

2013 National FFA Agronomy CDE

Clinic Problem

FOR EVENT USE ONLY

Using the provided resources, formulate a recommendation for the farmer below.

Farmer: Richard Taylor

135 Trenton Road

Dover, Delaware 19901

DATE: August 23, 2013

This 35 acre corn field was seeded on April 28, 2013 using a Roundup-Ready, BT variety at recommended seeding rates. The herbicide program this season was Roundup applied pre-emergence and post emergence. The BT variety was chosen due to problems with corn rootworm in neighboring fields. This field has a high organic matter content.

Last year this area of the field was in watermelons. Treflan was used and incorporated according to labeled rates for weed control. Drought conditions existed statewide.

The damage in the photographs happened after a thunderstorm. Winds were recorded at 35 MPH.





Blown down plants.



Roots of plants after washing.

Photos courtesy of Dr. William Curran, University of Delaware.

As requested my soil test is attached.

I need to know what caused this damage and what can be done to prevent it in the future.

FOR THE FERTILITY SECTION USE THE SOIL TEST AND FERTILIZER COST SHEET TO MAKE YOUR RECOMMENDATION FOR THE FIELD. WRITE YOUR ANSWER AT THE BOTTOM OF THE CLINIC PAGE.

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Fertilizer Cost Sheet –Clinic Problem

Product		Price per ton
46-0-0	Urea	\$425
11-52-0	MAP	\$580
82-0-0	NH3	\$640
0-0-60	Potash	\$650
21-0-0-24	Ammonium sulfate	\$340

Lime

Ag-ground limestone \$32.00 per acre, per ton delivered and applied.

SOIL TEST RECOMMENDATION SHEET

Crop Year	Field ID	Field Descriptio	Acreage
2013	1	Taylor 12	35

Soil Test Information

P	K	Ca	Mg	pH	LTl	Subsoil pH (optional)	Depth of Tillage
45	75	1300	250	5.4	69	5.9	4

Units

lb/A (P2O5 & K2O)

CEC	% Ca	% Mg	% K	% BS	Previous Crop
5.6	58.5	18.5	1.4	78	Other

Crops in Rotation

Build/Maintenance

Year One	Yield Goal, bu/A	Lime Req, t/A	N Rec, lb/A	P2O5 Rec, lb/A	K2O Rec, lb/A	Liming Material ENP	Lime Rec, t/A	N source	P source	K source	N material rate, lb/A	P material rate, lb/A	K material rate, lb /A
Corn	190	2.5	220	70	50	2000	2.5	Sludge/waste	Sludge/waste	Sludge/waste	65	152	83
Year Two	None		N Rec, lb/A	P2O5 Rec, lb/A	K2O Rec, lb/A			N source	P source	K source	N material rate, lb/A	P material rate, lb/A	K material rate, lb /A
No Crop	0		0	0	0			UAN - 28	DAP	Potash	0	0	0
Year Three	None		N Rec, lb/A	P2O5 Rec, lb/A	K2O Rec, lb/A			N source	P source	K source	N material rate, lb/A	P material rate, lb/A	K material rate, lb /A
No Crop	0		0	0	0			UAN - 28	DAP	Potash	0	0	0

Sufficiency

Year One	Yield Goal, bu/A	Lime Req, t/A	N Rec, lb/A	P2O5 Rec, lb/A	K2O Rec, lb/A	Liming Material ENP	Lime Rec, t/A	N source	P source	K source	N material rate, lb/A	P material rate, lb/A	K material rate, lb /A
Corn	0	0.1	0	0	140	2000	0.1	Sludge/waste	Sludge/waste	Sludge/waste	0	0	233
Year Two	None		N Rec, lb/A	P2O5 Rec, lb/A	K2O Rec, lb/A			N source	P source	K source	N material rate, lb/A	P material rate, lb/A	K material rate, lb /A
No Crop	0		0	0	0			UAN - 28	DAP	Potash	0	0	0
Year Three	None		N Rec, lb/A	P2O5 Rec, lb/A	K2O Rec, lb/A			N source	P source	K source	N material rate, lb/A	P material rate, lb/A	K material rate, lb /A
No Crop	0		0	0	0			UAN - 28	DAP	Potash	0	0	0

Liming Material

TNP, %	Moisture	% passing 8 mesh	% passing 20 mesh	% passing 60 mesh
98	12	97	95	90

HERBICIDE PERSISTENCE AND HOW TO TEST FOR RESIDUES IN SOILS

TOPICS OF INTEREST

- Factors affecting herbicide persistence
- Herbicide families that persist in soils
- Precautions to avoid herbicide carryover
- Testing soils for herbicide residues
- Practices to overcome herbicide residues in soils

FACTORS AFFECTING HERBICIDE PERSISTENCE

Herbicides are applied to the soil in hopes of obtaining season-long weed control. It is desirable for the chemicals to control weeds during the season of application, but they should not remain long enough to affect subsequent crop growth. The length of time that a herbicide remains active in the soil is called “soil persistence” or “soil residual life.” Anything that affects the disappearance or breakdown of a herbicide affects persistence. Many factors determine the length of time herbicides persist. Most factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. These categories strongly interact with one another.

Herbicides vary in their potential to persist in the soil. Some herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, pigment inhibitors, imidazolinones, and certain plant-growth regulators. Table 1 lists several common herbicides in these groups. Table 2 lists the soil persistence of some common herbicides.

SOIL FACTORS

The soil factors affecting herbicide persistence fit into three categories: physical, chemical, and microbial. Soil composition is a physical factor that measures the relative amounts of sand, silt, and clay (the soil texture) and the organic-matter content of the soil. Chemical properties of the soil include pH, cation-exchange capacity (CEC), and nutrient status. The microbial aspects of the soil environment include the type and abundance of soil microorganisms present.

Soil composition affects herbicide phytotoxicity and persistence through adsorption, leaching, and volatilization. Generally, soils high in clay, organic matter, or both have a greater potential for herbicide carryover because there is increased adsorption to soil colloids, with a corresponding decrease in leaching and loss through volatilization. This “tie-up” results in decreased initial plant uptake and herbicidal activity. Therefore, more herbicide is held in reserve to be released later, potentially injuring susceptible future crops.

