenone, Paraquat, and Parkinson's Disease*. Caroline M. Tanner, Freya Kamel, G. Webster Ross, Jane A. Hoppin, Samuel M. Goldman, Monica Korell, Connie Marras, Grace S. Bhudhikanok, Meike Kasten, Anabel R. Chade, Kathleen Comyns, Marie Barber Richards, Cheryl Meng, Benjamin Priestley, Hubert H. Fernandez, Franca Cambi, David M. Umbach, Aaron Blair, Dale P. Sandler, J. William Langston *in* Environmental Health Perspectives. 2011 June; 119(6): 866–872. Published online 2011 January 26. *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3114824/*

*The Pesticide Book.* 2004. George W. Ware and David M. Witacre. Sixth Edition. MeisterPro Information Resources. Willoughby, Ohio.

*Toxic Syndrome Condition — Nerve Agent and Organophosphate Pesticide Poisoning.* 2005. U.S. Centers for Disease Control and Prevention. *http://emergency.cdc.gov/agent/nerve/tsd.asp*

## Pesticide Safety Telephone Numbers

***Emergency Telephone Numbers*** **911**

**Poison Control Center** **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.

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

University of Nebraska Lincoln

University of Nebraska Lincoln EXTENSION
Know how. Know **now.**

**EC2507**
**(Revised May 2013)**

# 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**

IANR

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

University of Nebraska–Lincoln Extension educational programs abide with the nondiscrimination policies of the University of Nebraska–Lincoln and the United States Department of Agriculture.

Most accidental pesticide poisonings occur when pesticides are mishandled. Young children are often the victims. Pesticide accidents can be prevented by careful planning, using a secure storage location, adopting safe handling methods during transport, and following proper disposal guidelines for both products and containers.

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

• Buy only the amount that can be used in a reasonable length of time.

• Don't be tempted by "sale prices."

• Buy pesticides in quantities that you will use in the near future. Some pesticides should not be stored for long periods of time, allowed to freeze, or be stored in direct sunlight because they may become less effective.

Always keep pesticides in their original containers. Using any other container is illegal and could cause an accidental pesticide poisoning. Also, using another container could make it very difficult to retrieve the pesticide label information in the case of pesticide poisoning or environmental contamination.

# Transporting Pesticides

Certain precautions should be taken when transporting pesticides. Traffic accidents can happen even when you travel only a short distance, and improperly loaded pesticide containers can fall off your vehicle or become punctured or torn. Because pesticides are transported on public roads, the potential damage from such accidents is great.

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

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

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

## What Vehicle to Use

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

## Loading Pesticides

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

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

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

## Unloading Pesticides

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

Always carry a pesticide spill kit and carefully secure all pesticide containers.

## Transporting Hazardous Pesticides

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

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

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

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

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

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

### Accessing the Regulations

Hazardous materials regulations are available online and in print versions.

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

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

It is published by the Office of the Federal Register National Archives and Records Administration as a Special Edition of the Federal Register.

**Placarding.** For most hazardous pesticides (HMT II) in non-bulk, you will need to placard your vehicle when you transport as little as 1,000 pounds of the chemical. When transporting hazardous pesticides (HMT II) in bulk (over 119 gallons) or any amount from HMT I, placarding is required at all times. Place placards, which are available from your pesticide dealer, on all four sides of your vehicle.

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


Check all shipping containers for proper DOT labeling and marking.

## Farmer Exception

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

## Transporting Hazardous Pesticide Waste

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

- "Characteristic" wastes. These are waste materials with one or more of these characteristics: ignitable, corrosive, reactive, TCLP toxic1. These are considered "hazardous wastes" even though they may not be "listed," or,
- "Listed" substances. See the Code of Federal Regulations 40, parts 261.3 and 261.32 for those pesticides that have been declared to be "hazardous waste."

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

# Storing Pesticides

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

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

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

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

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

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

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

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

## Be Prepared for Pesticide Spills

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

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

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

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

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

## Pesticide Storage and Spill Reporting Requirements

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

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

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

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

## Selecting a Site for Pesticide Storage

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

The site also should be in an area where flooding is unlikely. It should be located where runoff can be diverted and drainage from the site cannot contaminate surface or groundwater.

Ideally, a drainage system should be built to collect any runoff water from the storage area. Pesticides that may be present in tank rinsate, spills, seepage from storage, and heavy runoff in the event of fire or flooding must be controlled. Dikes, collecting pools, and washing slabs with sumps provide a proper drainage system. All of the collected runoff water should be treated as a surplus pesticide and disposed of properly.

## Storage Area

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

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

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

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

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

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


Danger! Pesticide storage sign.

# Disposing of Excess Pesticides and Pesticide Containers

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

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

## Types of Pesticide Containers

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

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

## Removing Pesticide Residues from Nonrefillable Liquid Containers

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

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

## Proper Rinsing

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

Pressure-rinsing a pesticide container.

## Pressure-rinsing

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

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

## Triple-rinsing

Triple-rinsing can be done as follows:

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

## When Rinsing Is Not Possible

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

### Bags

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

### Pressurized cans

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

## Disposal of Excess Pesticide Waste

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

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

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

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

# Vehicle Maintenance Checklist

## Cab Interior

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

## On-board Pesticide Containers

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

## Spill Control

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

## Equipment Check

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

## Personal Protective Equipment

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

## Tires

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

## Lights

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

## Wipers

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

## General Vehicle Maintenance

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

Vehicle ID ________________________ Notes ________________________

Inspected by ________________________ ________________________

Date ________________________ ________________________

Adapted from Pesticides and Commercial Vehicle Maintenance, Purdue University.

# Pesticide Storage Checklist

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

Enter date of each inspection: ____________ ____________ ____________

| | Yes | No | Yes | No | Yes | No |
|---|---|---|---|---|---|---|
| **General Information** | | | | | | |
| Clean, neat pesticide storage site | ____ | ____ | ____ | ____ | ____ | ____ |
| Current, on-site pesticide inventory | ____ | ____ | ____ | ____ | ____ | ____ |
| Emergency phone numbers posted | ____ | ____ | ____ | ____ | ____ | ____ |
| Labels and MSDS available | ____ | ____ | ____ | ____ | ____ | ____ |
| Accurate storage inspection log maintained | ____ | ____ | ____ | ____ | ____ | ____ |
| **Pesticide Containers** | | | | | | |
| Containers marked with purchase date | ____ | ____ | ____ | ____ | ____ | ____ |
| Insecticides, herbicides, and fungicides segregated | ____ | ____ | ____ | ____ | ____ | ____ |
| Pesticides stored in original containers | ____ | ____ | ____ | ____ | ____ | ____ |
| Dry formulations stored on pallets | ____ | ____ | ____ | ____ | ____ | ____ |
| Feeds stored separately from pesticides | ____ | ____ | ____ | ____ | ____ | ____ |
| Used containers rinsed and drained | ____ | ____ | ____ | ____ | ____ | ____ |
| Rinsed and unrinsed containers separated | ____ | ____ | ____ | ____ | ____ | ____ |
| Liquid formulations stored below dry formulations | ____ | ____ | ____ | ____ | ____ | ____ |
| **Spills and Disposal** | | | | | | |
| Storage area free of spills or leaks | ____ | ____ | ____ | ____ | ____ | ____ |
| Shovel and absorbent materials available | ____ | ____ | ____ | ____ | ____ | ____ |
| Sealed floors | ____ | ____ | ____ | ____ | ____ | ____ |
| Floor drains closed off (if present) | ____ | ____ | ____ | ____ | ____ | ____ |
| **Safety Information** | | | | | | |
| *No smoking* signs posted | ____ | ____ | ____ | ____ | ____ | ____ |
| Personal protective equipment available | ____ | ____ | ____ | ____ | ____ | ____ |
| Fire extinguisher in good working order | ____ | ____ | ____ | ____ | ____ | ____ |
| Storage room locked, limited access to keys | ____ | ____ | ____ | ____ | ____ | ____ |
| Storage room posted: **Pesticides — Keep Out!** | ____ | ____ | ____ | ____ | ____ | ____ |
| Storage site well lit and ventilated | ____ | ____ | ____ | ____ | ____ | ____ |

Adapted from Pesticides and Commercial Vehicle Maintenance, Purdue University.

# Weather Variability and Disease Management Strategies

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

## Introduction

This year's title of 'weather variability and disease management strategies' was chosen because we need to remember how weather conditions this year have impacted crop productivity and disease development. This will enable us to look forward and develop better management decisions for future growing seasons. Agricultural production is dependent on many climatic factors such as rain, humidity, temperature, and sunlight. These climate conditions have direct effects on yield as well as other indirect effects. One specific indirect effect of extreme weather events is increased pressure from pathogens and pests. Plant pathogens are commonly favored by very specific, and sometimes extreme, weather conditions. Pathogens take advantage of these conditions to infect, reproduce, and cause disease in crops that can lead to economic losses, ultimately in the loss of yield quality or quantity. Scientific projections indicate that climate change will continue to have major impacts on crops across the country and the world. It is therefore not surprising that this year, the United Nations Summit in New York on September 23, focused on climate change in agriculture with discussions on Global Alliance for Climate-Smart Agriculture. Nebraska is known for its leadership in agricultural production and one germane concern is how we will be able to utilize the available climate data in a timely fashion to our advantage in protecting our crops from the negative impacts of climate change and pathogens. We need to act in a way that can leverage climate change to our advantage, where possible. It is important to monitor soil moisture and irrigation. Late planting and dryer than normal conditions in 2014 resulted in irrigation late into the season in some locations, which will unfortunately result in reduced profits for such farms.

Temperature is also an important factor. When conditions are warmer, crops tend to grow faster and the time for seed maturity reduces. However, warmer conditions have the potential to reduce yield and in addition, can promote certain diseases. The dry and hot weather conditions of 2014, for example, supported charcoal rot infections that were seen in both corn and soybean in many locations this year. Weed control and timely applications of herbicide will be crucial preparation steps in mitigating the impacts of climate change in 2015. Weeds not only act as alternate hosts for many pathogens but also deplete soil moisture. Below we present information on the influence of weather variability on development of diseases in Nebraska field crops. In 2015, crop production practices should be well planned to be climate-ready and climate-compliant.

## Seedling Diseases in Corn and Use of In-Furrow Fungicides

The cool, wet, and often severe weather events during the 2014 cropping season led to numerous disease challenges in Nebraska's corn crop. Seedling disease pathogens especially took advantage of the cool and frequently rain in the spring of 2014. Some of the most common seedling diseases observed were those caused by *Pythium* species. *Pythium* species are in a group of fungus-like organisms called the Oomycetes. This group of organisms produces specialized long-lived and thick-walled reproductive and survival structures in the soil (called oospores). A common characteristic of *Pythium* species is that they require wet conditions (also giving them the name "water molds") for their specialized swimming "zoospores" to move through the soil seeking out plant roots. *Pythium* species (and the closely related *Phytophthora* species in soybean) can cause serious seedling disease and stand loss in corn (and soybean and many other crops). They can cause pre- and post-emergence damping off, root rot, seed decay and similar symptoms that can seriously affect stand establishment under adverse conditions killing a significant percentage of plants. Fortunately, all commercial field corn seed is treated with a seed treatment fungicide (except in very specialized cropping situations, such as organic production, etc.), or a cocktail of several products varying in their modes of action and efficacy on varying types of fungal pathogens. Specifically, products containing active ingredients like metalaxyl and mefenoxam, have been successful at controlling *Pythium* (and *Phytophthora*) species. Unfortunately, harsh weather, such as prolonged periods of wet and cool conditions like much of Nebraska experienced during the spring of 2014, can be especially favorable for long-term pathogen reproduction and plant infection. This sometimes exceeds the protection capabilities that some products are known to provide. Unfortunately, in commercial corn production where seed treatment products are pre-determined and applied at the seed company level prior to distribution, there are little to no opportunities to change or supplement seed treatment packages to gain added benefits in especially difficult planting environments. Altering the planting date is one way of manipulating the environment to favor a healthy stand establishment. Sometimes delaying planting date (by as little as a few days for certain high-risk fields with a history of seedling disease and stand establishment problems) can provide some reduction in disease pressure caused by certain pathogens. Doing so can sometimes allow time for field conditions to change, becoming more favorable for seed germination and emergence avoiding some disease pressure. Other practices, such as improving drainage in chronically wet fields or low areas (by tiling) can help to avoid wet conditions that can favor diseases caused by *Pythium* species. In addition, the increase in fungicide use and number of registered products available during recent years has increased dramatically in row crops, especially corn, providing another management option for several diseases. More recently, there has been an interest in expanding the ways that foliar fungicides are used in row crops, specifically the application timing and method. The use of the products in-furrow at planting has begun to increase and may provide additional benefits for seedling disease management in some crops. More extensive research trials have been conducted on the use of in-furrow fungicides in cotton, peanut, potato, and sugar beet. Testing conditions varied by year, location, crop, and disease pressure. However, during some crop years and testing conditions, improvements were reported in stand counts and height. These results indicate that under some growing conditions, in-furrow fungicides may provide benefits in stand establishment.

## Soybean Seedling Diseases

Just like in corn, the wet cool soils resulted in mostly *Pythium* seedling diseases in soybean early in the season and *Phytophthora* as the soils warmed up. The high corn yields in 2013 and extreme cold over the winter resulted in large amounts of residue in many fields which kept soil temperatures cooler with the added blanket of corn residue in our no-till fields. The variable soil moisture and temperature resulted in very uneven soybean stands in many fields. In addition to the cool wet soils, hail in many areas stressed and/or killed seedlings resulting in a need for replant. Management of seedling diseases is reviewed in the "Soybean Disease Update" section.

## Sclerotinia Stem Rot (White Mold)

The weather cycle over the last two years has provided conditions for more severe disease outbreaks with different profiles in soybean than the previous years. Sclerotinia stem rot, also referred to as white mold, is caused by a fungal pathogen that can reside in soybean fields for 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. These survival structures persist in soybean residue and soil waiting for optimum environmental conditions to occur. 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. Disease development and spread will occur from flowering until pod formation. As the flower is directly related to disease development, this disease will only develop if we have wet, humid conditions at flowering with moderate temperatures (<85° F). This is why stem rot is not a consistent problem in most of the Nebraska soybean crop acres. This is also why the disease was more severe in 2013 and 2014 as we had cool, wet conditions during flowering. 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. More information on symptoms and management are provided in the "Soybean Disease Update" section.

The white mold pathogen also causes a similar disease on dry beans, sunflowers, and potatoes. The incidence and severity on these crops is sporadic like that on soybeans described above due to these very specific environmental conditions that are needed for infections and disease progress. More information on this disease in dry beans is included in the "Specialty Crops Update" section.

## Sugar Beet Fungicide Applications for Managing Rhizoctonia Root and Crown Rot

Rhizoctonia root and crown rot caused by the soilborne pathogen, *Rhizoctonia solani* is a common soilborne pathogen, and the most widespread, consistently damaging disease of sugar beets in Nebraska. As a soilborne resident, once the pathogen becomes established, it is very difficult, if not impossible to eradicate. Thus managing it effectively before severe damage occurs is also very challenging.

For those producers who determine that they need to treat for Rhizoctonia root rot, one of the options is to use fungicide sprays. Over the last 10 years this procedure has been widely adopted by growers and the product of choice has been almost exclusively azoxystrobin (Quadris). Due to the concern that the pathogen may potentially develop resistance to Quadris, we have additionally been evaluating the use of several newer labeled products with different modes of action for their ability to suppress the disease. Those additional fungicides tested included Headline (pyraclostrobin), Proline (prothioconazole), and Priaxor. Priaxor is a new fungicide that combines a carboxamide fungicide with a strobilurin (active ingredient in both Quadris and Headline).

We have additionally compared different treatments involving the four fungicides utilizing in-furrow applications shortly after planting alone and in combination with foliar treatments that were employed when soil temperatures averaged 65° F for three sequential days. Previous work the last 4 years has indicated that this is the best time for application to the canopies, rather than applications made at particular crop growth stages.

The results show that the combination treatments (furrow + foliar) consistently provided better yields and lower levels of disease incidence and severity compared to the controls and the treatments individually. More importantly, no differences were observed with those combination treatments utilizing Quadris, Priaxor, and Proline. Each equally reduced disease and improved yields. This is very good news as they have different modes of action and could easily be rotated without loss of effectiveness.

## Common Bunt of Wheat

Another disease whose development is influenced by weather conditions is common bunt of wheat. In 2014, there were major outbreaks of common bunt in parts of western Nebraska and northeastern Colorado. These outbreaks can be attributed to wet, cool conditions during or following planting in the fall of 2013. The common bunt fungi infect wheat during germination. Spores of the fungi survive on the seed surface and in soil. The spores germinate and form mycelium in response to moisture. The mycelium penetrates and infects the coleoptile (sheath of tissue protecting the plumule or portion of the young shoot above the cotyledons) before the seedling emerges.

This process of infection is favored by cool temperatures (41 to 51° F). Therefore, in the presence of moisture and cool temperatures, the probability of infection of the seedling is significantly increased if the seed or soil is contaminated with common bunt spores. This explains the sporadic nature of common bunt. In years when these conditions (excessive moisture and cool temperatures) do not exist during planting in the fall, infection is not favored and therefore there may be no outbreaks of common bunt even in the presence of inoculum (spores) on the seed or in soil.

Once infection occurs, the mycelium systemically infects the plant and progresses to and inhabits the flower primordia of the head. The mycelium displaces all the seed tissues and eventually forms spores, resulting in bunt balls (seeds filled with common bunt spores). The bunt balls give off a pungent, fishy smell. During harvest, the bunt balls break and release the spores which contaminate the grain and soil.

The most effective strategies for managing common bunt are to plant clean seed and to treat seed with a systemic fungicide before planting. It is recommended that seed be treated by a professional seed treater. If seed is to be treated on-farm, ensure that it is cleaned thoroughly before treating and that there is thorough coverage with the fungicide. Avoid using farm-saved seed for the next wheat crop. Some wheat cultivars have partial resistance to the disease; however, most cultivars are susceptible.

# 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**
**Tony O. Adesemoye, Extension Plant Pathologist**

### Extension Plant Pathology Team Update

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

- Loren Giesler, Extension Specialist – UNL Lincoln Campus. Diseases in soybean and turf and extension team leader.
- Robert Harveson, Extension Specialist – UNL Panhandle Research and Extension Center (Scottsbluff, NE). Diseases in specialty crops, including chickpeas, dry beans, sugar beet, sunflower, etc. (all crops outside of corn, forages, small grains, sorghum and soybean).
- Tamra Jackson-Ziems, Extension Specialist – UNL Lincoln Campus. Diseases in corn and sorghum.
- Kevin Korus, Extension Educator-Plant Pathology - UNL Lincoln Campus. Coordinator of the Plant & Pest Diagnostic Clinic and diseases of trees and backyard fruits and vegetables.
- Tony Adesemoye, Extension Specialist – West Central Research and Extension Center (North Platte, NE). Cropping systems soilborne pathogens and integrated management of diseases.
- Stephen Wegulo, Extension Specialist – UNL Lincoln Campus. Diseases in forages, ornamentals and small grains.

### Changes to the Plant Disease Management Section of the 2015 Weed Guide

During the past year, several new products have become available for disease management. These products and additional products have been added to the Plant Disease Management Section of the 2015 Weed Guide. Products added to the Weed Guide have been summarized in Tables 1-3. Additional updates have also been made to the Plant Disease Management Section. For example, you will note that the Product Efficacy tables for corn, soybean, and wheat have been replaced with new efficacy tables. These tables were summarized by regional committees of plant pathologists from across the country that contributed the results of multiple locations of fungicide trials across several states. These new efficacy tables represent a consensus among numerous plant pathologists based on multi-state field trials and results published as technical reports on the American Phytopathological Society's website as Plant Disease Management Reports. In addition, both the efficacy tables and the product tables for every crop have been reorganized and sorted by mode of action. This change was made to raise awareness about product active ingredients and their classes/modes of action. This change will make it easier to compare and select products when rotating modes of action and reduce the selection pressure on pathogens that could potentially lead to fungicide resistance.

**Table 1. Foliar Products**

| Trade Name | Active Ingredient(s) | Fungicide Class | Labeled Crops |
|---|---|---|---|
| Affiance | azoxystrobin (9.35%)<br>+ tetraconazole (7.48%) | Mixed MoA | Corn, soybean |
| Aproach Prima | picoxystrobin (17.94%)<br>+ cyproconazole (7.17%) | Mixed MoA | Corn, soybean, wheat |
| Badge SC | copper oxychloride (16.81%)<br>+ copper hydroxide (15.36 %) | Inorganics | Corn, dry bean, sugarbeet |
| Bumper 41.8 EC | propiconazole (41.8%) | DMI Triazoles | Corn, soybean, wheat |
| Bumper ES | propiconazole (40.85%) | DMI Triazoles | Soybean, wheat |
| Champ | copper hydroxide (37.5%) | Inorganics | Dry bean, sugarbeet, wheat |
| Eminent VP | tetraconazole (11.6%) | DMI Triazoles | Sugarbeet |
| Evito 480 SC | fluoxastrobin (40.3%) | QoI Strobilurins | Corn |
| Evito T | flouxastrobin (18.0%)<br>+ tebuconazole (25.0%) | Mixed MoA | Wheat |
| Headline SC | pyraclostrobin (23.3%) | QoI Strobilurins | Dry bean, sorghum, soybean, sugarbeet, sunflower, wheat |
| Kocide 2000 | copper hydroxide (53.8%) | Inorganics | Corn, dry bean |
| Quadris | azoxystrobin (22.9%) | QoI Strobilurins | Sugarbeet |
| Quadris Opti | azoxystrobin (4.6%)<br>+ chlorothalonil (46.0%) | | Dry bean |
| Quadris Top SB | azoxystrobin (18.2%)<br>+ difenoconazole (11.4%) | Mixed MoA | Soybean |
| Quilt Xcel | azoxystrobin (13.5%)<br>+ propiconazole (11.7%) | Mixed MoA | Sorghum |
| Topsin 4.5 FL | thiophanate-methyl (45.0%) | MBC Thiophanates | Dry bean, soybean |
| Topsin M 70WP | thiophanate-methyl (70.0%) | MBC Thiophanates | Soybean |
| Topsin M WSB | thiophanate-methyl (70.0%) | MBC Thiophanates | Dry bean, soybean |
| Topsin XTR | thiophanate-methyl (37.5%)<br>+ tebuconazole (7.5%) | Mixed MoA | Soybean |

**Table 2. Seed Treatment Products**

| Trade Name | Active Ingredient(s) | Fungicide Class | Labeled Crops |
|---|---|---|---|
| Acceleron DX-109 | pyraclostrobin (18.4%) | QoI Strobilurins | Soybean |
| Acceleron DX-309 | metalaxyl (28.35%) | PA Acylalanines | Soybean |
| Acceleron DX-612 | fluxapyroxad (28.7%) | SDHI Carboxamides | Soybean |
| Allegiance Dry | metalaxyl (12.5%) | PA Acylalanines | Soybean, Wheat |
| Allegiance LS | metalaxyl (17.7%) | PA Acylalanines | Soybean, Wheat |
| ApronMaxx RTA + Moly | mefenoxam (1.02%)<br>+ fludioxonil (0.68%) | Mixed MoA | Soybean |
| Bean Guard/Allegiance | carboxin (12.5%)<br>+ metalaxyl (3.75%)<br>+ captan (24.45%) | Mixed MoA | Soybean |
| Charter F[2] | triticonazole (1.32%)<br>+ metalaxyl (0.79%) | Mixed MoA | Wheat |
| Dithane F-45 Rainshield | mancozeb (37.0%) | Dithiocarbamates | Wheat |
| Dyna-Shield Fludioxonil | fludioxonil (40.3%) | Phenylpyrroles | Wheat |
| Dyna-Shield Metalaxyl | metalaxyl (28.35%) | PA Acylalanines | Wheat |
| Dyna-Shield Metalaxyl 318 FS | metalaxyl (30.14%) | PA Acylalanines | Wheat |
| Dyna-Shield Small Grains | tebuconazole (0.48%)<br>+ metalaxyl (0.64%) | Mixed MoA | Wheat |
| Penncozeb 75DF | mancozeb (75.0%) | Dithiocarbamates | Wheat |
| Penncozeb 80WP | mancozeb (80.0%) | Dithiocarbamates | Wheat |
| Protector-L-Allegiance | thiram (14.29%)<br>+ metalaxyl (1.61%) | Mixed MoA | Soybean |
| Raxil 2.6F | tebuconazole (28.3%) | DMI Triazoles | Wheat |
| Warden CX | thiamethoxam (20.0%)<br>+ mefenoxam (5.99%)<br>+ fludioxonil (1.0%)<br>+ sedaxane (1.0%) | Mixed MoA | Soybean |

**Table 3. Seed Treatment Nematicides**

| Trade Name | Active Ingredient(s) | Labeled Crops |
|---|---|---|
| Avicta 500 FS | abamectin (46.3%) | Soybean |
| Avicta Complete Beans 500 | abamectin (22.2%)<br>+ thiamethoxam (11.1%)<br>+ mefenoxam (1.67%)<br>+ fludioxonil (0.55%) | Soybean |
| Avicta Complete Corn 250 | thiamethoxam (11.7%)<br>+ abamectin (10.3%)<br>+ thiabendazole (2.34%)<br>+ fludioxonil (0.3%)<br>+ mefenoxam (0.23%)<br>+ azoxystrobin (0.12%) | Corn (field, popcorn, seed, sweet) |
| Avicta Complete Corn 500 | thiamethoxam (23.1%)<br>+ abamectin (10.2%)<br>+ thiabendazole (2.31%)<br>+ fludioxonil (0.3%)<br>+ mefenoxam (0.23%)<br>+ azoxystrobin (0.12%) | Corn (field, popcorn, seed, sweet) |
| Avicta Duo Corn | abamectin (12.4%)<br>+ thiamethoxam (28.1%) | Corn (field, popcorn, seed, sweet) |

# Charcoal rot: an important disease in 2014

**Tony O. Adesemoye, Extension Plant Pathologist**

## Introduction

Dry and hot weather conditions and hail in 2014 enhanced charcoal rot infections in many parts of Nebraska. Charcoal rot (or dry weather wilt) is caused by *Macrophomina phaseolina*. This soilborne and seedborne fungus has over 500 hosts among which are soybean, corn, wheat, alfalfa, sorghum, potato, sweet potato, and dry bean. This year**,** charcoal rot was more spread in soybean and was confirmed in soybean samples collected from the following counties - Cass (Greenwood and Weeping Water), Burt (Oakland), Saunders (Ashland), and Keith (Ogallala).

Charcoal rot is among the top five important diseases of soybean when the right conditions are present. Direct and indirect yield losses to the disease can vary from minor to significant amounts, estimated at 5 to 50% depending on conditions in each location.

*Macrophomina phaseolina* overwinters in crop debris and soil as microsclerotia, a mass of hardened fungal material containing food reserves that help the fungus to survive environmental extremes. Microsclerotia are survival structures and allow the fungus to remain dormant until conditions are favorable for growth. Thus, the fungus may be present in the soil for several years without causing any noticeable infection.

Under favorable conditions, this pathogen can cause rots of the lower stem, stalk, and root. Also, it is associated with stem canker, seedling blight, stem blight, leaf blight, wilt, dry root rot, and damping off. In other places outside Nebraska, seedling damage from the disease has also been reported. Drought and soil temperature of 90° F or higher is optimal for disease development. Thus, the disease became very important during the year (and especially more in rain-fed/non-irrigated fields) because of the high temperature and dry conditions. In addition, wind and hail damages that occurred during the season stressed crops and helped the disease. For example, baseball-sized hail pelted soybean and corn fields in many locations in central and eastern Nebraska on June 3 and northeast Nebraska on June 30 injuring plants and making them weak and susceptible to infections.

As characteristic of the pathogen, infection might have occurred early in the season but did not manifest symptoms until mid or later in the season. In soybean, the dry and hot conditions occurred during the reproductive stages R1 to R7.

## Disease Symptoms

Symptoms may include yellowing and browning of leaves and stem, smaller than normal leaflets, and gray to silver lesions as well as black colored small growths of microsclerotia on the lower stem and root. The resemblance of microsclerotia to charcoal dust was the basis for the name of the disease. Wilting and drying are easily noticeable in infected parts of the field. Crops may have poorly filled pods or ears, and in some situations, pods may be flat without seeds. Ultimately, these symptoms will lead to direct and indirect yield losses.

## Management

As mentioned earlier, little is known about the pathogen so management is difficult. Cultural practices are currently the best management for the disease. Drought and the impact of high temperature must be cushioned. Irrigation to avoid drought or soil moisture management that reduces the impacts of drought in dryland production such as appropriate tillage will be useful. Short season varieties with quick maturity or early planting that help in fast canopy closure and reduction in soil temperature may help. Nutrition management will impact the pathogen by reducing plant stress.

There is little information about resistant varieties for this pathogen but some researchers have suggested that planting varieties that are resistant to other stalk rot pathogens like *Gibberella* may help. Crop rotation has little or no effect in managing this pathogen because of its wide host range. Fungicides are not effective either and little information is available about biological control.

## Detection and Diagnosis

Early detection and correct diagnosis of pathogens are crucial in managing disease. As seen this year in some locations, there could be mixed infections with other pathogens. For example, if white mold (Sclerotinia stem rot) is involved, it is possible for growers to think that the disease was only white mold, especially if disease was noticed after the development of the characteristic white colored microsclerotia of *Sclerotinia*. **T**herefore, growers are advised to contact the Plant and Pest Diagnostic Clinic at UNL or any of the plant pathologists whenever the pathogen is suspected in the field.

## Conclusion

It appears that weather conditions may continue to be conducive for this disease in subsequent years. Obviously, there is need for more understanding about this pathogen in the state. Henceforth, more energy will be devoted to the pathogen in Nebraska.

## Literature cited

Giesler L. J. Charcoal rot https://pdc.unl.edu/agriculturecrops/soybean/charcoalrot

Jackson-Ziems T. and Korus, K. 2014. Stalk and crown rot diseases likely in many fields. CropWatch http://cropwatch.unl.edu/archive/-/asset_publisher/VHeSpfv0Agju/content/stalk-and-crown-rot-diseases-likely-in-many-fields

Kaur, S., Dhillon, G. S., Brar, S. K., Vallad, G. E., Chand, R., and Chauhan, V. B. 2012. Emerging phytopathogen *Macrophomina phaseolina*: biology, economic importance and current diagnostic trends. Critical Reviews in Microbiology 38: 136-151.

# Specialty Crops Update – 2014

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

## Introduction

This report will summarize some of the major and unusual disease occurrences encountered during 2014 for sugar beets, dry beans, sunflowers, field peas, corn, chickpeas, fenugreek, and potatoes. Overall, conditions in western Nebraska in 2014 were radically 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 in previous years.

These climatic conditions had a major effect on the development of several plant production problems experienced during the season. For example, white mold and bacterial diseases in dry beans, and rust on sunflowers, 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 2014, including sugar beets, dry beans, corn, sunflowers, and yellow field peas.

## Sugar Beets

### Root rots

Root rot diseases in 2014 appeared again as substantial problems, similar to 2013 and 2011. The dry rot canker variant of Rhizoctonia root rot was again identified from a number of 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 from the Rhizoctonia root rot disease. 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 is a different species of *Rhizoctonia* (known as bi-nucleate) than the “typical” pathogen, *R. solani*. This thus confirms its identity as a distinct root pathogen causing a different disease than the more familiar Rhizoctonia root and crown rot.

Several fields were found to have plants infected with curly top – something that is not seen here often. Another relatively obscure root disease, violet root rot, has also been seen in increasing frequencies throughout the region.

### Nematodes

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

### Foliar Diseases

Cercospora leaf spot (CLS) was less problematic this year, although it did appear in isolated areas later into September with the additional moisture from 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 was 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 the cool wet weather, which favors this pathogen and disease. It is fortunate that this problem rarely affects economic yields, but can still appear problematic, causing concern to those unaware of the disease. As temperatures warm, the pathogen is often restricted to lower leaves and the plant essentially “grows out” of the problem.

## Dry Beans

Dry beans in 2014 were strongly affected by all of the bacterial blights. All four pathogens (halo and common blight, wilt and brown spot were all detected). The cooler weather further resulted in widespread white mold epidemics. Rust showed up late in some areas but did not affect yields because plants had already matured.

## Corn

Normally, our most severe and consistently occurring disease of corn in western Nebraska is Goss’ wilt. It was not as problematic overall in recent years, but was very prevalent early in May and June. However, the cooler weather did provide the opportunity for the fairly rare bacterial disease called chocolate spot, to appear again as it did in 2013. This disease is caused by the florescent bacterium, *Pseudomonas syringae*, and is related to the pathogen of similar diseases of other crops previously described in this article

## Sunflowers

The primary disease problems in sunflowers in 2014 were due to rust and Rhizopus head rot. Rhizopus head rot 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, due to the cool and wet weather. The rust disease was back and present throughout the region We did conduct some studies on both rust and Phomopsis stalk rot and were able to successfully produce levels of disease.

Another virus-like pathogen of unknown identity was again discovered from one field in Kimball County. It appears to be the same as one we found several years ago. It is not known at this point how serious a problem this will become, but right now is more of an oddity than a problem.

One of the more unusual finds this season was a parasitic plant that was infecting sunflower roots in one particular field. This plant has been tentatively identified as a species of *Orobanche*. It is known to occur throughout the Great Plains, but this is the first time it has been identified as a pathogen of sunflowers.

## Potatoes

2014 saw us wind up our participation 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 has not yet seriously affected yields or quality at this time in Nebraska.

The disease is caused by a bacterial pathogen and transmitted by potato psyllids. Once plants are infected, the pathogen induces a wilt of the vascular system causing chipping potatoes to have alternating light and dark brown patterns after being fried, hence the name for the disease being referred to as “zebra chip”. This condition makes the tubers and chips produced from them taste bitter and therefore, unmarketable.

## Chickpeas

Ascochyta blight was a persistent problem this year, as a result of the weather. Some moderate levels of disease were observed late in the season but they did not affect yields due to the onset of disease toward the end of the season. The conditions required for this disease are similar to that of CLS for sugar beet – warm, but not hot with high humidity 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, and another unknown problem that caused serious stunting and epinasty of new leaves. Fortunately, it did not occur in high numbers of plants. Few other serious potential disease issues have been noted.

A continuous, large increase in field peas was seen across the region in 2014. A bacterial blight, caused by the fluorescent bacterium, *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, peas were not adversely affected after the diseases receded with the arrival of warm temperatures in mid-summer.

# Corn Disease Update

**Tamra A. Jackson-Ziems, Extension Plant Pathologist**

The harsh growing conditions during 2014 contributed to several disease problems in corn, in spite of the overall high yields across the state. The extended cold and wet conditions early in the season led to development of seedling diseases and crop stress. Then, in many parts of the state, repeated and unprecedented strong storms battered and wounded crops with multiple and widespread hail events, high winds, very heavy rain, and devastating tornadoes. Many fields were planted late or replanted, some more than once, further delaying the crop. Cool summer and fall conditions delayed maturity and led to early frost events that prematurely killed plants in some fields prior to black layer. These stresses during the season led to some complications at harvest time and could continue to affect stored corn as ear rot pathogens continue to grow as grain molds.

## Seedling Diseases

The lengthy period of cool and wet soil conditions during the spring contributed to the development of seedling diseases in corn again in 2014 (and soybean – see the Soybean Disease Update for more information). 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 2015 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.

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.

Some of our most common stalk rot diseases are caused by pathogens that also cause seedling diseases. Plants that survive the initial infections while they are seedlings, may eventually succumb to the stalk and crown rot diseases late in the season when plants begin to senesce.

### 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.

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. Several seed treatment fungicides are often included that vary in their modes of action and provide protection against a diversity of seedling pathogens. But, in spite of their activity, seedling diseases may still develop in corn, such as during extended periods of inclement weather or under severe pathogen pressure. You can minimize the likelihood of developing seedling diseases by planting seed at appropriate planting depths and soil conditions to support rapid plant growth and emergence.

## Bacterial Diseases

The repeated and widespread wounding events across the state and subsequent development of bacterial diseases in corn were painful reminders that numerous species of pathogenic bacteria are common in our fields. Although some species can take advantage of natural openings in plants for infection routes, many of them opportunistically take advantage of wounds. Some of these diseases appeared simultaneously in the same fields and plants, such as Goss's bacterial wilt and blight and bacterial stalk rot.

**Goss's Bacterial Wilt and Blight**

Goss's bacterial wilt and leaf blight, or more commonly referred to as Goss's wilt, developed in many fields in 2014. The disease progressed rapidly in some fields following wounding events, and particularly so when plants were wounded during the seedling stages and leading to the early season systemic wilt phase of the disease. During mid- to late season, the more common leaf blight phase was developed and worsened in many fields across Nebraska and especially in areas that had repeated severe weather events. The bacteria causing Goss's wilt, *Clavibacter michiganensis* subsp. *nebraskensis*, are notorious for their ability to infect through wounds.