Some herbicides, principally the triazines (atrazine and simazine), are particularly affected by soil pH, an important part of the soil chemical makeup. Lesser amounts of these herbicides are adsorbed or held to soil colloids at higher soil pH, so they remain in the soil solution. Herbicides in the soil solution are available for plant uptake. Chemical breakdown and microbial breakdown, two major herbicide degradation processes, are often slower in soils of higher pH. So although decreased adsorption of triazine herbicides occurs in soils of higher pH, there is also less breakdown activity. Therefore, these herbicides are more available for plant uptake for a longer period on soils of higher pH. Certain members of the sulfonylurea group (chlorsulfuron

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Herbicide families with their persistent members

S-triazines atrazine (AAtrex, Atrazine) hexazinone (Velpar) prometon (Pramitol) simazine (Princep)	Phenylureas diuron (Karmex, Direx)	Sulfonylureas chlorimuron (Classic) chlorsulfuron (Telar) nicosulfuron (Accent) primisulfuron (Beacon) prosulfuron (Peak) sulfometuron (Oust)
Dinitroanilines benefin (Balan) oryzalin (Surflan) pendimethalin (Pendimax, Prowl) prodiamine (Barricade) trifluralin (Treflan, Tri-4, Trilin)	Uracils bromacil (Hyvar-X) terbacil (Sinbar)	Plant-growth regulators clopyralid (Stinger) picloram (Tordon) triclopyr (Garlon)
Others bensulide (Betasan, Prefar) clomazone (Command) tebuthiuron (Spike)	Imidazolinones imazapyr (Arsenal) imazaquin (Scepter) imazethapyr (Pursuit)	

and chlorimuron) can also persist in higher-pH soils because rates of chemical breakdown are decreased. Low pH affects the persistence of clomazone and the imidazolinones (imazaquin and imazethapyr). Soil pH has little effect on the persistence of other herbicides.

Research shows that various nutrients and cations in the soil affect both herbicide activity and degradation. The CEC, principally a function of clay type and organic-matter content, is directly involved in herbicide adsorption. Some herbicides are more available in the presence of certain cations, whereas others may be tied up and therefore unavailable. The literature indicates that there is much variation in the effect that cations and nutrients can have on herbicide activity and breakdown, depending on soil composition, nutrient type and concentration, and chemistry of the herbicide.

Soil microorganisms are partially responsible for the breakdown of many herbicides. The types of microorganisms and their relative amounts determine how quickly decomposition occurs. Soil microbes require certain environmental conditions for optimal growth and utilization of any pesticide. Factors that affect microbial activity are temperature, pH, oxygen, and mineral nutrient supply. Usually, a warm, well-aerated, fertile soil with a medium soil pH is most favorable for microorganisms and hence herbicide breakdown.

CLIMATIC CONDITIONS

The climatic variables involved in herbicide degradation are moisture, temperature, and sunlight. Herbicide degradation rates generally increase with increased temperature and soil moisture because both chemical and microbial decomposition rates increase under conditions of higher temperature and moisture. Cool, dry conditions slow degradation, causing greater carryover potential. If winter and spring conditions are wet and mild, herbicide persistence is less likely.

Sunlight is another important factor in herbicide degradation. Photodegradation, or decomposition by light, has been reported for many herbicides. The dinitroanilines (trifluralin and pendimethalin) are sensitive to light degradation. They may be lost when surface-applied if they remain for an extended time without rainfall. Therefore, degradation is accelerated on very sunny days. This sensitivity to light and loss by volatility are primary reasons for soil incorporation.

HERBICIDAL PROPERTIES

Finally, the chemical properties of a herbicide affect its persistence. Important factors include water solubility, soil adsorption, vapor pressure, and susceptibility to chemical and microbial alteration or degradation. The water solubility of a herbicide helps to determine its leaching potential. Leaching occurs when a herbicide is dissolved in water and moves down through the soil profile. Herbicides that readily leach may be carried away or carried to rooting zones of

Table 2. Soil persistence of some common herbicides applied at labeled Illinois use rates

1 month	1 to 3 months	3 to 12 months	More than 12 months
2,4-D	acetochlor	atrazine (AAtrex)	bromacil (Hyvar)
glufosinate	(Degree, Harness,	benefin (Balan)	chlorsulfuron (Telar)
(Liberty)	Surpass, TopNotch)	bensulide (Betasan, Prefar)	imazapyr (Arsenal)
glyphosate	alachlor (IntRRo, Micro-Tech)	bromoxynil (Buctril, many)	picloram (Tordon)
(Roundup, Touch-	ametryn (Evik)	chlorimuron (Classic)	prometon (Pramitol)
down, many)	bentazon (Basagran)	clomazone (Command)	sulfometuron (Oust)
MCPA	butylate (Sutan+)	diuron (Direx, Karmex)	tebuthiuron (Spike)
	DCPA (Dacthal)	ethalfluralin	
	dimethenamid (Outlook)	(Curbit, Sonalan)	
	EPTC (Eptam, Eradicane)	fomesafen (Flexstar, Reflex)	
	flumetsulam (Python)	hexazinone (Velpar)	
	foramsulfuron (Option)	imazaquin (Scepter)	
	halosulfuron (Permit)	imazethapyr (Pursuit)	
	lactofen (Cobra, Phoenix)	isoxaflutole (Balance Pro)	
	linuron (Lorox)	oryzalin (Surflan)	
	mesotrione (Callisto)	pendimethalin	
	metolachlor	(Pendimax, Prowl)	
	(Dual II Magnum)	primisulfuron (Beacon)	
	metribuzin (Sencor)	prodiamine (Barricade)	
	naptalam (Alanap)	pronamide (Kerb)	
	siduron (Tupersan)	prosulfuron	
		(Peak, in Spirit)	
		simazine (Princep)	
		sulfentrazone (Authority,	
		Spartan)	
		terbacil (Sinbar)	
		topramezone (Impact)	
		trifluralin (Treflan, many)	

susceptible plants. Herbicide leaching is determined not only by a herbicide's water solubility but also by its ability to adsorb to soil particles. Additionally, soil texture and available soil water affect herbicide leaching. Herbicides that are low in water solubility, are strongly adsorbed to soil colloids, and exist in dry soils are less likely to leach and have a greater potential to persist.

The vapor pressure of a herbicide determines its volatility, the process of changing from a liquid or a solid to a gas. Volatility increases with temperature. Volatile herbicides such as the thiocarbamates (EPTC, butylate) must be incorporated immediately to avoid gaseous losses. These herbicides are less likely to persist than herbicides with low vapor pressures.

Herbicides may be rapidly decomposed by microorganisms in the soil if the right kinds and numbers of microorganisms are present and if soil conditions are favorable for their growth. However, herbicides vary greatly in their susceptibility to microbial decomposition. For example, microbial degradation of 2,4-D oc-

curs very quickly in the soil, whereas microbial degradation of atrazine is slow.

Chemical decomposition is dependent not only on the chemistry of the herbicide (how susceptible it is to chemical breakdown) but also on soil and climatic factors. Chemical breakdown of a herbicide involves reactions such as hydrolysis, oxidation, and reduction. The occurrence of these reactions and the rates at which they take place vary with soil type and climatic conditions. These reactions, along with microbial degradation, are important processes in the decomposition of herbicides.

AVOIDING HERBICIDE CARRYOVER

There are several ways to avoid herbicide carryover problems. First, always apply the correct rate of any herbicide for your specific soil type and weed problem. This means applying the lowest labeled rate of the chemical consistent with obtaining the desired effect.

To accomplish this goal, accurate acreage determination, accurate chemical measurement, proper sprayer calibration, and uniform application are essential. Always read the label before applying any herbicide.

The method and time of application can be important in avoiding herbicide carryover. Incorporation dilutes herbicides; however, herbicides that have the potential to persist longer than desired will more likely remain longer if incorporated than if surface-applied without incorporation. Incorporating the herbicide makes it less susceptible to loss by volatilization and photodegradation. In addition, an incorporated herbicide is immediately exposed to soil particles and may be tied up temporarily through adsorption and later released. Decreased environmental losses (volatilization and photodegradation) and increased adsorption favor herbicide carryover. Banded herbicide applications can reduce carryover potential because less total herbicide is applied than in a broadcast application. Postemergence and late soil applications have greater potential than earlier applications for being present the following season.

The amount of tillage affects herbicide persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown. Minimum-till and no-till, which leave crop residue on the soil surface, also tend to leave a greater concentration of herbicide near the surface zone. Persistent herbicides present in this concentrated zone may affect susceptible crops. In addition, higher rates of herbicides are often used in reduced-tillage systems to maximize weed control and adjust for greater amounts of crop residues. If a herbicide-carryover problem already exists, some tillage to dilute the chemical may help.

Herbicide combinations may reduce the risk of carryover problems. By tank-mixing two or more herbicides, you may reduce the application rates of those products that can potentially cause problems and at the same time broaden the weed-control spectrum.

Herbicides may interact with one another or with other pesticides and may enhance crop injury when applied in the same year or in consecutive years. For example, a soybean crop may tolerate a certain level of atrazine carryover. However, if another photosynthetic inhibitor, such as metribuzin, is applied to soybeans after atrazine-treated corn, injury is more likely.

Plants absorb herbicides from the soil in which they are growing. Persistence may be reduced if the herbicide is metabolized (broken down) by the plant or if the plant containing the absorbed herbicide is harvested and removed from the field. Plant extraction of the herbicide from the soil may not be an important factor under most situations, but it has been used in

some cases to help remove persistent herbicides from treated soils.

Finally, the selection of a tolerant rotational crop or variety helps minimize carryover problems. Quite often, economics dictates crop rotation; however, there are varietal differences that might affect the likelihood of serious crop injury. For example, some soybean varieties are more sensitive to the triazine herbicides than others and should not be used if the potential for triazine injury exists. Also, as a general rule, smaller-seeded crops and varieties have a greater potential for injury from persistent herbicides than do larger-seeded species.

Many variables interact in predicting herbicide persistence. Factors involved in the degradation of herbicides include many soil, climatic, and herbicidal properties. The potential for herbicide carryover problems can be reduced by using the appropriate rates and accurate timing of proper application methods. The use of selective tillage, herbicide combinations, and tolerant crops and varieties can also help reduce the risk of crop injury.

TESTING FOR HERBICIDE RESIDUES

If herbicide carryover is suspected, a soil chemical test or a bioassay can be used to determine if harmful levels of herbicide are present. Chemical analysis can be expensive, so a bioassay conducted either in the suspect field or in a warm, sunny indoor location (such as a greenhouse) may be more feasible. These tests help predict potential herbicide-residue problems so the grower can make better decisions about crop rotation, herbicide selection, planting date, and other cultural practices.

SOIL COLLECTION AND PREPARATION

With the lab analysis or indoor bioassay, proper sampling of soil is the first step. The procedures for submitting a soil for laboratory analysis and for conducting an indoor bioassay are similar. These guidelines should be followed:

1. In early spring to midspring or before planting time, collect representative soil samples from the suspect field. Take samples from several locations in the field. For the bioassay or laboratory analysis, take 15 to 20 soil cores and combine them to make a composite sample. This sample should represent no more than 15 to 20 acres. Enough areas must be sampled to avoid missing locations with high herbicide-residue content. Take separate samples from areas where excessive residues are suspected,

such as sprayer turnaround points and end rows. Do not mix these samples with the others. Sample the soil to a 6-inch depth, and divide the samples into two sections for greater accuracy—those from 0 to 3 inches and those from 3 to 6 inches. Be sure to mark on the bags the depths from which the samples came. About 8 pounds of soil (about 4 quarts) are needed for each bioassay and 2 pounds of soil (about 1 quart) for each laboratory analysis.

2. Sample an area that is not suspect for use as a “check” soil. This soil may be taken from a nearby fencerow or another untreated area. Keep this sample separate from the others. Many laboratories require a check soil.
3. Submit the samples to the laboratory as soon as possible after sampling. If bioassays are to be performed, they should be run on the soil samples as soon as possible after they have been obtained from the field. If samples cannot be assayed immediately, store the soil in a refrigerator or freezer that is not used for food. If samples are stored in a warm environment, herbicide residue may decrease with time.

BIOASSAY

The bioassay can help predict potential crop injury. The test is inexpensive and can be done with a few simple supplies. A bioassay does not measure the amount of herbicide residue present in the soil, but it may indicate whether or not enough residue is present to injure a sensitive crop.

FIELD BIOASSAY

A field bioassay is conducted by planting one or more strips of a species sensitive to the suspect herbicide in the field. This procedure can be done in the fall or spring, but it is more accurate when performed closer to the planting of the intended crop. Before planting the desired crop, allow the test plants to grow and develop symptoms of injury from any herbicide residues. Plant the strips in several locations, if possible, and include an area that is most suspect and an area that can serve as a check. Choose an appropriate species for the bioassay, such as one of the more sensitive ones listed in this chapter. Include several species of differing sensitivity for greater accuracy.