**Symptoms**

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

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

**Goss's Wilt Management Strategies**

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

**More Resources:**

Additional information on these and other diseases and their management can be found at the website Crop Watch at http://cropwatch.unl.edu/ or in the following UNL Extension publications:

Goss's Bacterial Wilt and Leaf Blight of Corn

Publication:
http://www.ianrpubs.unl.edu/sendIt/g1675.pdf

Video:
http://marketjournal.unl.edu/corndiseases

**Literature Cited:**

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

**Bacterial Stalk Rot**

In Nebraska, bacterial stalk rot is most commonly caused by the bacterial pathogen *Pectobacterium carotovorum* (formerly known as *Erwinia carotovora* subsp. *carotovora*). In 2014, more bacterial stalk rot was observed than in previous years, likely because of the wounding events that occurred in corn. Samples submitted to the UNL Plant & Pest Diagnostic Clinic also often tested positive for the pathogen causing Goss's bacterial wilt and blight. Co-infections with both pathogens are not uncommon due to their similar growing needs and opportunistic natures taking advantage of wounds. It can be difficult to distinguish between the bacterial stalk rot and the systemic wilt phase of Goss's bacterial wilt and blight as they also have similar symptoms and can progress and kill young plants rapidly. Both, and especially bacterial stalk rot, causes the development of darkened/discolored stalk tissue and overall plant decline. One of the most noted characteristics of the disease is a very offensive odor.

## Northern Corn Leaf Blight

Northern corn leaf blight (NCLB) developed at higher incidence and severity in Nebraska, particularly in the eastern counties, than in recent years. Warm humid weather favors infection by the fungus, *Exserohilum turcicum*, which causes this disease. Weather conditions, including cloudy days, moderate temperatures (64-81°F), high humidity and frequent rainfall will favor further infection and spread of this and other fungal pathogens that survive in infected corn residue from recent years.

Like most other diseases caused by pathogens in plant residue, lesions may develop on the lower leaves first and continue to develop on leaves higher up the plant as long as conditions are favorable. NCLB tends to have larger, cigar-shaped lesions with rounded ends. These lesions can be confused with Goss's bacterial blight lesions. Fungal spores may develop on NCLB lesions making them appear darker and/or dusty, especially in the middles of lesions.

**Management**

Development and spread of NCLB prior to tasseling could reduce corn yield, particularly as lesions develop and expand, killing leaf area that's necessary for grain fill later. It is most important to protect leaves at the ear leaf and above that contribute the most to grain fill. In 2014, lesions developed on leaves 4-6 relatively early in the season on susceptible hybrids.

Foliar fungicides can be used to slow disease spread and protect uninfected leaf tissue in affected fields. Lesion development requires up to two weeks after infection occurs. Thus, it is possible that one to two leaves are already infected above the highest leaf on the plant that has recognizable lesions. To determine if a fungicide application is economical for you, consider the price of corn, yield potential, cost of treatment, and disease severity.

No treatment thresholds have been established for NCLB. However, you can assess your risk for developing yield-limiting disease severity by considering the high risk factors listed below. Having more of these risk factors will increase the likelihood of increasing severity of NCLB and getting a return on the cost of a fungicide application:

- Poor hybrid disease rating(s) for NCLB (consult seed catalog or company representatives for ratings)
- Development prior to tasseling
- Continuous corn
- History of NCLB
- Substantial corn residue
- Humid/wet weather forecast

In fields that were affected by NCLB, it will be important to consider this disease in the future when making corn hybrid selections, since the fungus can survive in infected residue. Hybrids with better ratings for NCLB resistance and other management decisions, especially crop rotation, tillage, etc. should be made a priority to reduce its severity in the future.

**More Resources:**

Additional information on NCLB and other diseases and their management can be found at the website Crop Watch at http://cropwatch.unl.edu/
or in the following:
Northern Corn Leaf Blight
Video: http://marketjournal.unl.edu/corndiseases

**Stalk Rot Diseases**

The crop stress created by the growing conditions in 2014 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.

**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 weakened stalks, 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 likely 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. For more information on charcoal rot, see the article, "Charcoal rot: An Important Disease in 2014" in these 2015 CPC Proceedings.
- **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/sendIt/ec1868.pdf

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

**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."

# Wheat Disease Update

**Stephen Wegulo, Extension Plant Pathologist**

## Disease Occurrence in 2014

In 2014, drier than normal weather and cool temperatures early in the growing season delayed development of foliar fungal diseases. In addition, the amount of rust spores blowing in from southern states was small. As a result, foliar fungal disease levels were generally low during most of the growing season.

Leaf rust arrived in mid-June in south central and southeastern Nebraska, which was much later than its normal arrival time of mid- to late May. Statewide, levels of leaf rust were low.

Other fungal diseases observed during the 2014 growing season included loose smut, common bunt, tan spot, Septoria tritici blotch, powdery mildew, and trace levels of Fusarium head blight (scab).

Bacterial streak, also known as black chaff when it affects heads of wheat and other small grains, was the predominant disease in the eastern half of the state. At the Agricultural Research and Development Center (ARDC) near Mead and at Havelock Research Farm in Lincoln, very severe levels of bacterial streak were observed in wheat, oats, and triticale in breeding nurseries.

Wheat soilborne mosaic virus (WSBMV) occurred sporadically in southeast Nebraska early in the growing season, but at much lower levels than in 2013. As temperatures warmed up, symptoms of wheat streak mosaic virus (WSMV) and Triticum mosaic virus (TriMV) became more noticeable. Levels of virus diseases were generally low except in two fields in the southern Panhandle where high incidence and severity of wheat streak mosaic virus was observed in June.

Freeze injury was observed in some wheat fields throughout the state, but it was not as extensive as that observed in 2013.

Because bacterial streak occurred at higher levels than any other disease and because the frequency of its occurrence has increased in recent years, the rest of this update will focus on this disease.

## Bacterial Streak and Black Chaff

Bacterial streak is favored by warm temperatures, high humidity, and wetness. During frost conditions, the bacterium, if present on or in the plant, causes ice to form, that is, it is an ice nucleation bacterium. The damage caused to plant tissue by the ice creates conditions favorable for invasion and multiplication of the bacterium in the plant. Therefore, frost can lead to bacterial streak outbreaks and most likely contributed to its outbreak in wheat, oats, and triticale in 2014. Yield losses caused by the disease range from negligible to about 40% and result mainly from reduced grain filling.

Symptoms can be seen early in the growing season, but are most noticeable after heading, at which time large leaf lesions appear suddenly on the upper leaves.
Lesions are light brown and elongated between veins. They are initially water-soaked, but the water-soaking phase is short-lived in the absence of continuous wetness. Usually, lesions appear as necrotic streaks. These streaks may coalesce and affect large areas on leaves.

Bacterial streak symptoms can be confused with those of Septoria tritici blotch. Thin flakes usually can be seen adhering to the surface of leaves affected by bacterial streak, but are absent on leaves affected by Septoria tritici blotch. These flakes are dried bacterial exudate that forms during moist conditions.

On wheat, the head phase of bacterial streak, known as black chaff, is characterized by black longitudinal stripes on the glumes and purple-black lesions on the peduncle (stem below the head and above the flag leaf) and rachis (main axis of the head).

Bacterial streak is primarily seedborne. Seed is the most important source of primary (initial) inoculum. The bacterium resides mostly in the external seed coat. From the seed coat, the bacterium infects the plumule (portion of the young shoot above the cotyledons) through wounds or through stomata on the coleoptile (sheath of tissue protecting the plumule). Infection of the plumule, which consists of the leaves and shoot apex, occurs before the first leaf emerges.

During moist conditions and warm temperatures, the bacterium colonizes and invades leaf tissue. Later, yellow or milky bacterial exudates (secondary inoculum) form on the surface of leaf lesions in the presence of moisture. When these exudates dry, they form tiny granules or thin flakes. Spread in the field is facilitated by blowing rain, splashing water, and plant to plant contact. Secondary inoculum enters healthy plants through the stomata or wounds (caused by hail, sand blasting, or insects) and multiply in large masses in the soft tissue of the leaves, causing elongated streaks limited by the veins. Insects landing on leaves with bacterial exudate can contribute to spread and infection in the field.

Temperature plays a key role in the development of bacterial streak. Multiplication of the bacterium in leaf tissue is directly dependent on temperature, with optimum growth at temperatures above 79$^{o}$ F. Because the bacterium is inside the plant, dry conditions do not slow down disease progress within the plant, but limit spread in the field. Low temperatures slow down pathogen growth and disease progress.

The bacterium can survive epiphytically (on plant surfaces) on wheat and other grasses including grassy weeds. It survives poorly in soil and on crop debris. When epidemics occur in the field, the most likely source of primary inoculum is seed.

## Management of Bacterial Streak and Black Chaff

The most effective management strategy for bacterial streak and black chaff is to plant pathogen-free seed. There are no cultivars known to be highly resistant to the disease. Cultivars known to be highly susceptible should be avoided. There are no effective seed treatments available commercially, and since it is a bacterial disease, it cannot be controlled by foliar fungicide applications. Avoid excessive irrigation which favors pathogen growth and spread in the field. Irrigating such that the foliage dries between irrigations will slow down disease spread in the field, but not disease progress within an individual plant.

# Soybean Disease Update

**Loren J. Giesler, Extension Plant Pathologist**

With a surprising soybean crop in 2014 came a gamut of soybean disease problems. An extremely cool winter with large amounts of residue from 2013 resulted in cool, wet soils that favored early season seedling diseases in many fields by *Pythium*. Then 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 2014. 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 2014, *Pythium* was the most common seedling disease problem due to cool and wet 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 60ºF) 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". A complete product listing and ratings is included in the current Guide for Weed Management.

Criteria for assessing the use of seed treatment fungicides to manage seedling disease problems: (If these conditions are part of your production system your risk is greater.)

- History of a stand problem
- No-till
- Early planting date when soils are cool
- Poor seed quality

### Phytophthora Root and Stem Rot (*Phytophthora sojae*)

Phytophthora root and stem rot of soybean, is caused by, a soilborne fungus that is present in many Nebraska soybean fields. The pathogen survives primarily as "resting" spores in the soil or in association with infested crop debris. Disease development is favored at soil temperatures of 60ºF and high soil moisture. We have observed in the past that dry conditions followed by heavy rain events can result in higher amounts of *Phytophthora*. This is most likely due to the plants being slightly stressed and the higher soil temperature. It is most common in low areas of a field, on poorly drained or compacted soils, and in soils with high clay content, although it is not limited to these sites or conditions. It may also occur on well-drained hillsides during wet growing seasons.

Occurrence of *Phytophthora* should be documented in the field record book and the genetics used in the field should be checked. This disease is best managed with resistance, but there are over 70 races of the pathogen and several races are not impacted by any resistance genes currently deployed in commercial varieties. In Nebraska surveys conducted in 2000-02, Race 25 was found in several fields. Race 25 infested fields should be planted to *Rps3a* resistant varieties. The most common gene deployed in resistant varieties (*Rps1k*) is not effective against Race 25.

**Symptoms**

Symptoms associated with *Phytophthora sojae* infections include seed rots, pre- and post-emergence damping off of seedlings and stem rot of plants at various growth stages. The stem rot phase is easily identified by the dark brown color on the exterior surface of the stem and lower branches. Discoloration of the stem extends from below the soil to 6 inches or more above the soil line. The taproot turns dark brown and the entire root system may be rotted. Leaves on older infected plants become chlorotic between the veins followed by general wilting and death. Leaves will remain attached.

**Management of Phytophthora Root and Stem Rot**

*Genetic Resistance*. Using resistant varieties is the most effective way to manage Phytophthora root and stem rot of soybean. Genetic resistance in the host is expressed in terms of Rps ("resistant to *Phytophthora sojae*") genes. The race-specific genes are complete resistance to a specific race of *P. sojae* and genes are denoted as Rps 1a, 1b, 1c,1d,1k, 3,6,7. The pathogen exists in races or biotypes that interact with these genes. In a resistant reaction, the plant survives infection; susceptible varieties are killed when infection occurs. Race-specific resistance is effective in the early stages of germination.

The other parameter on which soybean varieties are rated for *P. sojae* is partial resistance (also called field resistance or tolerance). Soybean varieties with high levels of partial resistance can become infected with *Phytophthora* but the symptoms are not as severe as highly susceptible varieties. In field research trials conducted in Nebraska, good partial resistance performed as well as varieties with resistance genes and partial resistance. In fields where the *P. sojae* biotype is aggressive against the resistance genes available in commercial varieties, this is the only choice for management with genetics. If possible, a combination of good partial resistance and an Rps gene are recommended. Partial resistance alone will not be as effective during early growth stages or under high disease pressure.

*Cultural Practices*. Anything which can be done to improve soil drainage and structure will reduce disease potential. Soil drainage can be improved through tilling in many cases. Compacted soils will also result in increased disease levels. Crop rotation should also be done, as continuous soybean production will increase fungal inoculum and promote development of new biotypes.

*Fungicide application***.** Seed treatment fungicides containing mefenoxam or metalaxyl should be used in fields with a history of this disease. Note that many products require increased rates for activity against *Phytophthora*.

## Brown Stem Rot (*Phialophora gregata*)

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

### Symptoms

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

### Favorable Environmental Conditions

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

### Management of Brown Stem Rot

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

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

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

## Sudden Death Syndrome (*Fusarium virguliforme* syn. *Fusarium solani* f. sp. *glycines)*

The sudden death syndrome (SDS) pathogen is spread with soil; thus, the methods used to prevent soybean cyst nematode spread are also applicable to preventing spread of SDS. For symptoms to develop there needs to be high soil moisture available at flowering. As this is a soilborne disease, it will not spread rapidly across the field from individual spots that show up. Infected areas in a field can also have an oblong distribution in the direction of tillage or equipment traffic.

### Symptoms

The first signs of SDS appear as scattered yellow or white spots on the leaves in the upper portion of the canopy. In the intermediate stage, these spots eventually coalesce to form brown streaks between the veins (interveinal necrosis). On these leaves only the midvein and major lateral veins remain green. As the disease reaches the more advanced stages, premature defoliation occurs with petioles (leaf stems) remaining on the plant. The progression from early symptom to defoliation will occur rapidly (less than 14 days in most cases). Symptoms of SDS can be confused with brown stem rot symptoms. To differentiate the two, split the stems of infected plants and check for discoloration. If the pith (center stem) is discolored, this is a symptom of brown stem rot. Stem discoloration will be confined to the outer stem layers (vascular tissue) with SDS and can extend up the stem of infected plants.

**Favorable Environmental Conditions**

Sudden death syndrome is favored in high-yield environments. The disease is more prevalent during cool, wet growing seasons and is favored by early planting in cool soils. In 2014, cooler soil temperatures were similar to those for early planting in the previous year. Hot, dry weather appears to slow disease development, but depending on the stage and infections which may have occurred prior to dry weather it can become severe under these conditions. Heavy rains around the flowering time promote foliar symptom development. The series of events for weather in 2014 is why this disease occurred more severely in some areas than others.

**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 by traditional seed treatment products. In 2015, Bayer Crop Science is launching a new seed treatment (ILeVO™) which has shown some promise in fields with SDS.

## 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.

**Symptoms**

Initial symptoms are visible during pod development. Leaves will wilt and turn gray-green before turning brown, curling and dying. It is important to observe stems and pods for white mycelium and sclerotia to differentiate Sclerotinia stem rot from other stem and root rot diseases. Since blossoms are infected first, early stem or pod water-soaked symptoms often initiate near colonized flowers. In a few days diseased areas on the stem are killed and become tan and eventually bleached. This bleached stem will have a pithy texture and will shred easily. Infected plant parts generally will have signs of the fungal pathogen as white, fluffy mycelium during humid conditions and sclerotia on the surface of or embedded in the stem tissue. Although stem and pod infection usually occurs about 6 to 14 inches above the soil line, some basal infection also may be found. Infections will occur after flowering has initiated in the crop.

**Favorable Environmental Conditions**

Disease development and spread will occur from flowering until pod formation. As the flower is directly related to disease development, this disease will only develop if we have wet, humid conditions at flowering with moderate temperatures (<85° F). This is why this is not a consistent problem in most of the Nebraska soybean crop acres. This is also why the disease was more severe again in 2014 as we had cool, wet conditions during flowering in many parts of the state.

**Management of Sclerotinia Stem Rot**

*Resistance.* Soybean varieties vary in their response to Sclerotinia and most companies have ratings in the seed catalog. Avoid planting highly susceptible varieties in fields with a history of this disease. In addition, planting varieties which are short and do not lodge will reduce disease potential.

*Cultural Practices.* Row spacing has been shown to influence this disease, with narrow rows resulting in more Sclerotinia stem rot. Fields with a history of Sclerotinia should not be planted in narrow rows. Avoid irrigation during flowering. The common corn-soybean rotation will not reduce the potential for disease development. Utilizing a longer rotation with corn and wheat has been shown to reduce pathogen buildup and disease risk. As several weeds can be a host for this fungus, it is important to maintain good weed control during rotation years.

*Fungicide application.* Foliar fungicide applications are typically only recommended for consideration 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).

# Differentiating Chemical and Disease Symptoms in the Field

**Kevin A. Korus, Extension Educator**
**Loren J. Giesler, Extension Plant Pathologist**
**Robert M. Harveson, Extension Plant Pathologist**
**Tamra A. Jackson-Ziems, Extension Plant Pathologist**
**Lowell Sandell, (former) Extension Educator**
**Stephen Wegulo, Extension Plant Pathologist**

## Introduction

In years with conditions favorable for seedling disease and other disease there are typically concerns and inquiries about the cause(s) of symptoms in agronomic plants. Many of the questions focus on differentiating between plant injuries potentially caused by recent herbicide applications versus symptoms caused by plant pathogens. Chemical injury in row crops is caused by chemicals such as herbicides, fertilizers, fungicides, insecticides, growth regulators, and crop oils when they are applied individually, as a mixture, or together with adjuvants. If chemicals are applied incorrectly, plants may be damaged at any point during the growing season. Chemical injury can result from carryover in the soil, contamination of the spray tank, spray drift, or misapplication. Damage may even be realized with chemical applications when recommended application guidelines are followed if other environmental conditions are adverse, including low soil temperatures, high soil moisture levels, or if young plants are exposed to high levels of various fertilizers. Factors such as the mode of action of the chemical, application rate, growing conditions, and growth stage of the crop determine the extent of injury and symptom expression. Symptoms of chemical damage are diverse and include leaf lesions with burned, necrotic patches, wilting, damping off and sometimes death of mature plants. These symptoms could easily be confused with those caused by various plant pathogens found throughout the state. In most instances management actions cannot be taken during the year of the injury once you are past the replant timing. Therefore, you will want to correctly identify what is causing any stand problems to aid with future management actions.

## Scouting – Determine Symptom Distribution

*Field Distribution:*

Symptom distribution in the field and on the plants can be the most valuable clues to the cause of the problem. Diseased plants can be identified by their overall wilting and discoloration of leaves. They will have rotted, decaying roots and/or lower stems. Because some organisms that cause disease survive in the soil, their diseases usually occur in patches in the field — randomly scattered or often associated with low, wet areas (Figure 1). Typically, when chemical injury is the cause, a high percentage of the plants will exhibit symptoms and the distribution will be more uniform across a field or in patterns that may be associated with applications (Figure 2.). Injury is not likely to be concentrated in pockets. Diseased plants also may be randomly scattered among otherwise healthy plants in the field. Field topography will be key in distribution factors. In very flat fields it is possible to have plants with seedling disease scattered across the field but this is rare. In the event that a high percentage of the plants are affected across the entire field, typically another stress or injury is triggering the plant response. Depending on the chemical history, it may be the result of an underlying chemical injury.