INDOOR BIOASSAY

The procedures for conducting an indoor bioassay vary, depending on what herbicide residue is of concern. However, for the indoor bioassay, the procedures for soil collection and preparation are the same.

1. For an indoor bioassay, collect the samples and allow them to air dry if needed until they can be worked readily. Do not overdry. If the soil is cloddy, crush the clods into pieces (the size of a pea or smaller). If the soil contains a high amount of clay, the addition of coarse sand (50 percent by volume) improves its physical condition. If sand is added, mix it thoroughly with the soil.
2. Tin cans, milk cartons, and cottage cheese containers are appropriate containers in which a bioassay can be conducted. Punch holes in the bottoms of the containers to allow water drainage. Fill two or more containers (a set) with soil from each sample. Additional containers increase the accuracy of the test. Place the soil samples obtained from depths of 0 to 3 inches in one set of containers; and, in another set, place the soil obtained from depths of 3 to 6 inches. Follow this procedure for the composite sample and the sample taken from areas where excessive residues are expected. In addition, fill a final set of containers with the check soil.

TESTING FOR SPECIFIC HERBICIDE GROUPS

TRIAZINE RESIDUES

For suspected carryover from triazine herbicides, such as atrazine and Princep (simazine), an oat plant bioassay works best. Place about 15 oat seeds in each container of soil and cover the seeds with about 1 inch of soil. Wet the soil with water, but do not saturate it.

Place the containers in a warm location (70° to 75°F) where they can receive ample light. Sunlight is essential for the development of the plant, as well as for inducing symptoms of triazine injury. The container should be watered as needed.

Injury symptoms should become apparent within 10 to 14 days after emergence. Triazine injury is characterized by chlorosis (yellowing), then necrosis (browning) of leaf tissue. As injury symptoms start at the leaf tip and develop toward the base, a comparison with the plants in the check soil is essential.

If injury appears on the oats, enough herbicide residue may be present to injure a susceptible crop. Planting a more tolerant crop is suggested. In general, the order of susceptibility from most to least susceptible to triazine herbicides is as follows:

Ryegrass > Alfalfa > Oats > Wheat >
Soybean > Sorghum > Corn

DNA RESIDUES

If residues from dinitroaniline (DNA) herbicides, such as Treflan (trifluralin) or Prowl, Pendimax (pendime-

thalin), are suspected, a different assay technique is used. A sorghum or corn root bioassay is relatively quick and easy to perform.

Wrap a number of sorghum or corn seeds in a moist paper towel and store them at room temperature for 2 to 3 days. This procedure allows the seed to imbibe water and germinate. Once the seed has germinated, carefully place three to five seeds into containers with the suspect soil and the check soil. Cover the seeds with soil to a depth of about 1 inch and leave them for 10 to 14 days, depending on the air temperature. Water the plants as needed but do not saturate the soil.

At the end of the period of 10 to 14 days, carefully remove the plants and observe the root formation. DNA herbicides inhibit root development. Symptoms include stunted plants, stubbed roots, inhibited root-hair development, thickened hypocotyls on broadleaf species, and leaves that fail to unroll. If the plants in the suspect soil display any of these symptoms in comparison to the check plants, DNA residues may be present at concentrations high enough to injure susceptible crops. In general, the order of susceptibility from most to least susceptible to DNA herbicides is as follows:

Annual rye > Oats > Sorghum > Corn >
Wheat > Alfalfa > Soybean

IMAZAQUIN, IMAZETHAPYR, AND CHLORIMURON RESIDUES

Imazaquin, the active ingredient in Scepter; imazethapyr, the active ingredient in Pursuit and a component of Pursuit Plus, Extreme, and Lightning; and chlorimuron, the active ingredient in Classic and a component of Canopy, Canopy EX, and Synchrony XP, have the same mode of action. These herbicides affect root and shoot growth and development. Symptoms of plant injury include inhibited root development, stunted plants, and interveinal chlorosis or leaf striping. Therefore, a sorghum or corn-root bioassay performed according to the procedure outlined for suspected DNA residue is appropriate. Corn is more sensitive to imazaquin, and sorghum is more sensitive to imazethapyr and chlorimuron. In addition to making root observations, look for stunted shoot growth and interveinal chlorosis or yellowing. Bioassay plants should be grown for 14 to 21 days. The order of crop susceptibility from most to least susceptible to imazaquin, imazethapyr, and chlorimuron is as follows:

Imazaquin: Canola > Alfalfa = Corn = Sunflower >
Sorghum > Oats > Wheat > Soybean

Imazethapyr: Canola > Sorghum > Sunflower >
Oats > Wheat > Corn > Alfalfa > Soybean

Chlorimuron: Canola > Alfalfa > Sunflower >
Sorghum > Corn > Oats > Wheat > Soybean

Introduction and commercialization of Clearfield (CL) corn hybrids resistant to the imidazolinone herbicides provide producers with a viable option for corn production in fields suspected of having soil-residue levels (carryover) of imidazolinone herbicides high enough to cause injury to conventional hybrids. If bioassay results show residue levels of imidazolinone herbicides are high enough to cause potential injury to conventional hybrids, you may consider planting a Clearfield hybrid if corn is the rotational crop of choice.

COMMAND (CLOMAZONE) RESIDUES

Clomazone, the active ingredient in Command, inhibits the production of photosynthetic pigments in susceptible plants, causing them to emerge lacking green color (that is, they are white). Lower levels of Command injury may appear as a chlorosis or mild bleaching of the plants. Oats or wheat can be used to detect Command residues using the same procedure as was outlined for detecting triazine residues. Bioassay plants should be grown for 10 days to 2 weeks. Susceptible plants that are exposed to significant levels of Command residues will be white, while untreated or tolerant plants will be green. Keep in mind that oats and wheat are usually more susceptible than corn to injury from Command. The order of susceptibility from most to least susceptible to Command residues is as follows:

Oats = Wheat = Alfalfa > Sunflower =
Sorghum = Corn > Soybean

OTHER RESIDUES

Bioassays may be made for other herbicides using similar techniques. If the site of action of a specific herbicide is known, then a procedure for detecting the herbicide can be developed. For example, if the herbicide is a root meristematic inhibitor (that is, if it stops cell division in the roots), then a root bioassay is the appropriate test. If the herbicide inhibits photosynthesis, then injury symptoms first appear in the leaves. Choose a species that is moderately susceptible to the suspected herbicide, and always include a check soil. Wheat and oats are very good indicator plants for many herbicides but may be more sensitive than the desired crop. Include several species in the bioassay to give a better range of susceptibility. The desired rotational crop is a good bioassay plant to include.