*Plant Distribution:*

After the distribution of symptoms has been identified in the field, the next level to evaluate is the symptom distribution on individual plants (Figure 3). The actual plant part affected can give critical clues to differentiating the cause of the problem. Most seedling diseases caused by a pathogen will result in root symptoms.
Conversely, the roots of a plant displaying herbicide injury on the aboveground parts may be completely healthy.

*Plant Part Distribution:*

Distribution patterns on the individual plant part (root, stem, leaf) can offer clues as to the pathogen involved. For example, soybean damage at the lower portion of the root system can often be associated with *Fusarium*, while lesions near the soil line are often due to *Rhizoctonia* (Figure 4).

## Early Crop Development Symptoms and Injury

Seedling diseases are common in both soybean and corn. The most common seedling diseases have been those caused by *Pythium* species. These organisms require wet conditions so that their swimming spores can move toward and infect plant roots. Frequent and/or heavy rainfall events and cool temperatures are very conducive for infection by *Pythium* species.
Seedling diseases are often difficult to diagnose because their symptoms are very similar among several seedling diseases and may also be easily confused with other problems. Seedling diseases can be confused with insect injury, herbicide damage, planting problems, or environmental stresses that often have similar symptoms. 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

Carefully dig up symptomatic plants/roots, as any rotted roots may be broken off more easily and lost in the soil. Distribution patterns on the individual plant root systems can offer clues as to the pathogen involved. We encourage you to correctly identify what's causing any stand problems to aid with future management actions.

More specific examples of early season injury are below.

## Soybeans and Preemergence PPO Herbicide Injury

Three PPO herbicides are predominantly used for pre-emergence weed control in soybeans. These are:

- flumioxazin (in Valor®, Valor XLT®, Gangster®, Enlite®, and Envive®),
- saflufenacil (in Sharpen®, Optill®, Optill® PRO, and Verdict®), and
- sulfentrazone (in Authority First®, Authority Assist®, Authority® MTZ, Authority® XL, Authority® Elite®, Spartan®, and Sonic®).

These active ingredients provide residual control of many important annual broadleaf weeds in soybeans. They also can be effective in preplant burndown situations — depending upon the rate and weed species — because of their postemergence activity. They can be applied early preplant to shortly after soybean planting; however, severe injury can occur if they're applied as the soybean is cracking through the soil surface. (All labels of these products warn against applications at this point.)

From a weed management perspective, using these products in a diversified herbicide weed control program is beneficial and can help curb the progression of glyphosate-resistant weed development in Nebraska. However, if these products are not used properly, as with most herbicides, crop injury can occur. In very general terms, injury potential increases

- as the use rate increases, and/or
- as soil organic matter decreases, and/or
- the closer the application is to planting.

Additionally, there is a variable injury response among soybean varieties, ranging from highly tolerant to fairly susceptible. In the future, informing your seed dealer of your planned herbicide program is an important step to avoid pairing a susceptible variety with a preemergence PPO-based soybean herbicide program. Prolonged cool and wet weather conditions are ideal for adverse crop response to these products. Frequent or heavy rains as the hypocotyl arch is cracking through the soil surface or shortly after the cotyledons emerge can cause excessive herbicide uptake and subsequent injury. Cool temperatures reduce the rate at which the plant can metabolize (break down) the herbicide.

Injury will commonly display as reddish to purplish to brownish spots leading to necrotic tissue on the cotyledons and possible whittling of the stem at or near the soil surface. The potential to see injury often remains through the first few vegetative stages. Rain can splash soil with herbicide onto the unifoliates and first trifoliates, causing necrotic spotting and a crinkled appearance to some of the early developing trifoliates. In some instances it is difficult to assign specific levels of stand reduction to suspected causes such as herbicide injury, a soil-borne seedling disease, or cultural problems such as improper planting depth and soil crusting/compaction. Tissue injury from an excessive concentration or uptake of a PPO herbicide could cause points of infection for seedling diseases, while lack of vigor from seedling diseases could reduce a plant's ability to metabolize the PPO herbicide fast enough to prevent injury. Therefore, in many cases it can be difficult to identify the main cause of the injury.

## Reduced Stands Can Still Perform Relatively Well

The fortunate reality is that soybean yield potential can remain relatively high, even at reduced populations resulting from herbicide injury or seedling disease. Based on the calendar date, decisions must be made regarding destroying and replanting thin soybean stands and should be considered in only the most extreme circumstances. Populations of 70,000-90,000 plants/acre and above should be accepted and retained at this point in the growing season.

While often difficult, it is important to correctly identify the cause of the stand reduction before determining future management actions for the field.

## Wheat Disease or Herbicide Injury?

Diagnosing chemical injury in wheat can be difficult because the symptoms often resemble those caused by other abiotic agents and even some plant pathogens. To diagnose chemical injury requires thorough knowledge of individual plant symptoms, distribution of the injury in the field, chemicals that were recently applied to the field and its surroundings, environmental conditions, cultural practices, and field history. Clues to chemical injury include uniformly distributed symptoms that appear suddenly in the entire field or within areas in the field and absence of plant pathogen signs (e.g. fungal mycelium, fruiting structures, or spores; or bacterial ooze).

There is a wide variety of symptoms caused by chemical injury. Some symptoms are general whereas others result from specific chemicals or groups of chemicals. Phytotoxic seed treatments or excessive fertilizers can cause poor root development and seedling emergence. Excessive amounts of some herbicides (e.g. trifluralin) can cause swollen or ruptured coleoptiles.

Photosynthetic inhibitor herbicides such as atrazine can cause chlorosis followed by necrosis of leaves, starting from the leaf tip and progressing toward the base. Bleaching of foliage can result from exposure to pigment inhibitor herbicides such as clomazone.

A common symptom of chemical injury in wheat is localized foliar burn or leaf desiccation. This symptom, which can easily be confused with lesions caused by plant pathogens, insects, or physical damage, results when chemicals such as foliar fertilizers and certain herbicides are applied in concentrated droplets or drift from adjacent fields. Plants usually recover from this injury because it does not affect new growth and physiological development of the wheat crop.

Several different symptoms are caused by plant growth regulator herbicides such as 2, 4-D and dicamba. These symptoms include prostrate growth of tillers, stunting, and head abnormalities such as trapped or twisted awns, spikelet abortion, or sterility.

Exposure of wheat to glyphosate can cause severe injury at all stages of growth. Exposure during the vegetative growth stages can result in chlorosis, discoloration, and gradual plant death. In the heading growth stage, exposure to glyphosate at low levels can cause whitening and death of heads, leaving the rest of the plant green. This symptom can easily be confused with Fusarium head blight or scab (Figure 5).

**Dry Bean Disease or Herbicide Injury?**

*Salt Damage*

Beans are particularly susceptible to high levels of salinity whether in soil or irrigation water. This can be seen early in the season on newly emerging seedlings, or can also occur anytime during the season when salt from irrigation water may accumulate around plant stems at the soil level. This can then be confused with root disease caused by *Pythium* or *Rhizoctonia* as post-emergence damping-off. Plants affected by either problem will wilt quickly and die.

This is largely due to herbicide carryover due to lack of moisture that would normally flush any remaining chemicals out of the profile. The same relationship can be observed with salt. It accumulates in soils and doesn't get flushed out of the profile when we receive less than normal amounts of moisture from rain or snow.

**Management**

The best strategy for avoiding chemical injury is to follow label instructions and restrictions when applying a fertilizer, herbicide, fungicide, or insecticide. Application equipment should be correctly calibrated to avoid misapplication and applications should be avoided during extreme environmental conditions such as gusty winds and high or low temperatures.

Even with all of these clues, diagnosis of plant injury might require submission to a diagnostic laboratory for further confirmation. The Plant and Pest Diagnostic Clinic at the University of Nebraska – Lincoln offers disease diagnosis and can identify chemical injury based on field history and symptom identification.

Figure 1. Patchy distribution of symptoms in the field often associated with plant disease.

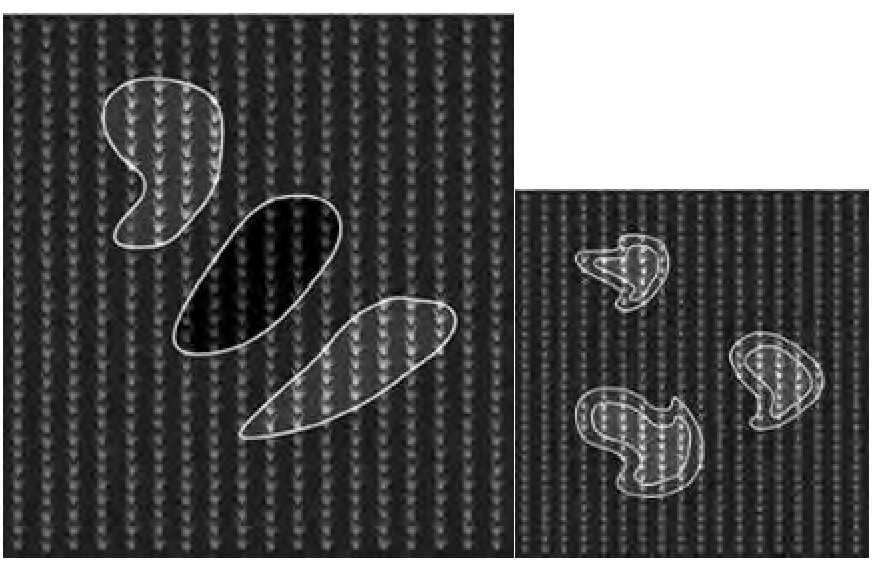


Figure 2. Uniform distribution of symptoms in the field associated with chemical injury.

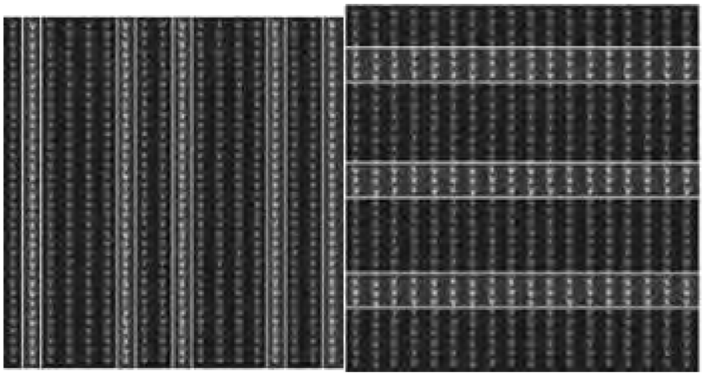


Figure 3. Symptom distribution on the plant level showing various plant parts affected.

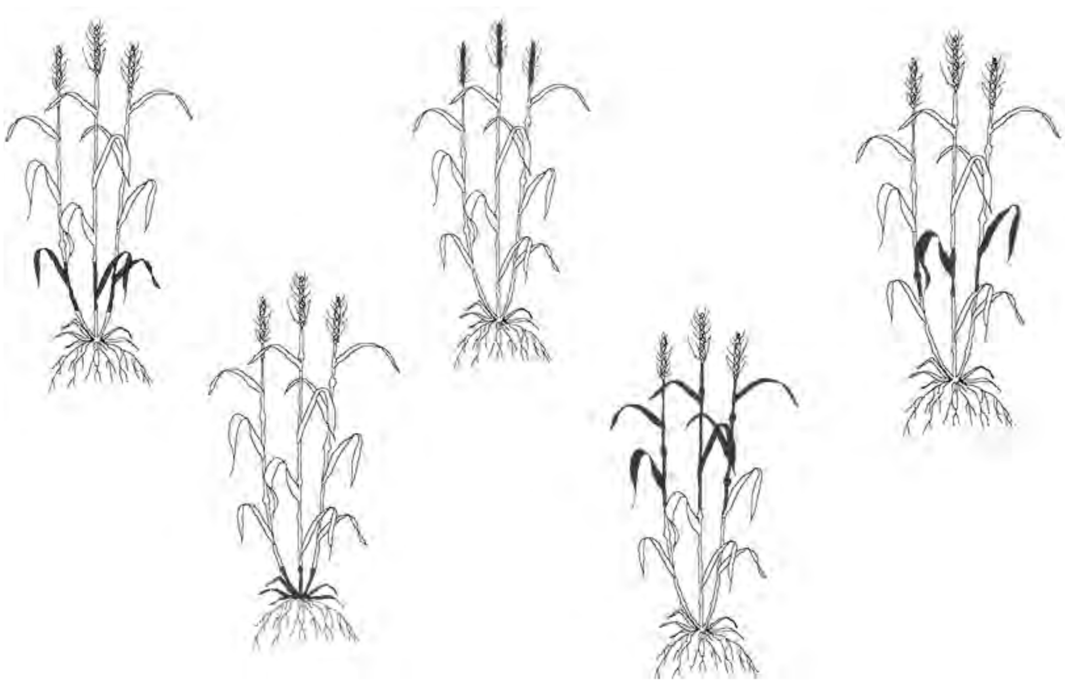
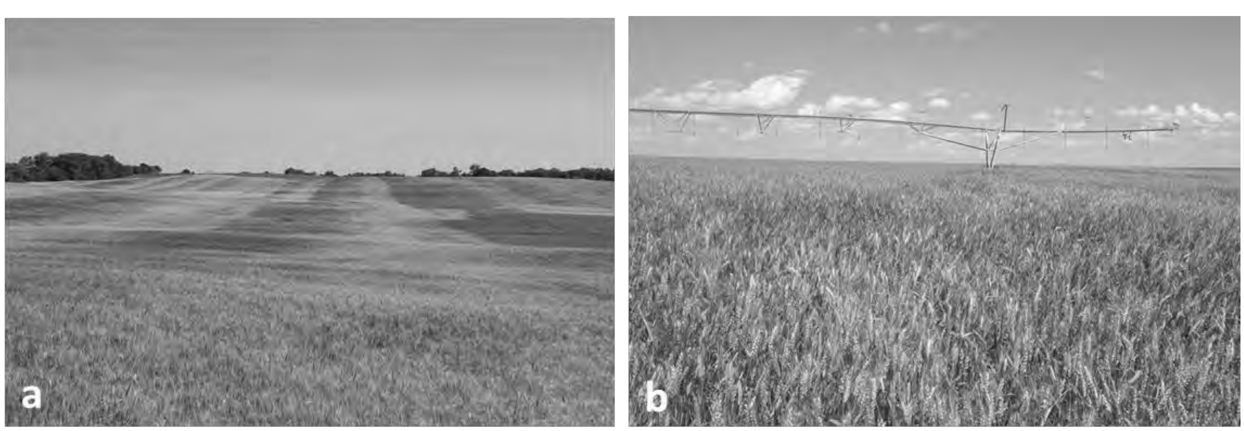


Figure 4. The difference in symptom expression between a) *Fusarium* and b) *Rhizoctonia* seedling diseases of soybean. *Fusarium* causes lesions on the lower root portions while *Rhizoctonia* causes lesions near the soil line. (Photo: Jim Stack, Kansas State University)


Figure 5.  a) Glyphosate damage in a wheat field.  Symptoms follow the pattern of the spray application.  b) Fusarium head blight of wheat.  Symptoms are randomly distributed throughout the field.  Some heads are blighted while others are not.



# Grazing and Bailing Effects on Soil Compaction

**Tim Shaver, UNL Nutrient Management Specialist**
**Richard Ferguson, UNL Soil Specialist**
**Gary Hergert, UNL Soil and Nutrient Management Specialist**
**Brian Krienke, UNL Extension Educator**
**Charles Shapiro, UNL Soil and Crop Nutrition Specialist**
**Charles Wortmann, UNL Soil and Nutrient Management Specialist**

## Introduction

Cattle grazing of corn residue is a common practice in most corn producing states. Mechanical removal of corn residue such as baling is widely practiced as well. The consequences of residue removal by grazing and baling on soil and crop production are poorly understood; experts and producers alike lack the information to make informed recommendations and decisions. Understanding the impacts of corn residue removal on soil properties and on crop yields is vital to corn productivity and sustainability.

Potential issues arise from grazing and baling because crop residue is a valuable resource when returned to the soil. It has been shown that crop residue management directly affects soil physical properties and is beneficial to characteristics related to soil quality and crop yields including nutrient cycling and soil organic carbon (SOC). Management practices that minimally disturb the soil and produce and leave more residue biomass on the soil surface have the potential to improve beneficial soil properties.

It has been suggested that corn residue removal costs more in terms of long-term soil quality, water use and crop productivity than is returned from its use as a feedstuff. If this is true, long-term profitability and sustainability is threatened. On the other hand, limited corn residue removal may be found not to be detrimental, making it possible for producer profitability to be increased by carefully managing its use. While the existing research suggests corn residue removal by grazing is not detrimental to subsequent productivity and sustainability, the body of research is small (especially in corn-corn systems) and suggests the potential for interaction with multiple factors. Additionally, little work has been done regarding the effects of mechanical removal of residue through baling which removes far more crop residue than does grazing.

## Grazing and Bailing Study

To study these concerns, a project was initiated at the University of Nebraska-Lincoln Water Resources Laboratory near Brule NE. The goal of this project was to quantify the impacts of residue removal on soil quality parameters associated with corn residue removal by grazing and baling. Specific objectives were to quantify the effects of five years of corn residue removal by grazing and mechanical means on soil penetration resistance (indicator of soil compaction). Four residue removal treatments including control (no grazing), light grazing, heavy grazing, and baling were carried out for 5 years. Soil penetration resistance was measured after 3, 4, and 5 years of residue removal.

## Results

Soil penetrometer readings are a measurement of the resistance encountered when penetrating the soil and is essentially a measurement of soil compaction. Soil compaction is often the chief concern of farmers when considering whether or not to graze corn residue and when determining what stocking rate should be used. Compaction is also a concern when baling residue as heavy equipment is required.

Soil penetration resistance in 2011 (after 3 yr of residue removal) for depth 0-2.5 cm (surface 1 inch of soil) is shown in Figure 1.

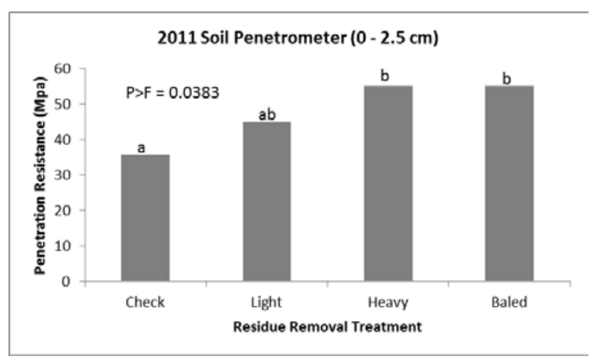



**Figure 1. Soil Penetration Resistance as Affected by Residue Removal in 2011.**

In the surface 0-2.5 cm, the penetration resistance was significantly lower in the no residue removed (check) treatment (35.9 kpa) than the heavy grazing (55.2 kpa) and the baling treatment (55.2 kpa). The light grazing treatment was intermediate with a penetration resistance of 44.8 kpa. The results in 2011 suggest that soil penetration resistance is directly affected by residue removal. Treatments with larger amounts of residue removal also resulted in higher levels of penetration resistance at the 0-2.5 cm soil depth.

These results support the hypothesis that grazing cattle and the heavy equipment associated with baling of corn residue affect soil compaction.

However, results from the exact same locations in 2012 and 2013 complicate these findings. In 2012 (after 4 yr of residue removal) no significant differences were found in penetration resistance across any residue removal treatments (Figure 2).

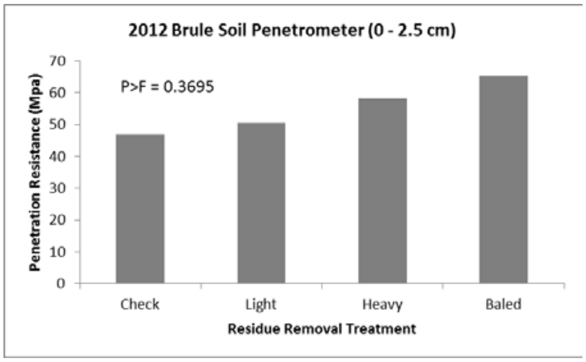



**Figure 2. Soil Penetration Resistance as Affected by Residue Removal in 2012.**

At the 0-2.5 cm depth penetration resistance measurements of 46.9, 50.6, 58.3, and 65.3 kpa were recorded for the no removal, light grazing, heavy grazing, and baling treatments respectively. While no significant differences were found in 2012, trends in the data are similar to those found in 2011 with the more intensive residue removal treatments resulting in increased penetration resistance.

In 2013 (after 5 years of residue removal) significant differences in penetration resistance were found (Figure 3) but the trends observed in 2013 were different than those seen in 2011 and 2012. The no residue removed treatment (42.3 kpa) and the light grazing treatment (31.9 kpa) were not significantly different. However, both treatments were significantly lower than the heavy grazing treatment (62.5 kpa). The baled treatment (54.1 kpa) was significantly higher than the light grazing treatment but not significantly different than the no residue removed or the heavy grazing treatment.

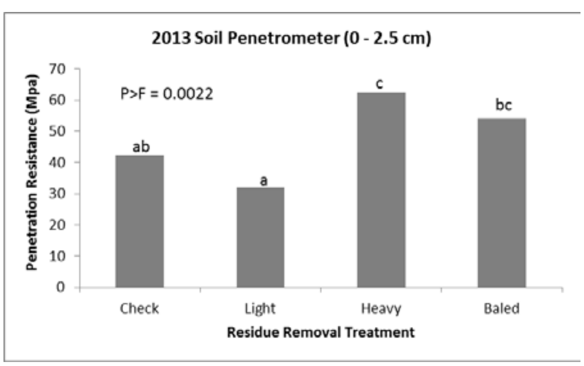



**Figure 3. Soil Penetration Resistance as Affected by Residue Removal in 2013.**

## Discussion

Overall, soil penetration resistance results were found to vary from year to year. These variations are most likely explained by variations in the amount of residue cover present and climate factors (temperature and precipitation) that also vary from year to year. When looking at temperatures, there was little difference in average temperatures during the times of grazing between 2011 (-2.0$^{o}$ C), 2012 (-3.9$^{o}$ C), and 2013 (-1.1$^{o}$ C). This suggests that temperatures do not explain the yearly variation observed in this study. However, when looking at precipitation during the time of grazing, there were larger differences. In 2011 there was 1.47 cm of precipitation, in 2012 there was .53 cm and in 2013 there was .76 cm of precipitation during the time of grazing. The wetter year in 2011 may explain why more intensive residue removal practices lead to higher resistance readings during this time. The driest year (2012) showed no significant results (although trends were present), and the intermediate precipitation year (2013) showed intermediate results. It would stand to reason that the amount of precipitation received during the time of cattle grazing would directly affect the levels of compaction.

## Conclusions

Overall the results suggest that intensive grazing and baling practices increase penetration resistance over no residue removed and that the extent of the effect can vary from year to year likely related to precipitation and/or temperature. Generally light grazing showed no significant differences compared to the check treatment suggesting that the light grazing management practice has the least effect on soil compaction. Depending on year, significantly higher penetration resistance values were found with heavy grazing and baling treatments suggesting that these management practices may not be ideal if soil compaction is a concern. However, the amount of penetration resistance does not appear to be cumulative from year to year as the 2013 penetration resistance is lower in most cases than the 2011 values treatment by treatment.

## Resources:

1. Stalker, A., R. Klein, B. Liu, T. Shaver, M. Stockton, S. van Donk, and S. Young. 2012. Grazing Cornstalks – a decision support tool to evaluate economics. Extension Circular, University of Nebraska-Lincoln Extension EC290.

2. van Donk, S., R. Klein, B. Liu, T. Shaver, A. Stalker, M. Stockton, S. Young. 2012. Baling corn residue - a decision support tool for evaluating the economics. Extension Circular, University of Nebraska-Lincoln Extension EC711.

# Nutrient Management Update

**Charles Shapiro, UNL Soil and Crop Nutrition Specialist**
**Brian Krienke, UNL Extension Educator**
**Tim Shaver, UNL Nutrient Management Specialist**
**Richard Ferguson, UNL Soil Specialist**
**Gary Hergert, UNL Soil and Nutrient Management Specialist**
**Charles Wortmann, UNL Soil and Nutrient Management Specialist**

## Introduction

Several topics in nutrient management have recently become relevant and of interest to crop producers and managers. This paper will summarize these topics.

## Crop Canopy Sensors

Recent research at UNL has focused on improving the use of crop canopy sensor technology for N management. A two year study across three states evaluated the use of crop canopy sensors in comparison to a crop model approach for in-season N management (Figure 1).

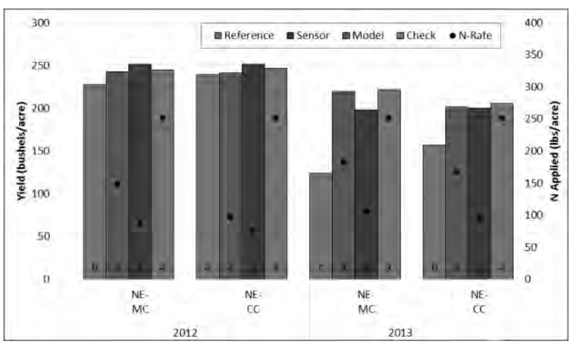



**Figure 1: Comparison of different N management methods at 2 Nebraska locations in each of 2012 and 2013. Bars represent yield on the primary axis, and the N rate is represented as dots (secondary axis). Letters (inside lower base of bars) with the same letter indicate no statistical difference in yield within each site. Check plots received no N.**

Results show with the exception of one site (2013, NE-MC) that the sensor based N application yielded similarly to the high N reference, while using significantly less N to do so. The model approach was computed using Maize-N, which incorporates several years of past weather information, and projects possible mineralized N to adjust the N rate for the current year.

Unmanned aerial vehicles (UAVs) may also be a useful tool for using sensors for in-season N management in the future. Research in 2013 and 2014 has shown that using UAVs to collect crop canopy information can be an effective method in detecting N stress, and may help farmers be more efficient in how they use N fertilizers.

## UNL Extension, In-Season N Project

Crop canopy sensor technology has been researched for over a decade, yet producer adoption has remained minimal in Nebraska. Much of the lack of adoption may relate to limited exposure and experience of the technology by crop producers, and hesitance to invest in the technology without more experience, or consistent results on farms that represent similar conditions for the grower. An on-farm research project will start in 2015 to raise awareness of the use of canopy sensor technology for management of N, and also to give producers hands-on experience in doing so, without the commitment of investing in equipment. Producers will be needed to participate in this project as part of the Nebraska On-Farm Research Network. Several field days will be held every year to provide information about in-season N management, and to share results from the project. The overall objective of the project is to encourage adoption of in-season N fertilization, in order to improve N use efficiency in areas where nitrate contamination of groundwater is an issue. The project will also provide an opportunity for researchers to refine canopy sensor approaches for N management in various cropping systems and conditions.

## Adapt N

The University of Nebraska nitrogen recommendation procedure is designed to be used before the season starts, and is based on several soil factors, but is not appropriate for use in season. The Adapt-N program (http://www.adapt-n.com/) is designed to adjust nitrogen rates in season based on weather data. One goes to the internet and uses a GIS program to find the field that is to be managed:

After you have found your location you can add some field practices such as tillage, residue cover, and soil test information. On another screen the crop information is added. This includes maturity class, previous crop, expected yield, planting date, populate and information if it was a pasture. One also has to enter in manure, irrigation and fertilizer applications as they happen in the season.

As the season progresses the information related to the nitrogen balance in the field is updated. The software, which is run weekly or as often as one wants uses the base soil data, and the actual weather data that occurs to predict N uptake in the crop, N released from the soil, N losses, current soil water status, and several other parameters.

We have not done extensive field testing in Nebraska, but research has been done in Iowa. At the Haskell Agricultural Laboratory in the summer of 2014 one field was followed using the Adapt-N system.

At the end of the season the program suggested 245 lbs of N, calculated 134 lbs of N lost and 97 lbs of N from soil mineralization (Figure 2). The Adapt-N strip was split in to a full recommended N rate, a partial N rate, and a zero control. The Adapt-N strip was adjacent to another N experiment.

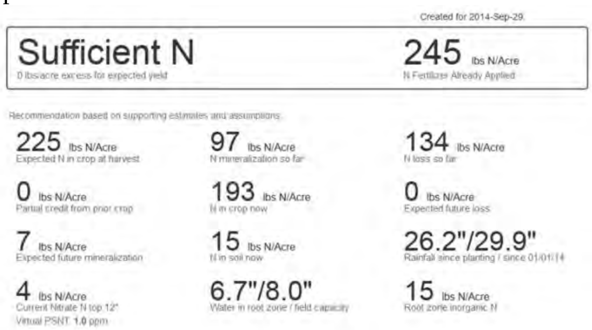



**Figure 2. Adapt N Program Recommendations.**

**Table 1. Effect of Adapt-N recommendations on several mid-season indicators of N sufficiency. 2014.**

| Method | N rate | SPAD V7/8 6/26/14 | SPAD V10/11 7/8/14 | SPAD V18/VT 7/22/14 | SPAD R3 8/14/14 | SPAD R5 9/2/14 | Stalk nitrates | Yield |
|---|---|---|---|---|---|---|---|---|
| | lbs N/ac | ---------------- % of max for each date -------------- | | | | | ppm | bu/ac |
| Adapt full N | 245 | - | 104 | 94 | 99 | 99 | 3878 | |
| ½ rate initial | 162 | - | 99 | 89 | 93 | 100 | 2021 | |
| Control | 0 | - | 73 | 62 | 50 | 56 | 200 | |
| High N (12b) | 202 | 100 | 100 | 100 | 100 | 100 | 2994 | |
| Chloro N (13a) | 68P +120 | 91* | 97 | 92* | 88* | 93 | 382 | |
| Chloro N Instinct early (14a) | 68P + 80 | 93 | 96 | 96* | 90* | 96 | 527 | |
| Chloro N ESN early (15b) | 68P +120 | 96 | 86* | 94* | 92* | 98 | 740 | |

## N Application App

Our nitrogen recommendations are available in many forms: the EC 117 that goes through each nutrient and how to make a recommendation for corn, the on-line soil testing site that allows one to put in a soil test and get a recommendation for any crop, the corn nitrogen calculator that is a slide rule that approximates the results of the information in EC117, and our Excel spreadsheet that allows the calculation of a nitrogen recommendation for corn, and also adjusts for timing, and economics.

Because of the widespread use of smartphones and tablets, a nitrogen recommendation app for these platforms is being developed, and is expected to be available for the winter of 2015. The app will have the same functions as the Excel spreadsheet, but have slightly different data entry.

## Solvita/Haney Soil Tests

The Solvita and Haney/Soil Health Tests are emerging methods of soil testing which integrates chemical and biological soil test data to assess the health of the soil (Haney et al., 2006; Haney et al., 2008). These tests may complement or supplement traditional soil testing procedures. For the purpose of this paper we will call these tests biological soil tests. The Solvita test quantifies the amount of respired CO2 after rewetting a dried soil sample over a 24hr period and has been proposed to be used to quantify microbial activity and mineralizable N and P. The Haney or Soil Health Test uses water and the extractant, H3A (which was designed to mimic plant root exudates) plant available nutrients and soil health. This extractant is a combination of lithium citrate, citric acid, malic acid and oxalic acid. The Soil Health Calculation (SHC) uses values from both of these tests to provide a score indicating the overall health of the soil (a “good” score is above 7). The equation used to calculate the SHC is as follows: SHC= ((Solvita CO2 / Organic C:N) + (Water Extracted Organic C / 100) + Water Extracted Organic N /10)). The details of each of these tests can be found at: http://solvita.com/pdf-files/Haney-Brinton_paper2_SPA.pdf. In addition the laboratory that conducted these analysis (Ward Laboratories, Kearney, NE) has more information.

http://www.wardlab.com/haney/haney_info.aspx

http://www.wardlab.com/solvita/solvita_info.aspx

The H3-A extract is well correlated with several of the established extractants (Haney et al., 2006). Our interest is not in the correlation with other extractants, it is with what these tests can add to our understanding of the soils, and whether we can quantify the effect of management. The purpose of this project is to compare the results of conventional chemical soil tests with the biological tests to determine what additional understanding about the effect of our long-term field experimental treatments of tillage, crop rotation, and nitrogen rates can be gained. This is a preliminary analysis and we will focus on several soil nitrogen tests, the Solvita CO2, and the SHC.

## Resources:

1. Haney, R., W. Brinton and E. Evans. 2008. Estimating soil carbon, nitrogen, and phosphorus mineralization from short-term carbon dioxide respiration. Communications in Soil Science and Plant Analysis 39: 2706-2720.

2. Haney, R. L., E. B. Haney, L.R. Hossner, and J.G. Arnold. 2006. Development of a new soil extractant for simultaneous phosphorus, ammonium, and nitrate analysis. Communications in Soil Science and Plant Analysis. 37:1511-1523.

# Herbicide Update 2015

**Amit Jhala, Weed Management Specialist**
**Stevan Knezevic, Integrated Weed Management Specialist**
**Greg Kruger, Cropping Systems 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.

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

**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.

## Soybean Herbicides

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

**Authority®Elite** [Sulfentrazone (7.55) + S-metolachlor (68.25)]. It is soil applied herbicide for control of broadleaf, grass and sedge weeds in soybeans. The crop rotation restriction for corn and sorghum is 10 months. It should not be applied more than 38.7 fl oz/A per year. EPA Reg. No. 279-3442.

**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 Kixor based herbicides from the BASF. This co-pack features three modes of action Sharpen, Pursuit and Outlook herbicides (Group 2, 14, and 15). It provides both contact burndown and residual pre-emergence weed control in soybean. 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.

**Rumble**® [Fomesafen (1.88 lb ai/gal)]. For POST control of broadleaf weeds in soybeans. MANA. EPA Reg. No. 66222-246. 2012. {Group 14}.

**Tailwind™** [Metolachlor (5.25 lb ai/gal) + Metribuzin (1.25 lb ai/gal)]. For PRE control of annual grasses and broadleaf weeds in soybeans and potatoes. MANA. EPA Reg. No. 66222-245. 12/2012. {Group 15 + 5}.

**Torment™** [Fomesafen (2 lb ae/gal) + Imazethaypr (0.5 lb ae/gal)]. Torment is a new product from MANA that can be applied preplant, pre-emergence 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.

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

### 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.

**Cody** [clopyralid (5.1%) + 2,4-D (39.0%)]. For selective control of broadleaf weeds in wheat and barley not under seeded with a legume, corn, fallow cropland, grasses grown for seed, rangeland and permanent grass pastures, conservation reserve program (CRP) acres, and non-cropland. Alligare. EPA Reg. No. 81927-28.

### Herbicides Labeled for Use in Multiple Crops

**Anthem™** [pyroxasulfone + fluthiacet]. Anthem is a new premix from FMC for pre-emergence or early post-emergence control of annual grasses and some small seeded broadleaf weeds in corn and soybean. MOA: Pyroxasulfone is a seedling growth inhibitor (Group 15) and fluthiacet-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%) + pyroxasulfone (42.5%)]. Fierce is a new premix from Valent for pre-emergence control of broadleaf and grass weeds. It will be labeled for use in soybeans and no-till & minimum till corn. The use of residual herbicides can help manage or prevent the development of glyphosate-resistant weed biotypes and reduce early season weed competition. MOA: flumioxazin is a PPO inhibitor and pyroxasulfone is a seedling growth inhibitor. EPA Reg. No. 63588-93-59639.

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

**Glory™** [Metribuzin (75%)]. For PRE control of certain broadleaf and grass weeds in corn, potatoes, soybeans and other crops. MANA. EPA Reg. No. 66222-106. 01/2013. {Group 5}.

**Outflank™** [Flumioxazin (51%)]. For PRE control of many broadleaf weeds in dry beans, field corn, potato, soybean, fallow and non-crop areas. MANA. 2013. {Group 14}.

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

**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. It can be applied in corn, but only post-emergence. This herbicide has residual activity only; therefore, it should be tank mixed with foliar active herbicide for control of existing weeds. EPA Reg. No. 524-591.

**Picloram 22K** [Picloram (2 lb ae/gal)]. For control of susceptible annual and perennial broadleaf weeds in rangeland and pasture. Alligare. EPA Reg. No. 81927-18. {Group 4}.

**Piper** [Flumioxazin (33.5%) + Pyroxasulfone (42.5%)]. For control and/or suppression of certain weeds to maintain bare ground noncrop areas. Valent. EPA Reg. No. 59639-193. {Group 14 + 15}.

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

# Glyphosate-Resistant Kochia in Nebraska

**Robert Wilson, Extension Weed Specialist**
**Greg Kruger, Extension Cropping Systems Specialist**

Kochia has been a nemesis to producers in the west for many years. Just when growers think they have developed a new control strategy the weed adapts and it is back to the drawing board. Kochia is a successful weed because it can emerge early in the spring, has a rapid growth rate, can tolerate drought and salinity, produces abundant seed, and can distribute the seed with the aid of wind by tumbling across the landscape. In Nebraska kochia is more prevalent in the western half of the state where the plant has a competitive advantage. In central and eastern Nebraska other weed species such as waterhemp, ragweeds, velvetleaf, and annual grasses are better crop competitors than kochia. With that said, kochia has been reported as a problematic weed further east in 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 gets 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).