LABORATORY ANALYSIS

Laboratory analysis involves extracting herbicide from the soil with the use of specialized equipment to detect very small amounts. The amount is usually expressed in parts of herbicide per million parts of soil (ppm). This measurement can be transposed into pounds of herbicide active ingredient per acre (lb a.i./A) if we assume that an acre of soil weighs 1 million pounds in the top 3 inches and 2 million pounds in the top 6 inches. For a soil sample taken to a 3-inch depth, 1 ppm = 1 lb/A of residue. For a soil sample taken to a 6-inch depth, 1 ppm = 2 lb/A of residue.

A lab report of 0.2 ppm atrazine, then, means that there is 0.2 pound of atrazine per acre if the samples were taken to a 3-inch depth, and 0.4 pound per acre if taken to a 6-inch depth.

The location and concentration of the chemical depend on the herbicide used, the soil type, whether the ground was tilled, and the amount of rainfall since application. In most medium-textured soils (silt loams, silty clay loams, sandy clay loams), the herbicide remains primarily in the top 3 inches unless there was excessive rainfall, the ground was plowed, or the herbicide was deeply incorporated. If the soil has a high sand content (coarse texture), then herbicide leaching may be greater. Movement of the herbicide from the surface soil zone by tillage or by rainfall decreases the likelihood of crop injury. The risk of injury is greater when the herbicide residue is concentrated in the top 3 inches rather than distributed throughout a 6-inch soil depth. Therefore, it is best to sample in two separate sections, from 0 to 3 inches and from 3 to 6 inches.

Whether parts per million or pounds of active ingredient of herbicide per acre is used, it is difficult to translate these units of measure into potential crop injury. Many variables affect crop susceptibility or tolerance, including soil type, crop sensitivity, and environmental conditions after planting. Crop injury is more likely on more coarsely textured soils or under cool, wet weather conditions. Additionally, high soil pH increases the potential of triazine or chlorimuron injury. General guidelines are provided in Table 3

although you are cautioned that crop injury may still occur below these levels.

Laboratories may differ in available tests and in the prices for analysis. The cost can range from \$20 to \$200 per sample for herbicide analysis. Most laboratories can analyze a sample and have the results in 5 to 7 days. Contact your local Extension office for more information on laboratory selection.

CORRECTING FOR HERBICIDE RESIDUES

If the lab test or bioassay indicates a potential herbicide-residue problem, several steps can be taken.

1. First select a tolerant crop or variety. This selection depends on what herbicide is of concern. Check current herbicide labels for more information on crop tolerance.
2. Tillage can help dilute herbicide in a problem field.
3. Plant the field that concerns you last. Delaying planting allows more time for the herbicide to dissipate.
4. If the triazine herbicides or chlorimuron is suspect, be sure to check the soil pH and adjust your management practices accordingly.
5. If imazaquin or imazethapyr is suspect, check for low soil pH (< 5.5). Liming would both benefit crop growth and minimize carryover of these herbicides.

Soil bioassays or laboratory tests are not 100 percent accurate in predicting herbicide-residue problems. Crop response to herbicide residue depends on various factors, including species and variety, soil type, and environmental conditions after planting. So, predicting crop injury is often difficult. However, using a soil chemical test or bioassay can help in deciding whether a potential problem exists and in choosing the appropriate crop or variety.

Table 3. General guidelines for interpreting laboratory soil analysis

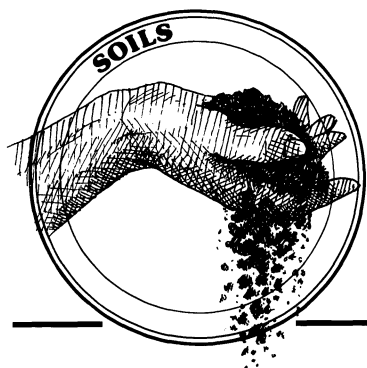
Herbicide	Safe level*		Crop
	Parts per billion	Parts per million	
Triazine	150–250	0.150–0.250	Soybean
	40–100	0.04–0.100	Alfalfa
	60–150	0.06–0.150	Oats
	75–180	0.075–0.180	Wheat
Dinitroaniline	100–200	0.100–0.200	Corn
	200–300	0.200–0.300	Wheat
Clomazone	50–200	0.050–0.200	Corn
	15–100	0.015–0.100	Wheat, alfalfa
Imazaquin	2–10	0.002–0.010	Corn
	10–30	0.010–0.030	Wheat
Imazethapyr	10–30	0.010–0.030	Corn
	4–15	0.004–0.015	Sorghum
Chlorimuron	1–2	0.001–0.002	Corn
	2–5	0.002–0.005	Wheat

*Due to differences in herbicide availability from the soil, “safe” values for herbicide residues differ according to soil type. Low-range values are for coarsely textured soils with low levels of organic matter; higher-range values are for finely textured soils with higher levels of organic matter. 1 ppm = 1,000 ppb.

AUTHORS

Aaron G. Hager and Dawn Nordby

Department of Crop Sciences



Persistence of herbicides in soil

Herbicides are applied to soil to manage weeds. While it is desirable for the chemicals to control weeds during the season of application, it is not desirable for them to persist and affect subsequent crop growth.

The length of time a herbicide remains active in soil is called “soil persistence,” or “soil residual life” (Figure 1). For some herbicides, there may be a fine line between controlling weeds for the entire growing season and then planting a sensitive rotation crop. Anything that affects the disappearance or breakdown of herbicides affects persistence.

Herbicides vary in their potential to persist in soil. Herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, isoxazolidinones, imidazolinones, and certain plant growth regulators belonging to the pyridine family. Table 1 lists common herbicides in these groups.

Several factors determine the length of time herbicides persist. These factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. Factors from each category strongly interact with one another.