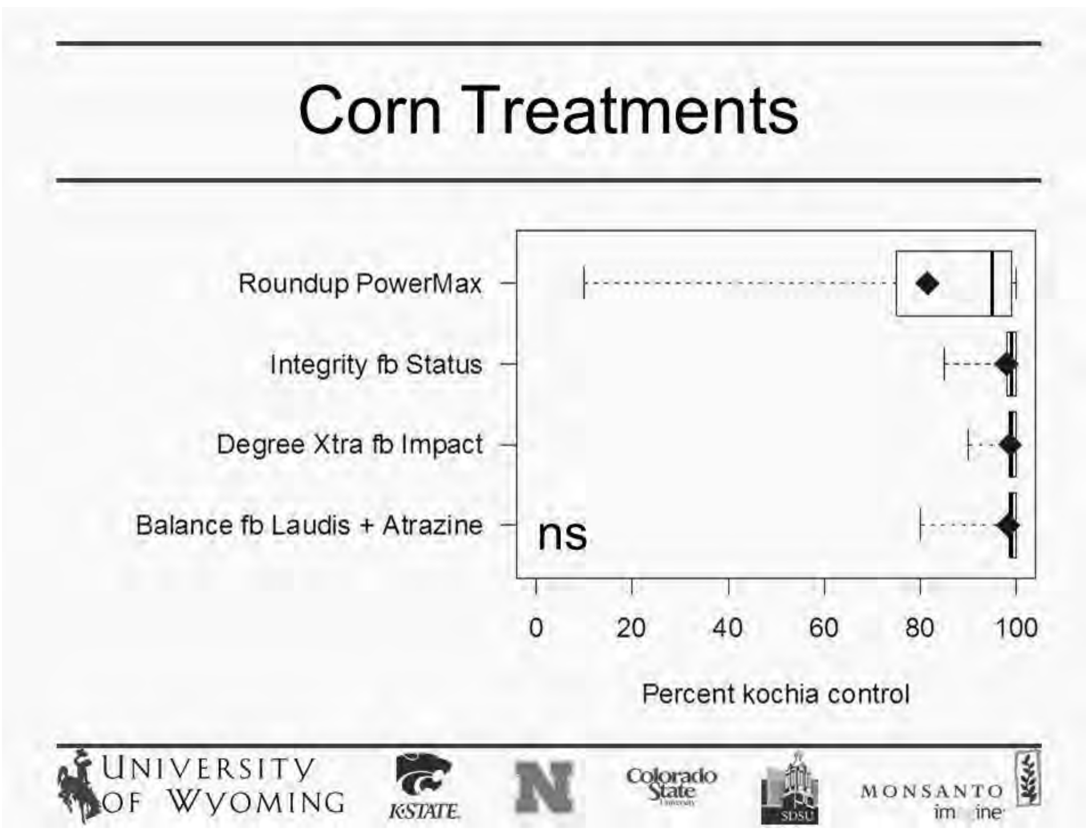
Kochia is a strong competitor in both rainfed and irrigated crops. A typical scenario with center pivot irrigation is to have an irrigated crop in the center and rainfed winter wheat or fallow on the pivot corners. In rainfed sites corn or soybeans are included in a rotation with winter wheat and fallow. 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.

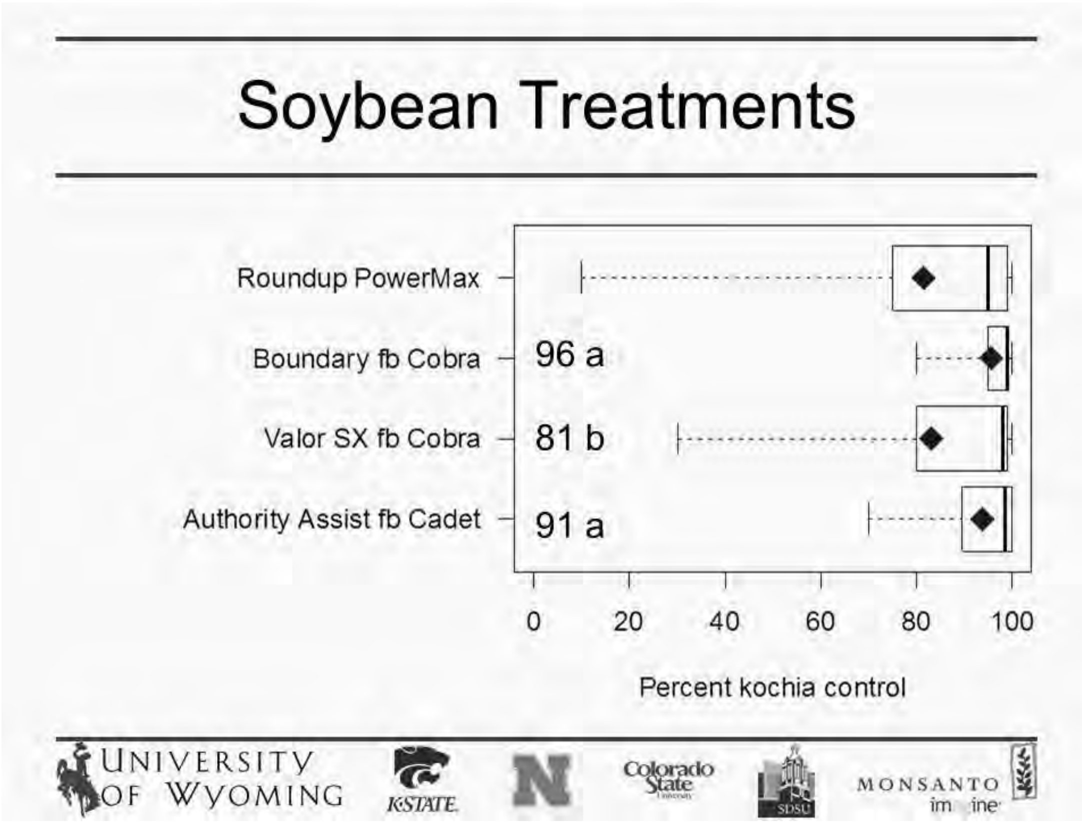
Since the initial reports of glyphosate-resistant kochia in Kansas in 2007, glyphosate-resistant kochia has been reported in Nebraska, Colorado, Montana and North Dakota. A survey was conducted in the fall of 2012 to examine the presence of glyphosate-resistant kochia in the sugarbeet growing regions 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 sulfonyurea family of herbicides.

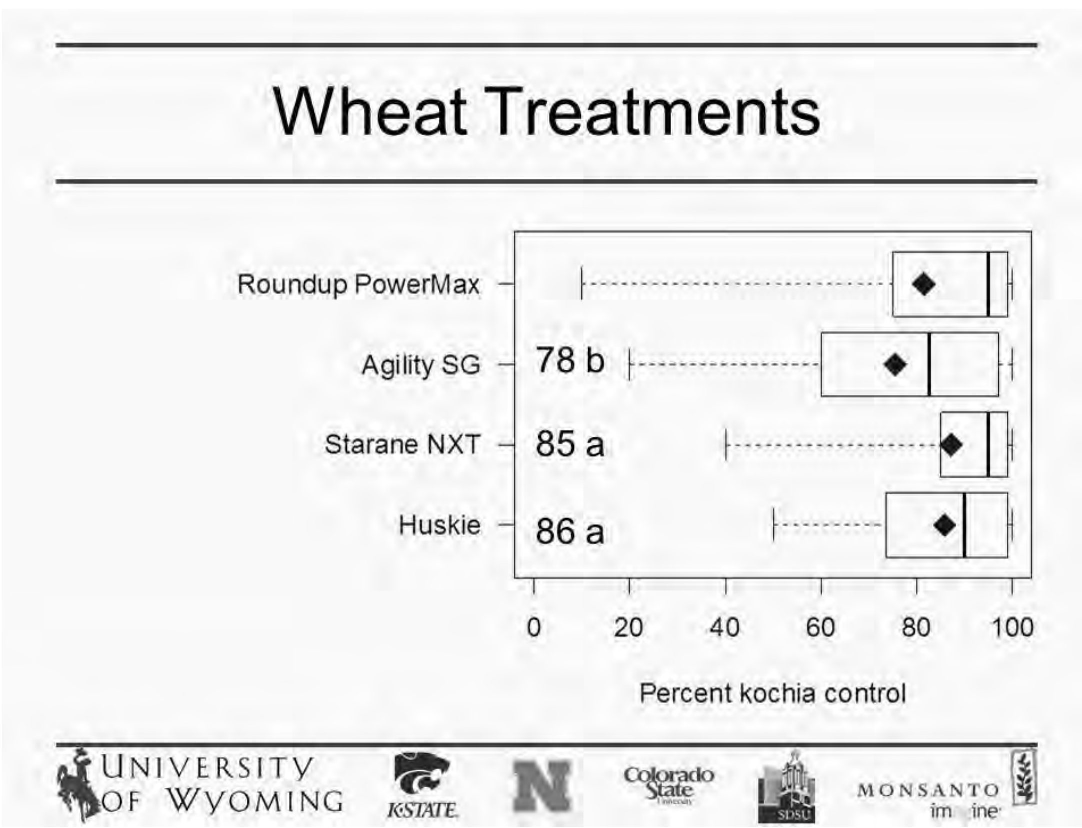
Approximately 50% of the kochia populations demonstrated resistance to UpBeet.

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.

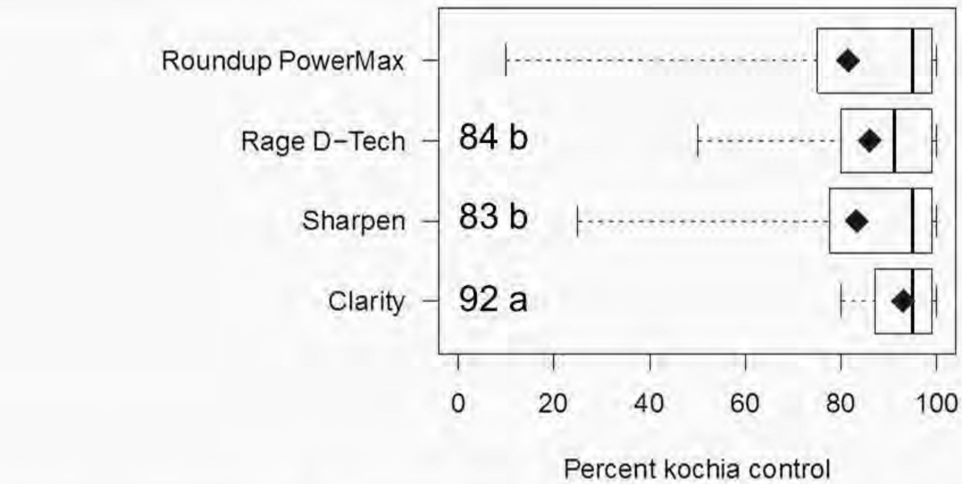
Table 1 provides suggestions for managing kochia in corn, small grains and dry beans.  Information is also provided on rotational restrictions for various herbicides to sensitive crops.



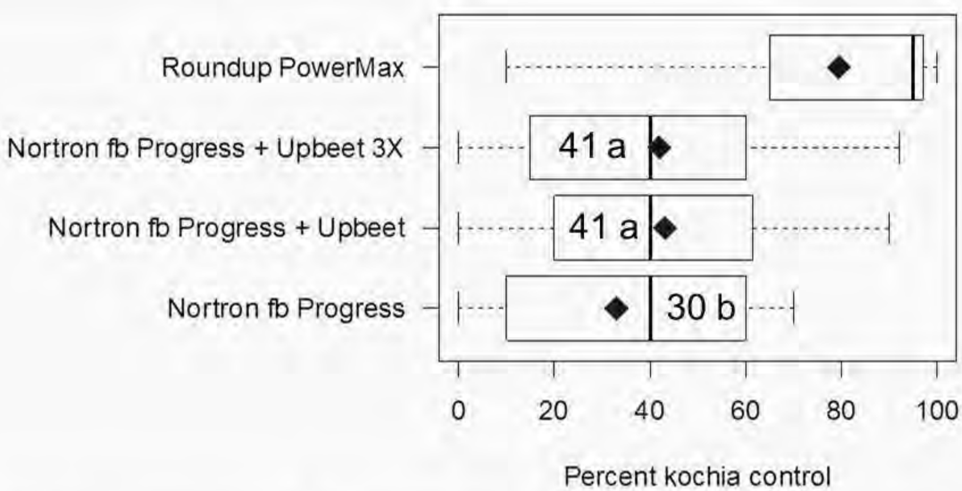

Soybean Treatments
Roundup PowerMax
Boundary fb Cobra
Valor SX fb Cobra
Authority Assist fb Cadet
96 a
81 b
91 a
0
20
40
60
80
100
Percent kochia control
UNIVERSITY OF WYOMING
K-STATE
Colorado State
SDSU
MONSANTO


Wheat Treatments
Roundup PowerMax
Agility SG
Starane NXT
Huskie
78 b
85 a
86 a
0
20
40
60
80
100
Percent kochia control
UNIVERSITY OF WYOMING
K-STATE
Colorado State
SDSU
MONSANTO

# Fallow Treatments




# Sugarbeet Treatments



**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**

| | Rotational Crops | | |
|---|---|---|---|
| Herbicide used in corn | Sugarbeet | Dry bean | Small grain |
| | (months) | | |
| Preemergence | | | |
| Sharpen @ 2 oz/A + Prowl $H_2O$ @ 32 oz/A | 12 | 12 | 4-12+ |
| TripleFlex @ 1.5 pt/A | 24 | 12 | 4 |
| Valor @ 2 oz/A | 12 | 3 | 3 |
| Verdict @ 12 oz/A | 12 | 12 | 4 |
| Zidua @ 2 oz/A + Prowl $H_2O$ @ 32 oz/A | 12 | ? | ? |
| Postemergence with glyphosate | | | |
| Armezon @ 0.5 oz/A | 18 | 9 | 3 |
| Clarity @ 8 oz/A | 4 | 4 | 1 |
| Laudis @ 3 oz/A + Buctril @ 6 oz/A | 18 | 12* | 4 |
| Prowl $H_2O$ @ 32 oz/A | 12 | 0 | 4-12+ |
| Require Q @ 4 oz/A | 10 | 10 | 9 |
| Resolve Q @ 1.2 oz/A | 10 | 10 | 9 |
| Status @ 5 oz/A | 4 | 4 | 1 |
| Starane Ultra @ 7 oz/A | 12 | 12 | 4 |

*Crops grown under sprinkler irrigation

+ 12 months for oats

**Adding Herbicide Diversity in Small Grains for Kochia Control**

| | Rotational Crops | | |
|---|---|---|---|
| Herbicide used in small grain | Sugarbeet | Dry bean | Corn |
| | (months) | | |
| Postemergence | | | |
| Bronate Advanced @ 19 oz/A | 2 | 1.5 | 1 |
| Huskie @ 13.5 oz/A + MCPA @ 12 oz/A | 9 | 9 | 9 |
| Starane NXT @ 14 oz/A | 12 | 12 | 12 |

**Adding Herbicide Diversity in Dry Bean for Kochia Control**

| | Rotational Crops | | |
|---|---|---|---|
| Herbicide used in dry bean | Sugarbeet | Corn | Small grain |
| | (months) | | |
| At planting | | | |
| Prowl $H_2O$ @ 32 oz/A | 12 | 12 | 4-12+ |
| Sonalan @ 32 oz/A | 12 | 12 | 12 |
| Postemergence | | | |
| Raptor @ 4 oz/A + Basagran @ 16 oz/A | 18-26* | 8.5 | 4-9+ |

*Dry bean grown under sprinkler irrigation

+ Oats more sensitive than wheat or barley

# Glyphosate-resistant Marestail on the Increase in Nebraska

**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 $ED_{90}$ 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).

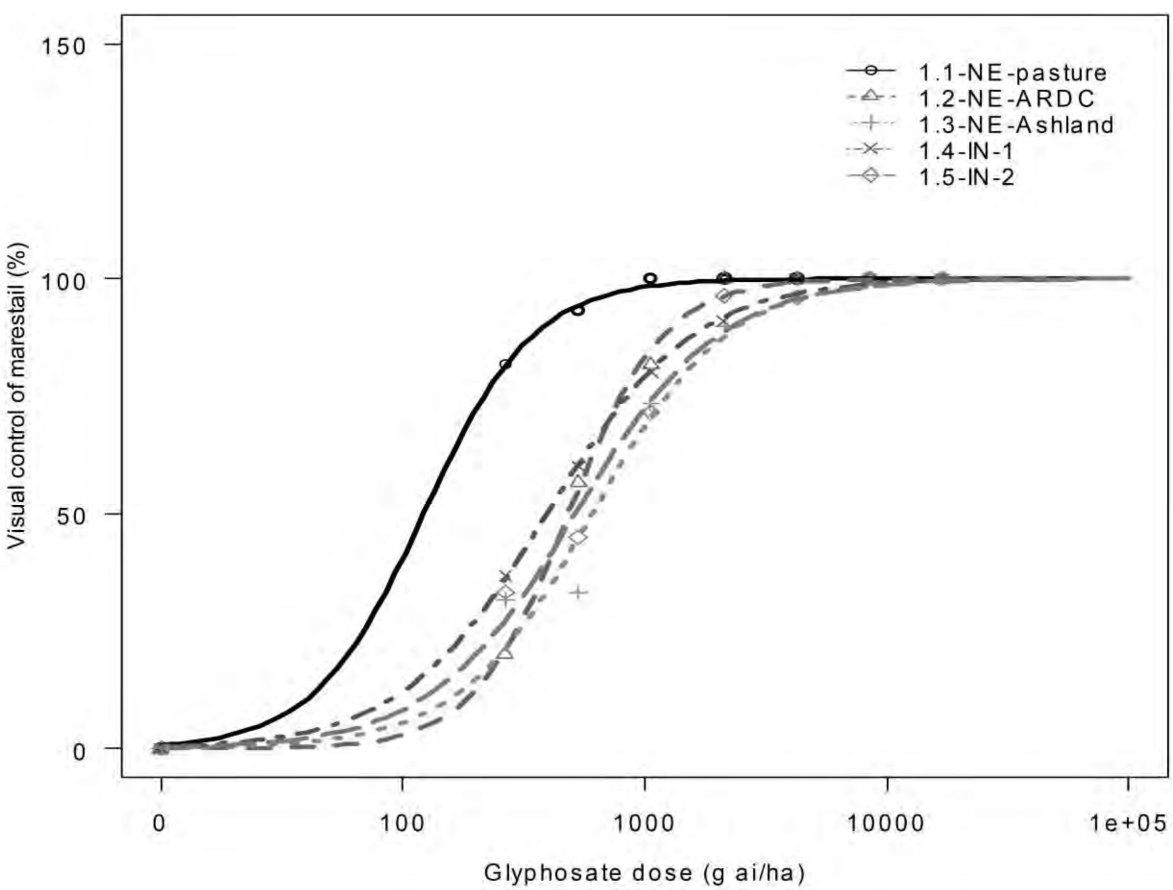
***2-4" tall plants***

| Population | Resistance level | Rates of glyphosate to get 90% suppression | |
|---|---|---|---|
| | | 4.5 lbs ae/gal | 3 lbs ae/gal |
| 1.1=NE-pasture | 1x | 22 oz/acre | 32 oz/acre |
| 1.2=NE-ARDC | 3.4x | 75 oz | 109 oz |
| 1.3=NE-Ashland | 6.3x | 138 oz | 202 oz |
| 1.4=IN 1 | 4.7x | 103 oz | 150 oz |
| 1.5=IN 2 | 5.9x | 130 oz | 189 oz |

***5-6"tall plants***

| Population | Resistance level | Rates of glyphosate to get 90% suppression | |
|---|---|---|---|
| | | 4.5 lbs ae/gal | 3 lbs ae/gal |
| 1.1=NE-pasture | 1x | 22 oz/acre | 32 oz/acre |
| 1.2=NE-ARDC | 4.4x | 96 oz | 140 oz |
| 1.3=NE-Ashland | 5.1x | 110 oz | 163 oz |
| 1.4=IN 1 | 4.1x | 112 oz | 131 oz |

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.



# Control of Glyphosate-Resistant Giant Ragweed in Soybean and Corn

**Amit J. Jhala, Extension Weed Management Specialist**
**Stevan Knezevic, Integrated Weed Management Specialist**
**Lowell Sandell, Weed Science Extension Educator**
**John Scott, Weed Science Technologist at HAL**

## Glyphosate-Resistant Giant Ragweed

Giant ragweed (*Ambrosia trifida* L.), a member of Asteraceae family, is an annual, broadleaf species that is native to the United States and it is found throughout North America and several other continents. Giant ragweed has been common throughout the eastern United States, and in recent years the weed has become more problematic in Illinois, Iowa, Minnesota, and Nebraska.

Repeated use of herbicides with the same mode-of-action can impose selection pressure for resistance within or among weed species that have previously been susceptible. For example, a widespread and repeated use of the acetolactate synthase (ALS)-inhibiting herbicides resulted in the evolution of ALS inhibitors-resistant giant ragweed. In 2005, a giant ragweed biotype in Ohio was reported to have reduced sensitivity to glyphosate. In 2007, glyphosate-resistant giant ragweed was confirmed in Tennessee, and now it has been confirmed in several states including Arkansas, Indiana, Iowa, Kansas, Minnesota, Mississippi, Missouri, Nebraska, Ohio, and Wisconsin. Therefore, management of glyphosate-resistant giant ragweed is not only a challenge in soybean fields in Nebraska, but also in several other states and crops.

## Control of giant ragweed in Roundup Ready Soybean

Field experiments were conducted at David City, NE for control of glyphosate-resistant giant ragweed in Roundup Ready soybean in 2012 and 2013. Burndown applications of 2,4-D followed by PRE or POST herbicide treatments were effective for control of glyphosate-resistant giant ragweed. PRE or POST herbicides prevented regrowth of the partially controlled giant ragweed plants that survived the burndown treatments. For example, OpTill, Boundry, or Authority First applied PRE resulted in 99% control of giant ragweed (Table 1). Similarly, FirstRate, Classic, Flexstar, Pursuit, or Cobra tank-mixed with Warrant resulted in 85 to 97% control of giant ragweed at 7 days after POST treatment (DAPT) with no difference between them. Poor control of giant ragweed (≤ 68%) was usually observed when the burndown-only treatments were not followed by PRE or POST herbicides at 30 DAPT (Table 1).

## Control of giant ragweed in Liberty Link Soybean

Field experiments were conducted at David City, NE for control of glyphosate-resistant giant ragweed in Roundup Ready soybean in 2012 and 2013. Treatments including Liberty, Gramoxone, or Sharpen applied alone or in tank mixes resulted in 91 to 97% giant ragweed control at 7 days after burndown treatment (DABT) (Table 2). Although comparable with several other treatments, 2,4-D and Sharpen alone or in tank mixes resulted in 88 to 99% giant ragweed control at 21 DABT. Liberty applied alone or in tank mixes was effective for control of giant ragweed and prevented regrowth from any partially controlled plants that were not completely eliminated with the burndown treatment. Preplant herbicides followed by early POST application of Liberty usually resulted in 88 to 100% giant ragweed control at 7 days after treatment. Although comparable with several other treatments, 2,4-D applied alone or with Sharpen resulted in 99% giant ragweed control. This indicated that preplant program was critical for early season control of giant ragweed (Table 2).

## Control of giant ragweed in Roundup Ready Corn

Field studies were conducted at David City, NE to evaluate commonly used PRE and POST herbicides to control glyphosate-resistant giant ragweed in Roundup Ready corn in 2012 and 2013. Visual estimates recorded 30 days after treatment (DAT) indicated that applications of any of the 12 treatments provided at least 90% control (Table 3). For example, PRE application of 2 qt of atrazine followed by 16 oz/A of 2,4-D at V4 corn provided 100% control at 60 DAT.

## Conclusion

Glyphosate-resistant giant ragweed can be effectively controlled in Roundup Ready and Liberty Link soybean. Preplant application of several herbicides, including 2,4-D, Valor, Liberty, Gramoxone, Sharpen, and Authority alone or in tank mixes followed by PRE and POST herbicides resulted in season-long giant ragweed control and greater soybean yields. Several herbicides have been tested for control of giant ragweed in corn. An integrated management approach should be adopted that may include tillage, use of herbicides with different site-of-action, rotation of herbicide-resistant trait, and crop rotation for control of glyphosate-resistant weeds.

**Table 1. Control of glyphosate-resistant giant ragweed in Roundup Ready soybean (Abbreviations: DABT, days after burndown treatment; *fb*, followed by; DAPOST, days after post-emergence treatment).**

| Herbicide Treatment[a] | Application timing | Rate | Giant ragweed control after burndown treatments[b,c] | | | Giant ragweed control after POST herbicide treatments[b,c] | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7 DABT | 14 DABT | 21 DABT | 7 DAPOST | 30 DAPOST | At harvest |
| | | Oz/Acre | % | | | | | |
| Nontreated Control | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| Roundup PowerMax *fb* | Burndown | 22 | 36 d | 54 b | 56 b | 43 c | 46 b | 10 c |
| Roundup PowerMax | POST | 22 | | | | | | |
| 2,4-D Amine 4 *fb* | Burndown | 16 | 63 b | 87 a | 92 a | 93 a | 92 a | 89 ab |
| Roundup PowerMax | POST | 22 | | | | | | |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 64 b | 98 a | 99 a | 99 a | 99 a | 99 a |
| *fb* OpTill | PRE | 2 | | | | | | |
| OpTill + Roundup PowerMax | Burndown | 2 + 22 | 93 a | 94 a | 89 a | 85 a | 68 b | 63 b |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 66 b | 98 a | 99 a | 99 a | 99 a | 99 a |
| *fb* Boundary | PRE | 36 | | | | | | |
| Boundary + Roundup PowerMax | Burndown | 36 + 22 | 28 d | 48 b | 51 b | 41 c | 23 c | 5 c |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 64 b | 94 a | 99 a | 99 a | 97 a | 96 a |
| *fb* Authority First | PRE | 6 | | | | | | |
| Authority First + Roundup PowerMax | Burndown | 6 + 22 | 51 c | 64 b | 65 b | 50 c | 47 b | 25 c |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 64 b | 86 a | 87 a | 85 a | 89 a | 87 ab |
| *fb* FirstRate+ Warrant | POST | 0.3 + 68 | | | | | | |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 65 b | 92 a | 95 a | 97 a | 93 a | 90 ab |
| *fb* Classic + Warrant | POST | 0.33 + 68 | | | | | | |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 65 b | 94 a | 96 a | 96 a | 95 a | 95 a |
| *fb* Pursuit + Warrant | POST | 4 + 68 | | | | | | |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 65 b | 94 a | 93 a | 97 a | 90 a | 89 ab |
| *fb* Cobra + Warrant | POST | 12.5 + 68 | | | | | | |
| 2,4-D Amine 4 + Roundup PowerMax | Burndown | 16 + 22 | 65 b | 91 a | 92 a | 94 a | 95 a | 94 a |
| *fb* Flexstar + Warrant | POST | 16 + 68 | | | | | | |

[a] Roundup PowerMax was applied at 22 fl oz/A + 17 lb/100 gal of AMS late-POST for control of late emerging weeds
[b] Data were arc-sine square-root transformed before analysis; however, data presented are the means of actual values for comparison based on interpretation from the transformed data.
[c] Means within columns with no common letter(s) are significantly different according to Tukey-Kramer's pairwise comparison test at $P \leq 0.05$.

**Table 2. Control of glyphosate-resistant giant ragweed at 7, 14, and 21 days after burndown treatment (DABT) and 7 and 21 days after early POST (DAEP) treatment, and at harvest in Liberty Link soybean at David City, NE.**

| Herbicide[a] | Application timing | Rate | Giant ragweed control after preplant treatments[b,c] | | | Giant ragweed control after POST herbicide treatments[b,c] | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7 DABT | 14 DABT | 21 DABT | 7 DAEP | 21 DAEP | At harvest |
| | | Oz/Acre | % | | | | | |
| Nontreated control[e] | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| OpTill + Outlook *fb* | Preplant | 2 + 10 | 91 ab | 93 a | 97 a | 97 ab | 99 a | 99 a |
| Liberty | Early POST | 29 | | | | | | |
| Authority First *fb* | Preplant | 7 | 68 c | 75 ab | 88 ab | 95 abc | 95 a | 92 ab |
| Liberty | Early POST | 29 | | | | | | |
| Valor XLT *fb* | Preplant | 3 | 70 bc | 79 ab | 79 ab | 91 c | 94 a | 70 abc |
| Liberty | Early POST | 29 | | | | | | |
| Boundary *fb* | Preplant | 36 | 21 d | 31 c | 35 d | 79 c | 53 b | 25 c |
| Liberty | Early POST | 29 | | | | | | |
| Enlite *fb* | Preplant | 2.8 | 69 bc | 58 b | 50 cd | 80 bc | 60 b | 32 bc |
| Liberty | Early POST | 29 | | | | | | |
| 2,4-D Amine *fb* | Preplant | 16 | 66 c | 90 a | 98 a | 99 a | 99 a | 99 a |
| Liberty + Pursuit | EarlyPOST | 29 + 4 | | | | | | |
| Roundup PowerMax *fb* | Preplant | 22 | 41 d | 32 c | 33 d | 94 abc | 94 a | 89 abc |
| Liberty + FirstRate + Warrant | EarlyPOST | 29 + 0.3 + 68 | | | | | | |
| Gramoxone SL *fb* | Preplant | 32 | 91 ab | 77 ab | 80 ab | 88 abc | 90 a | 76 abc |
| Liberty + Classic + Warrant | EarlyPOST | 29 + 0.33 + 68 | | | | | | |
| Liberty 280 *fb* | Preplant | 29 | 91 ab | 94 a | 91 ab | 93 abc | 96 a | 90 abc |
| Liberty *fb* | EarlyPOST | 29 | | | | | | |
| Cobra | LatePOST | 12.5 | | | | | | |
| Sharpen *fb* | Preplant | 1 | 97 a | 96 a | 93 ab | 91 abc | 90 a | 80 abc |
| Liberty + Warrant | EarlyPOST | 29 + 68 | | | | | | |
| Sharpen + 2,4-D Amine *fb* | Preplant | 1 + 16 | 95 a | 99 a | 99 a | 100 a | 99 a | 99 a |
| Liberty + Warrant | EarlyPOST | 29 + 68 | | | | | | |
| Sharpen + Roundup PowerMax *fb* | Preplant | 1 + 22 | 91 ab | 96 a | 94 a | 97 abc | 98 a | 97 ab |
| Liberty + Warrant + Pursuit | EarlyPOST | 29 +68 + 4 | | | | | | |

[a] All herbicide treatments were followed by late POST application of Liberty at 29 fl oz/A + ammonium sulfate 17 lb/100 gal.
[b] Data were arc-sine square-root transformed before analysis; however, data presented are the means of actual values for comparison based on interpretation from the transformed data.
[c] Means within columns with no common letter(s) are significantly different according to Tukey-Kramer's pairwise comparison test at $P \leq 0.05$.

**Table 3. Control of glyphosate-resistant giant ragweed in Roundup Ready corn.**

| Product (PRE) | Rate/Acre | Growth Stage | Product (POST) | Rate Oz/Acre | Growth Stage | ~30 DAT | ~60 DAT |
|---|---|---|---|---|---|---|---|
| Nontreated Check | - | - | - | - | - | 0 | 0 |
| Atrazine | 2 qt | PRE | 2,4-D | 16 oz | POST | 93 | 100 |
| Balance Flexx | 6 oz | PRE | 2,4-D | 16 oz | POST | 94 | 100 |
| Balance Flexx + Atrazine | 6 oz+1 qt | PRE | 2,4-D | 16 oz | POST | 95 | 100 |
| Callisto | 6 oz | PRE | Hornet | 5 oz | POST | 88 | 100 |
| Corvus | 5.6 oz | PRE | 2,4-D | 16 oz | POST | 95 | 100 |
| - | - | - | 2,4-D | 16 oz | POST | 0 | 91 |
| Guardsman Max | 4 pt | PRE | 2,4-D | 16 oz | POST | 93 | 100 |
| Lumax EZ | 2.7 qt | PRE | 2,4-D | 16 oz | POST | 94 | 100 |
| Sharpen | 3 oz | PRE | Distinct | 6 oz | POST | 69 | 100 |
| Verdict | 16 oz | PRE | Status | 5 oz | POST | 87 | 100 |
| Zemax | 2 qt | PRE | Status | 5 oz | POST | 89 | 100 |

All post-emergence treatments included NIS and AMS; results averaged from 2 studies

# Control of Glyphosate-Resistant Common Waterhemp in Glyphosate- and Glufosinate-Tolerant Soybean

**Debalin Sarangi, Weed Science Graduate Student**
**Lowell D. Sandell, Weed Science Extension Educator**
**Amit J. Jhala, Extension Weed Management Specialist**

### Glyphosate-Resistant common waterhemp

Common waterhemp is a summer annual weed and it is one of the difficult-to-control weeds in the Midwestern United States. Widespread adoption of conservation tillage and evolution of herbicide-resistance resulted in dominance of small-seeded broadleaf weed species such as common waterhemp in corn-soybean production system.

Common waterhemp has a rapid growth habit, extended germination window (May to August), and potential for producing over a million seeds per plant, that have contributed to the success of this weed species. It is a highly competitive weed that reduces corn and soybean yield significantly. Furthermore, common waterhemp is a dioecious species, which means male and female flowers occur on two different plants, that requires the movement of pollen for successful reproduction. So the herbicide-resistant traits can travel a long distance via pollen-movement and outcrossing.

Glyphosate, a broad-spectrum nonselective POST herbicide, was first commercialized in 1974. The label of Roundup PowerMax (glyphosate) herbicide lists over 100 annual broadleaf and grass weeds and almost 60 perennial weed species that can be controlled. The use of glyphosate changed dramatically after 1996 with the commercialization of glyphosate-tolerant crops. According to the recent report of USDA, 94% of soybean and 89% of corn grown in 2014 were herbicide-tolerant; and primarily glyphosate-tolerant. Wide-spread adoption of glyphosate-tolerant crops has increased farmers' reliance on glyphosate in weed management programs by replacing residual soil-applied herbicides and other POST herbicides.

Over-reliance on any particular herbicide may create a selective advantage for a specific resistant weed species. In Nebraska, eight weed species (common waterhemp, common ragweed, giant ragweed, kochia, marestail, Palmer amaranth, redroot pigweed, and shattercane) have been confirmed resistance to at least one mode-of-action of herbicide and six of them are resistant to glyphosate. The first glyphosate-resistant common waterhemp in the United States was confirmed in Missouri in 2005, but by 2014 glyphosate-resistant common waterhemp has been confirmed in 13 states.

### Glyphosate-Resistant Common Waterhemp Confirmed in Nebraska

In the fall of 2012, seedheads of common waterhemp plants that survived repeated glyphosate applications were collected from fields of seven eastern Nebraska Counties (Antelope, Dodge, Fillmore, Lancaster, Pawnee, Seward, and Washington) and were suspected to be glyphosate-resistant biotypes. Greenhouse dose-response experiments were conducted at the University of Nebraska- Lincoln and common waterhemp biotypes were treated with 9 rates (0 to 16×, where ×= recommended rate of glyphosate i.e. 24 fl oz/ac) of Touchdown HiTech (glyphosate). Dose response study has shown that common waterhemp biotypes were 3- to 39-fold resistant to glyphosate depending on the biotype being investigated. The results suggested that 90% control in certain biotype could be achieved by spraying Touchdown HiTech at 900 fl oz/a, which is absolutely impractical for the growers. The confirmation of glyphosate-resistance in common waterhemp biotypes in Nebraska is further evidence of an ever-evolving weed spectrum, and further proof that using only glyphosate for weed control in corn and soybean is not a sustainable approach to weed management. In the face of herbicide selection pressure, common waterhemp has repeatedly proven to be an ecological survivor. As a consequence, common waterhemp biotypes resistant to ALS (Pursuit), triazine (Atrazine), growth regulator (2,4-D), HPPD (Callisto), and now glyphosate (Roundup) have been confirmed in Nebraska.

### Glyphosate-Resistant Common Waterhemp Control in Roundup Ready (Glyphosate-Resistant) Soybeans

Field experiments were conducted in the summer of 2013 and 2014 at Fremont, NE in a grower's field infested with glyphosate-resistant common waterhemp. From greenhouse study at the University of Nebraska- Lincoln, we have confirmed that more than 350 fl oz Touchdown Hitech/acre is required to control 90% of the common waterhemp biotypes from that same field. The field was under rain-fed condition throughout the season. The history of the site was a heavy reliance on glyphosate for weed control at least two times per season for the last few years in a glyphosate-resistant corn and soybean rotation. The soil at the experimental site was clay type with pH 6.7, and 4% organic matter. Glyphosate-resistant soybeans (Cv. "Pioneer 93Y12") were planted with 30 inch row spacing. In this study, plot size for each treatment was 10 ft × 30 ft and each treatment was randomly replicated four times.

A total of 18 herbicide programs including pre-emergence herbicide followed by post-emergence were compared for control of glyphosate-resistant common waterhemp. Nontreated control plots were included for comparison. Herbicides were applied with a $CO_2$-pressurized backpack sprayer calibrated to deliver 15 gal/ac at 40 psi equipped with a five-nozzle boom and AIXR11015 flat fan TeeJet nozzles. Pre-emergence (PRE) herbicides were applied right after the soybean planting in the field, whereas early post-emergence (Early POST) herbicides were applied at 15 days after soybean planting (DAP) and mid post-emergence (Mid POST) were applied at 30 DAP. Visual estimations of common waterhemp control were recorded on a scale of 0% to 100% (0 equals no common waterhemp control and 100 equals complete control of common waterhemp) at 14, 28, 42, 90 days after soybean planting and at harvest. Middle two rows of soybean were harvested for estimating soybean yield.