SOIL FACTORS

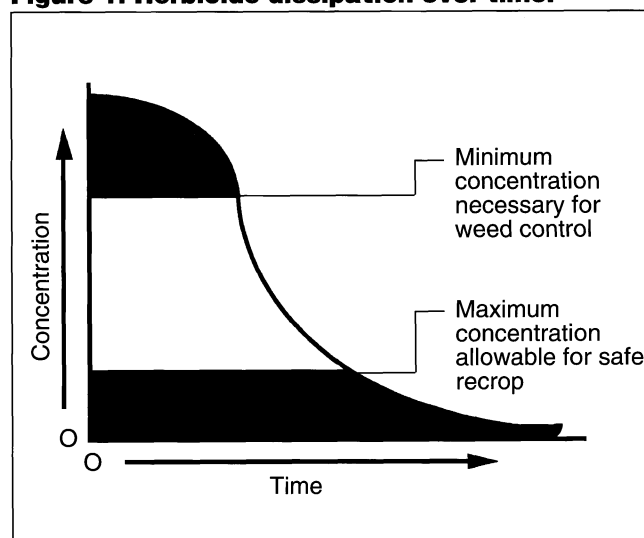
Soil factors affecting herbicide persistence include soil composition, soil chemistry, and microbial activity. Soil composition is a physical factor determined by the relative amounts of sand, silt, and clay in the soil (the soil texture), as well as by the organic-matter content. An important chemical property of soil that can influence herbicide persistence is pH. The microbial aspects of the soil environment include the types and abundance of soil microorganisms present in the soil.

Soil composition affects herbicidal activity and persistence through soil-herbicide binding (adsorption), leaching, and vapor loss (volatilization). Generally, soils high in clay, organic matter, or both have a greater potential for carryover because of increased binding of the herbicide to soil particles, with a corresponding decrease in leaching and loss through volatilization. This “tie-up” results in decreased initial plant uptake and herbicidal activity. More herbicide is held in reserve, potentially injuring susceptible crops in the future.

In general, medium- and fine-textured soils with an organic matter content of more than 3 percent have the greatest potential to bind or hold herbicides and to injure sensitive rotation crops. Coarse- to medium-textured soils with a lower organic matter content (less than 3 percent), more typical of the soils common to Pennsylvania, are less likely to retain herbicides and to have carryover problems. Under the right circumstances, however, herbicide carryover can occur in any type of soil.

Soil pH can influence the persistence of some herbicides, especially the triazines and sulfonylureas (see Table 1). Chemical and microbial breakdown, two ways herbicides degrade in soil, often are slower in higher-pH soils. In particular, the chemical degradation rate of the triazine and sulfonylurea herbicide families slows as the soil pH increases, particularly above pH 7.0. In addition, in higher-pH soils, lesser amounts of these herbicides are bound to soil particles, making more available for plant uptake. So in higher-pH soils, the triazine and sulfonylurea herbicides persist longer, and more is available for plant uptake. (Some triazine and sulfonylurea herbicides do not persist and carry over, regardless of how high the soil pH is.)

Figure 1. Herbicide dissipation over time.



Low pH also can affect the persistence of both the triazine and the sulfonylurea herbicides. Soil pH levels below 6.0 allow a more rapid dissipation of both these herbicide families. In acid soils, herbicides like atrazine become bound to soil particles, making them unavailable for weed control, but at the same time, they are chemically degraded more quickly. This makes liming an acid soil important for achieving an adequate performance from these two herbicide families.

In contrast, a low soil pH increases the persistence of the imidazolinone herbicides, imazaquin (Scepter) and imazethapyr (Pursuit). As the soil pH drops below 6.0, imazaquin and imazethapyr become increasingly bound, or adsorbed, to soil particles. Adsorption of these herbicides appears to reduce their availability to soil microorganisms, the primary mechanisms of degradation. Even though adsorption is greater in lower-pH soils, the herbicide can still be released several months later, becoming available for plant uptake and potentially injuring a sensitive follow crop.

Degradation processes by *soil microorganisms* probably are the most important pathways responsible for the breakdown of herbicides. The types of microorganisms (fungi, bacteria, protozoans, etc.) and their relative numbers determine how quickly decomposition occurs. Microorganisms require certain environmental conditions for optimal growth and utilization of any pesticide. Factors that affect microbial activity are moisture, temperature, pH, oxygen, and mineral nutrient supply. Usually, a warm, well-aerated, fertile soil with a near-neutral pH is most favorable for microbial growth and, hence, for herbicide breakdown.

CLIMATIC FACTORS

The climatic variables involved in herbicide breakdown are *moisture*, *temperature*, and *sunlight*. Herbicide degradation rates generally increase as temperature and soil moisture increase, because both chemical and microbial decomposition rates increase with higher temperatures and moisture levels. Cool, dry conditions slow down herbicide degradation. Carryover problems are always greater the year following a drought. If winter and spring conditions are wet and mild following a previously dry summer, the lower the likelihood of herbicide carryover. The relative importance of rainfall, clay and organic matter content, and soil pH for increasing the persistence of selected herbicides is shown in Table 2.

Sunlight is sometimes an important factor in herbicide degradation. Photodecomposition or degradation catalyzed by sunlight (photolysis) has been reported for many herbicides, especially in liquid solution (i.e., water) or on plant leaf surfaces. But for most of the more persistent soil-applied herbicides, once soil contact is made, losses due to

Table 1. Herbicide families with potentially persistent members.

Triazines	Phenylureas	Sulfonylureas
atrazine	diuron (Karmex)	chlorimuron (Canopy, Classic)
hexazinone (Velpar)	tebuthiuron (Spike)	chlorsulfuron (Glean, Finesse)
simazine (Princep)		metsulfuron (Ally)
		nicosulfuron (Accent)
		primisulfuron (Beacon)
		proflufuron (Peak, Exceed, Spirit)
		sulfometuron (Oust)
Dinitroanilines	Uracils	
benefin (Balan)	terbacil (Sinbar)	
pendimethalin (Prowl)		
trifluralin (Treflan)		
Others	Imidazolinones	Plant growth regulators
clomazone (Command)	imazapyr (Arsenal, Lightning)	clopyralid (Stinger)
sodium borates	imazaquin (Scepter)	picloram (Tordon)
	imazethapyr (Pursuit)	

photolysis are small. The exception may be the dinitroanilines, including trifluralin (Treflan) and pendimethalin (Prowl). These can be lost if they remain on the soil surface for an extended period without rainfall. A sensitivity to sunlight, as well as losses through volatilization, are primary reasons for incorporating the dinitroanilines at application time.

HERBICIDE PROPERTIES

A herbicide's chemical properties affect its persistence. These properties include water solubility, vapor pressure, and the molecule's susceptibility to chemical or microbial alteration or degradation.

Leaching is one mechanism responsible for herbicide dissipation. The solubility of a herbicide in water helps determine its leaching potential. Leaching occurs when a herbicide is dissolved in water and moves down through the soil profile. Herbicides that readily leach may be carried away from crop and weed germination zones.

Herbicide leaching is determined by other factors as well. These include herbicide-soil binding properties, soil physical characteristics, rainfall frequency and intensity, herbicide concentration, and time of herbicide application. In general, herbicides that are less soluble in water and strongly attracted to soil particles are less likely to leach, particularly in dry years.

The *vapor pressure* of a herbicide determines its volatility. Volatilization is the process whereby a herbicide changes from a liquid or solid to a gas. Volatile herbicides (those with higher vapor pressures) generally dissipate more rapidly than herbicides with lower vapor pressures. Volatilization increases with temperature and moisture. Most herbicides are relatively nonvolatile under normal field-use conditions. The more volatile herbicides are

generally incorporated to avoid gaseous losses. Volatile herbicides include members of the thiocarbamate family, EPTC (Eradicane, Eptam) and butylate (Sutan+); the dinitroanilines, trifluralin (Treflan) and ethalfluralin (Sonalan); and clomazone (Command).

A herbicide's *chemical structure* dictates how the herbicide will degrade in soil. Some herbicides are rapidly decomposed by microorganisms if the right kind and number are present and if soil conditions are favorable for their growth. But herbicides vary greatly in their susceptibility to microbial decomposition. The chemical structure of 2,4-D, for example, allows microbes quickly to detoxify the molecule into inactive metabolites, whereas atrazine is not as prone to microbial attack; hence degradation is slower.

Some herbicides are prone to chemical reactions. Members of the sulfonylurea herbicide family, for example, are degraded through chemical hydrolysis as well as through microbial processes. Remember that for the sulfonylureas as well as the triazines, the rate of chemical hydrolysis is dependent on soil pH. Although it is less sensitive than microbes to fluctuations in soil physical characteristics and often soil moisture, the rate of chemical reaction also will vary depending on the surrounding soil environment. Several families of herbicides are degraded both through chemical and through microbial pathways. Others less prone to chemical breakdown are lost primarily through microbial alteration.

AVOIDING HERBICIDE PERSISTENCE IN SUBSEQUENT CROPS

There are several ways to avoid herbicide carryover problems. First, check the recrop statement on the herbicide label and do not plant a sensitive crop prior to the specified time. Check the most recent edition of the Penn State *Agronomy Guide* or the current herbicide label for recrop restrictions. Second, always apply the correct rate of any pesticide for your specific soil type and weed problem. This means applying the lowest rate of the chemical consistent with obtaining the desired effect. Higher rates of more persistent products certainly carry a greater risk of injury to subsequent crops. Accurate acreage determination, chemical measurement, proper sprayer calibration, and uniform application are essential for avoiding misapplication problems. *Always read the label before applying any herbicide.*

Several management considerations can influence herbicide persistence. One is *application timing*. In general, herbicide treatments applied later in the growing season have a greater potential for influencing subsequent crop growth than earlier applications. Early preplant timings may reduce the risk of carryover, and foliar applications may not carry the same risk as applications to bare soil if significant live vegetation is present at the time of application.

The *method of application* can influence herbicide residual activity. Some herbicides must be incorporated, while incorporation is optional for others. Mechanically incorporating the herbicide can make it less susceptible to loss by volatilization and photodecomposition. Also, an incorporated herbicide is immediately exposed to charged soil particles and may become tied up through adsorption. Decreased environmental losses (through volatilization and photodecomposition) and increased adsorption favor herbicide persistence.

Banded herbicide applications can reduce carryover potential compared to broadcast applications, since banding uses less total herbicide per unit of land. Herbicide residues should be lower between the banded herbicide zones regardless of tillage system or lower throughout the field following a primary tillage operation.

The *amount of tillage* following herbicide application can affect persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown. Minimum-till and no-till tend to leave a greater concentration of herbicide near the surface zone. Persistent herbicides present in this concentrated zone may affect shallow-planted susceptible crops. If a potential herbicide carryover problem exists and soil erosion is not a concern, moldboard plowing, in particular, can help dilute the pesticide.

Herbicide combinations may reduce the risk of carryover problems. Application rates can sometimes be reduced by tank-mixing two or more herbicides rather than making single-ingredient applications. At the same time, combining herbicides can broaden the weed control spectrum. However, avoid applying two or more herbicides with a longer residual life during the same season. More persistent herbicides can interact with one another when applied in the same year or in consecutive years, enhancing crop injury. A soybean crop, for example, may

Table 2. Soil and climatic conditions that increase the persistence of selected herbicides or families (ranked in order of importance).

IMPORTANCE	CLOMAZONE	DINITROANILINES	IMIDAZOLINONES	PYRIDINES	SULFONYLUREAS
very important	low rainfall	low rainfall	low rainfall	low rainfall	high pH
important	high clay/ organic matter	high clay/ organic matter	high clay/ organic matter	high clay/ organic matter	high clay/ organic matter
somewhat important	high or low soil pH	high or low soil pH	low soil pH	high or low soil pH	low rainfall

tolerate a certain level of atrazine residue. But if another photosynthetic inhibitor such as metribuzin (Sencor or Lexone) is applied to soybeans the year following atrazine-treated corn, soybean injury is more likely. The same type of interaction can occur when EPTC (Eptam) is used for alfalfa establishment if small amounts of atrazine residue remain from previous use in corn.

Finally, the use of *tolerant rotational crops or varieties* helps to minimize carryover problems. Crop rotation is often dictated by economics, but important differences exist between crops and even among varieties. In general, smaller-seeded crops or varieties are more susceptible to injury from persistent herbicides than larger-seeded species. Ask local seed suppliers about varietal differences that might affect the likelihood of serious crop injury.

Some soybean varieties are more sensitive than others to the triazine herbicides and should not be used with these herbicides or when triazine carryover is a concern. Corn varieties are available that possess greater tolerance to the imidazolinone herbicides. If imazaquin or imazethapyr carryover is a concern, certain varieties can be planted with minimal risk of herbicide injury.

If herbicide residues are suspected in a particular field, a chemical analysis or bioassay can help determine if harmful levels are present. Chemical analysis can be expensive and not all herbicides can be analyzed, so a bioassay may be more feasible. Either can help you determine if herbicide residues exist and if a tolerant crop or variety should be planted in a particular area. Consult your county extension office about available analyses.

In summary, the first step for avoiding herbicide persistence problems is to choose less persistent products. Check the herbicide label for recrop statements before selecting any material. For all pesticides, use the appropriate rates and application timings. Selective tillage, herbicide combinations, and tolerant crops and varieties also help reduce the risk of carryover crop injury. Wise herbicide use ensures the continued availability of these important weed management tools for the future.