**Results (Table 1).** Control of glyphosate-resistant common waterhemp varied among different treatments. PRE herbicides applied at planting of soybean provided > 80% control of glyphosate-resistant common waterhemp at 14 DAP. The residual activity of Dual II Magnum reduced at 28 DAP that resulted in 66% control, whereas tank-mix of Dual II Magnum with Flexstar (i.e. Prefix) or Sencor (i.e. Boundary) resulted in >90% control of glyphosate-resistant common waterhemp at 28 DAP. Poor control of common waterhemp (< 50% control) was usually observed at 90 DAP with two times application of Roundup PowerMax or Roundup PowerMax applied along with Pursuit (i.e. Extreme). POST treatments Extreme + Flexstar GT + Warrant followed by Cobra + Roundup PowerMax provided 71% control at 90 DAP. In addition, herbicide such as Cobra injured soybean-plant in early season and that delayed the canopy-closure, whereas Flexstar GT did not result in any significant soybean-injury.

Similar results were observed in visual control ratings recorded at soybean harvest. Most of the herbicide treatments containing PRE followed by POST herbicides performed better than POST-only treatments. Few herbicide treatments including, Optill + Outlook followed by Flexstar GT; Sonic followed by Flexstar GT; Prefix followed by Ultra Blazer + Roundup PowerMax; and Boundary followed by Flexstar GT were consistent in common waterhemp control (>90%). Overall, yield of the soybean were slightly lower in 2014 compared to the yield in 2013 because of excess rainfall in 2014.

### Glyphosate-Resistant Common Waterhemp Control in LibertyLink (Glufosinate-Resistant) Soybeans

Glufosinate (Liberty) is a non-selective, contact, post-emergence herbicide. It has a different mode-of-action group (group 10) than glyphosate (group 9), so it can be used to control glyphosate-resistant weeds in LibertyLink crops.

Field experiments were conducted at the same site at Fremont, NE as described in previous study. LibertyLink soybeans were planted with 30 inch row spacing. 18 different herbicide treatments including POST treatments of Liberty were randomly replicated four times and were compared in this study. Visual control of common waterhemp and yield of soybeans were recorded as mentioned in the previous study.

**Results (Table 2).** Herbicide treatments that included pre-emergence herbicide provided ≥ 88% control of glyphosate-resistant common waterhemp except Dual II Magnum and Dual II Magnum plus Pursuit at 14 DAP. Sequential applications of Liberty resulted in 76% control at 42 DAP, whereas all PRE and Early POST treatments followed by Liberty application provided ≥ 80% control of glyphosate-resistant common waterhemp.

The PRE herbicide treatments including Envive, Prefix, Boundary, Authority MTZ, Sharpen + Outlook followed by Liberty provided more than 90% control of glyphosate-resistant common waterhemp throughout the growing season. Additionally, there was no significant soybean injury due to application of Liberty or Flexstar in this study. The similar trend was followed in soybean yield; highest soybean yield (≥ 30 bu/a) were observed in the treatments having highest visual control, whereas untreated control produced only 12 bu/a.

### Common Waterhemp Management Considerations

Resistance to any herbicide mode of action is troubling, but multiple resistance (resistance in a weed biotype to more than one herbicide mode of action) is of particular concern. Common waterhemp biotypes with resistance to multiple herbicides have been confirmed in Illinois, Iowa, Kansas, Minnesota and Missouri. This resistance stacking is alarming and limits herbicide options for managing common waterhemp, especially for the soybean growers. Control of glyphosate-resistant common waterhemp will require an integrated approach including:

- Use of soil- residual herbicides
- Use of post-emergence herbicides with different modes-of-action, that will slow down the process herbicide-resistance development
- Rotational use of different herbicide resistant crop technologies (like, Roundup Ready, LibertyLink etc.) and crop rotation
- A combination of tillage system

**Table 1. Effect of different herbicide programs on control of glyphosate-resistant common waterhemp at 14, 28, 42, 90 DAP, and at harvest in Roundup Ready soybeans and on the soybean yield**

| Herbicide[a] | Mode-of-action[a] group | Application timing[a] | Rate | Common waterhemp control after planting[ab] | | | | | Soybean yield[b] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 14 DAP | 28 DAP | 42 DAP | 90 DAP | At harvest | 2013 | 2014 |
| | | | | % | | | | | bu/a | |
| Nontreated Control | ------- | ------- | ------ | 0 | 0 | 0 | 0 | 0 | 14 g | 13 i |
| Roundup PowerMax *fb*<br>Roundup PowerMax | 9 *fb*<br>9 | Early POST *fb*<br>Mid POST | 44 oz/a<br>22 oz/a | 0 f | 26 i | 56 g | 31 i | 23 i | 19 fg | 13 i |
| Extreme *fb*<br>Roundup PowerMax | 2 + 9 *fb*<br>9 | Early POST *fb*<br>Mid POST | 3 pt/a<br>22 oz/a | 0 f | 56 h | 59 g | 46 h | 37 h | 21 ef | 14 i |
| Extreme + Warrant *fb*<br>Roundup PowerMax | 2 + 9 +15 *fb*<br>9 | Early POST *fb*<br>Mid POST | 3 pt/a + 2 qt/a<br>22 oz/a | 0 f | 69 fg | 61 f | 53 h | 42 gh | 26 de | 16 hi |
| Extreme + Flexstar GT+ Warrant *fb*<br>Roundup PowerMax | 2 + 9 + 14 + 15 *fb*<br>9 | Early POST *fb*<br>Mid POST | 3 pt/a + 56 oz/a + 2qt/a<br>22 oz/a | 0 f | 70 fg | 60 g | 53 h | 49 fg | 25 def | 15 i |
| Extreme + Flexstar GT+ Warrant *fb*<br>Cobra + Roundup PowerMax | 2 + 9 + 14 + 15 *fb*<br>14 + 9 | Early POST *fb*<br>Mid POST | 3 pt/a + 56 oz/a + 2qt/a<br>12.5 oz/a + 22 oz/a | 0 f | 64 gh | 82 e | 71 g | 59 f | 25 def | 20 gh |
| Valor XLT *fb*<br>Flexstar GT | 14 + 2 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 4 oz/a<br>56 oz/a | 92 bcd | 85 cd | 90 bcd | 86 cde | 83 cd | 30 cd | 29 cde |
| Optill *fb*<br>Flexstar GT | 14 + 2 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 2 oz/a<br>56 oz/a | 91 cd | 87 bcd | 89 cde | 87 cd | 84 bcd | 31 bcd | 29 cde |
| Optill + Outlook *fb*<br>Flexstar GT | 14 + 2 + 15 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 2 oz/a + 10 oz/a<br>56 oz/a | 97 a | 93 ab | 97 a | 95 a | 96 a | 38 a | 36 a |
| Authority Assist *fb*<br>Flexstar GT | 14 + 2 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 12 oz/a<br>56 oz/a | 97 a | 94 a | 90 bcd | 86 cde | 83 cd | 28 d | 28 de |
| Authority XL *fb*<br>Flexstar GT | 14 + 2 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 8 oz/a<br>56 oz/a | 95 abc | 91 abc | 94 abc | 88 cd | 86 bc | 29 d | 30 cde |
| Sonic *fb*<br>Flexstar GT | 14 + 2 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 8 oz/a<br>56 oz/a | 96 ab | 94 a | 95 ab | 91 bc | 91 ab | 35 abc | 34 abc |
| Enlite *fb*<br>Flexstar GT | 2 + 2 + 14 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 2.8 oz/a<br>56 oz/a | 88 de | 83 de | 86 de | 79 f | 72 e | 26 de | 26 ef |
| Dual II Magnum *fb*<br>Flexstar GT | 15 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 1.33 pt/a<br>56 oz/a | 83 e | 66 g | 72 f | 65 g | 61 f | 25 def | 21 fg |
| Prefix *fb*<br>Ultra Blazer + Roundup PowerMax | 15 + 14 *fb*<br>14 +9 | PRE *fb*<br>Mid POST | 2 pt/a<br>2 pt/a + 22 oz/a | 96 ab | 93 ab | 97 a | 96 a | 96 a | 39 a | 35 ab |
| Fierce *fb*<br>Flexstar GT | 14 + 15 *fb*<br>14 +9 | PRE *fb*<br>Mid POST | 3.75 oz/a<br>56 oz/a | 94 abc | 86 cd | 90 bcd | 87 cd | 88 bc | 28 d | 31 bcde |
| Zidua *fb*<br>Flexstar GT | 15 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 3.5 oz/a<br>56 oz/a | 95 abc | 83 de | 88 de | 85 def | 83 cd | 28 d | 27 e |
| Boundary *fb*<br>Flexstar GT | 15 + 5 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 2.25 pt/a<br>56 oz/a | 97 a | 94 a | 96 a | 93 ab | 91 ab | 36 ab | 33 abcd |
| Prowl $H_2O$ + Sencor *fb*<br>Flexstar GT | 15 + 5 *fb*<br>14 + 9 | PRE *fb*<br>Mid POST | 3.6 pt/a + 0.5 lb/a<br>56 oz/a | 92 bcd | 77 ef | 86 de | 80 ef | 75 de | 26 de | 27 e |

[a]DAP, days after planting; PRE, preemergence; POST, postemergence; *fb*, followed by.

[b]Means presented within each column with no common letter(s) are significantly different according to Fisher's Protected LSD test where $P \leq 0.05$.

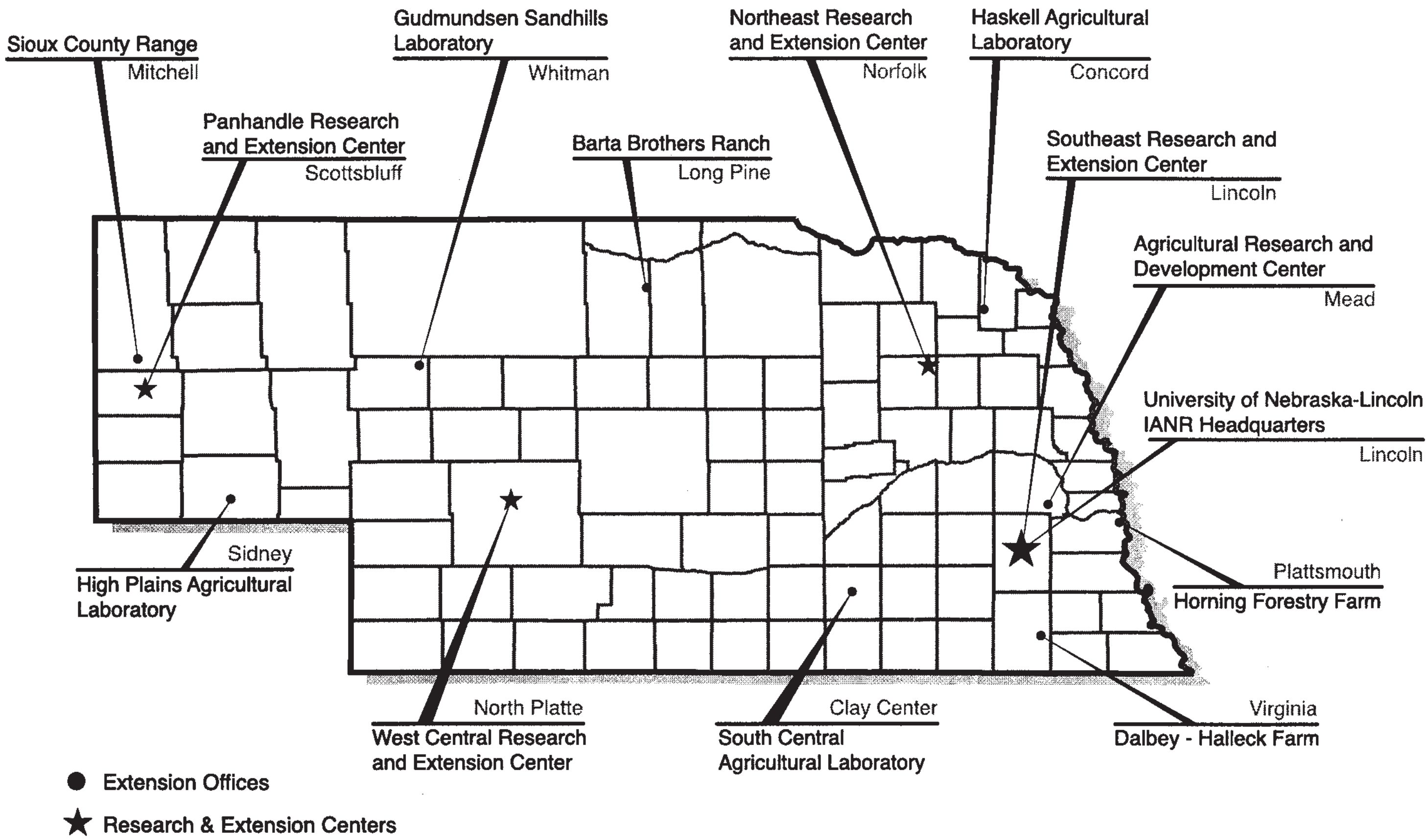
**Table 2. Effect of different herbicide programs on control of glyphosate-resistant common waterhemp at 14, 28, 42, 90 DAP, and at harvest in LibertyLink soybeans and on the soybean yield**

| Herbicide[a] | Mode-of-action[a] group | Application timing[a] | Rate | Common waterhemp control after planting[ab] 14 DAP | 28 DAP | 42 DAP | 90 DAP | At harvest | Soybean yield[b] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | % | | | | | bu/a |
| Nontreated Control | ------- | ------- | ------ | 0 | 0 | 0 | 0 | 0 | 12 i |
| Liberty *fb* Liberty | 10 *fb* 10 | Early POST *fb* Mid POST | 29 oz/a 29 oz/a | 0 e | 71 h | 76 f | 51 f | 41 f | 17 gh |
| Liberty + Warrant *fb* Liberty | 10 + 15 *fb* 10 | Early POST *fb* Mid POST | 29 oz/a + 2 qt/a 29 oz/a | 0 e | 77 efg | 81 ef | 60 ef | 53 e | 18 gh |
| Liberty + Warrant + Pursuit *fb* Liberty | 10 + 15 + 2 *fb* 10 | Early POST *fb* Mid POST | 29 oz/a + 2 qt/a + 4 oz/a 29 oz/a | 0 e | 77 efg | 81 ef | 64 de | 54 e | 19 fg |
| Liberty + Flexstar *fb* Liberty | 10 + 14 *fb* 10 | Early POST *fb* Mid POST | 29 oz/a + 16 oz/a 29 oz/a | 0 e | 75 fgh | 82 ef | 53 f | 41 f | 18 gh |
| Liberty + Flexstar + Warrant *fb* Liberty | 10 + 14 + 15 *fb* 10 | Early POST *fb* Mid POST | 29 oz/a + 16 oz/a + 2 qt/a 29 oz/a | 0 e | 79 def | 83 de | 68 de | 55 e | 20 fg |
| Liberty + Flexstar + Pursuit +Warrant | 10 + 14 + 2 + 15 | Early POST | 29 oz/a + 16 oz/a + 4 oz/a + 2 qt/a | 0 e | 81 cde | 58 g | 25 g | 19 g | 15 hi |
| Liberty + Flexstar + Pursuit + Warrant *fb* Liberty | 10 + 14 + 2 + 15 *fb* 10 | Early POST *fb* Mid POST | 29 oz/a + 16 oz/a + 4 oz/a + 2 qt/a 29 oz/a | 0 e | 82 cde | 85 de | 63 e | 58 e | 19 fg |
| Valor *fb* Liberty | 14 *fb* 10 | PRE *fb* Mid POST | 3 oz/a 29 oz/a | 88 c | 83 cd | 88 cd | 73 d | 59 e | 22 ef |
| Valor + FirstRate *fb* Liberty | 14 + 2 *fb* 10 | PRE *fb* Mid POST | 3 oz/a + 0.6 oz/a 29 oz/a | 99 a | 96 ab | 97 ab | 91 bc | 87 cd | 27 bc |
| Envive *fb* Liberty | 2 + 2 + 14 *fb* 10 | PRE *fb* Mid POST | 5.3 oz/a 29 oz/a | 99 a | 98 a | 99 a | 98 a | 96 ab | 32 a |
| Intrro *fb* Liberty | 15 *fb* 10 | PRE *fb* Mid POST | 3 qt/a 29 oz/a | 96 b | 93 b | 96 b | 90 bc | 86 cd | 26 bcd |
| Dual II Magnum *fb* Liberty | 15 *fb* 10 | PRE *fb* Mid POST | 1.33 pt/a 29 oz/a | 76 d | 71 h | 80 ef | 61 ef | 54 e | 23 def |
| Dual II Magnum + Pursuit *fb* Liberty | 15 + 2 *fb* 10 | PRE *fb* Mid POST | 1.33 pt/a + 4 oz/a 29 oz/a | 78 d | 74 gh | 81 ef | 68 de | 61 e | 23 def |
| Prefix *fb* Liberty | 15 + 14 *fb* 10 | PRE *fb* Mid POST | 2 pt/a 29 oz/a | 99 a | 99 a | 99 a | 98 a | 98 a | 31 a |
| Boundary *fb* Liberty | 15 + 5 *fb* 10 | PRE *fb* Mid POST | 2.25 pt/a 29 oz/a | 99 a | 98 a | 99 a | 97 a | 95 ab | 30 ab |
| Authority MTZ *fb* Liberty | 14 + 5 *fb* 10 | PRE *fb* Mid POST | 18 oz/a 29 oz/a | 98 ab | 96 ab | 96 b | 95 ab | 91 bc | 27 bc |
| Sharpen *fb* Liberty | 14 *fb* 10 | PRE *fb* Mid POST | 1 oz/a 29 oz/a | 90 c | 87 c | 92 c | 89 c | 83 d | 24 cde |
| Sharpen + Outlook *fb* Liberty | 14 + 15 *fb* 10 | PRE *fb* Mid POST | 1 oz/a + 18 oz/a 29 oz/a | 99 a | 99 a | 99 a | 98 a | 97 a | 33 a |

[a]DAP, days after planting; PRE, preemergence; POST, postemergence; *fb*, followed by.

[b]Means presented within each column with no common letter(s) are significantly different according to Fisher's Protected LSD test where $P \leq 0.05$

# Institute of Agriculture and Natural Resources
# University of Nebraska-Lincoln




---


- **Increasing Agricultural Profitability**
- **Enhancing Water Quality**
- **Youth and Families At Risk**
- **Food Safety and Quality**
- **Revitalizing Rural Communities**
- **Waste Management**