Prepared by William S. Curran, associate professor of weed science

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Insects

Western Corn Rootworm

Charles R. Patrick, Professor, Entomology & Plant Pathology
Scott Stewart, Associate Professor, Entomology and Plant Pathology
Angela Thompson, Assistant Professor, Plant Sciences

Introduction

Three species of corn rootworms are found in Tennessee. The Western corn rootworm is the most destructive of the three species. This insect is now prevalent from Texas to the Dakotas, and has moved into Tennessee within the past 10 to 15 years. Until 1955, this rootworm was found in Nebraska, Colorado, Kansas, South Dakota and Iowa. The Western corn rootworm has traditionally moved into the territory of the Northern corn rootworm, which is also found in Tennessee.

Appearance and Life History

The adult is about $\frac{1}{4}$ inch long; it is yellow with a black stripe on the outside of each wing cover. Males and females differ somewhat in their markings. The males' entire posterior half of each wing cover is black. The female has more pronounced stripes than the male. Some variation in color pattern can also occur.

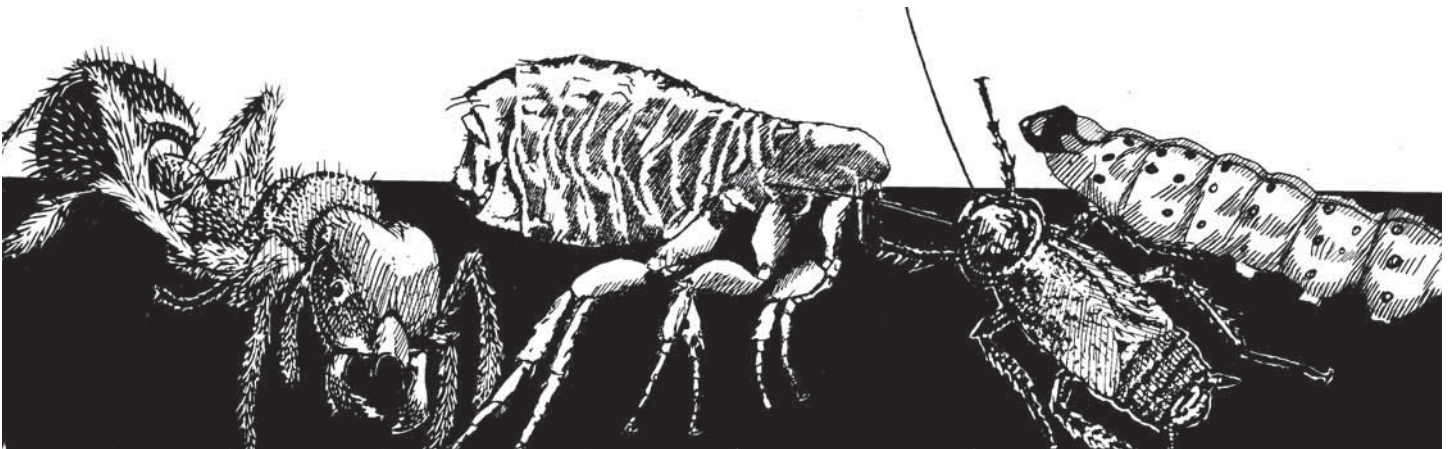
The Western corn rootworm (Fig. 1) has only one generation per year. Eggs are deposited in the soil in mid to late summer by the adult females. Eggs are white, shaped like a football and less than .004 inch long. They are usually found near the bases of corn plants and between the rows in fields. The eggs are usually concentrated in the upper 6 inches of the soil. New egg hatch occurs as early as mid-May, depending on soil



Figure 1. Adult Western Corn Rootworm

temperature. After hatching, the larvae move toward the corn roots and begin to feed. These larvae may move as much as 20 inches to a food source.

After about three weeks, the larvae stop feeding and construct a small cell in the soil to pupate. The pupal stage is white, delicate and resembles the adult. Pupation occurs in about five to 10 days, depending on the temperature. After pupation, the adults emerge from the soil. Males usually emerge before the females. The adults mate and females begin to lay eggs after about 14 days.



Damage

Several symptoms can be recognized as damage from the corn rootworms. The most obvious is “goose-necking” of the more mature corn plants. This is caused by the larvae feeding on the root-hairs and pruning the roots. Falling over of plants will occur in severely damaged plants.

Controls

Corn rootworms usually follow fields in which corn has been repeatedly planted. Rotation (two years away from corn production) may be necessary, because some eggs may hatch the second year. However, if rotation is not an option, granular insecticides must be used at planting to control this pest. Insecticides can either be placed in-furrow or banded. Recommended corn rootworm

insecticides are listed below. Adult beetles should be controlled during silking of corn to prevent clipping of corn silks. (See Fig. 2)



Figure 2. Rootworm Adult Silk Clipping
(Damaged silk on right side.)

Material (Larval Stage)	Rate/Acre	Placement
Lorsban 4E	8 oz./1000 row ft.	In-furrow/banded
Force 3G	8-10 oz./1000 row ft.	In-furrow/banded
Counter 20CR	6 oz./1000 row ft.	In-furrow/banded*
Cruiser 5FS	5.1-9.0/100 lb seed	Seed treatment only
Poncho	1.13 oz/80,000 seed units	Seed treatment only
Material (Adult Stages)		
Warrior	3.64 oz./acre	Foliar (See label) adult stage
Sevin XLR Plus	1-2 qt./acre	See label adult stage.
Baythroid 2	1.6 to 2.8 oz/acre	See label
Mustang Max	2.72 to 4.0 oz/acre	See label

Cultural Practices

Rotation is a valued practice if it is an option. Planting corn in the same fields usually leads to corn rootworm problems.

Soil types can influence the degree of rootworm infestations. Rootworms are not usually a problem on sandy soil that is not irrigated. Wet, cool springs influence

rootworm development. More eggs will be deposited in moist soil rather than dry soil.

Acknowledgment

A special thanks to Kevin Rose of Giles County for providing the photos for this publication.

Precautionary Statement

To protect people and the environment, pesticides should be used safely. This is everyone's responsibility especially the user. Read and follow label directions carefully before you buy, mix, apply, store, or dispose of a pesticide. According to laws regulating pesticides, they must be used only as directed by the label. Persons who do not obey the law will be subject to penalties.

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