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# Best Management Practices for Corn Production in South Dakota: Weeds and Herbicide Injury in Corn

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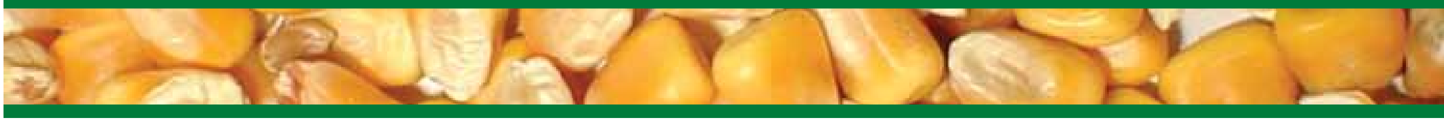
# CHAPTER 10
# Weeds and Herbicide Injury in Corn



This chapter addresses weed problems and herbicide injuries that commonly occur in South Dakota corn production. Photographs and information are provided to assist producers in managing weed pressure and to help identify herbicide injury symptoms resulting from improper application, unintentional exposure, or adverse environmental conditions.

Effective and economical weed management depends on reliable agronomic practices (Table 10.1). Uncontrolled weeds can reduce yield, harbor insects and diseases, or interfere with harvest. Weeds emerging early in the season are generally the most competitive, resulting in the greatest yield loss, whereas late-emerging weeds produce few seeds and have a lesser effect on yield. When controlling weeds, it is important to adopt management strategies that minimize the risk of producing herbicide-resistant weeds (Table 10.2). The competitiveness of a weed is dependent on its species and density (Table 10.3). Optimal control timing improves yield potential by reducing weed pressure at critical growth stages. Weed control between the V2 and V8 growth stages is more critical compared to control of weeds that emerge after V8.

**Table 10.1. Best management practices for weed control**

**Seed selection**
- Selecting hybrids well adapted for the area.
- Planting high-quality seed at optimal populations with clean equipment.

**Agronomic practices**
- Reliable fertility-, insect-, and disease-management practices.
- Crop rotation.
- Uniform crop stands.

**Weed identification and mapping**
- Scouting and mapping problem areas in fields.
- Identifying weed species, densities, and noting location changes from year to year.

**Herbicide selection**
- Selecting herbicides that provide optimal control of critical weed species.
- Rotating herbicides that control weeds at different sites of action.

**Herbicide application**
- Calibrating and maintaining application equipment to apply herbicides at optimal rates.
- Proper application timing of pre- and post-emergent herbicides with respect to both weed and crop growth stages.

## Herbicide Control

Effective herbicide programs are an integral component of the entire production enterprise and should be compatible with the entire cropping system. Well-developed programs are compatible with unique soils, tillage systems, weed problems, crops, and crop use. Herbicide selections should be based on the scope and magnitude of weed problems and on the potential return

**Table 10.2. Management to minimize the herbicide resistance of weeds**

- Scout fields for resistant weeds.
- Rotate herbicides by
  - mode of action,
  - active ingredient.
- Use tillage or cultivation for control when weeds are excessive.

*(Hager and Retsell 2008)*

**Table 10.3. Relative competitiveness of common South Dakota weeds**
Yield loss due to weeds varies by species, weed density, and time of emergence. Weeds that emerge early tend to cause more yield loss than those that emerge after crop establishment. All weeds have the potential to cause 100% yield loss; however, some are relatively more competitive with corn than others. This table gives a relative rating of different weed species and their ability to cause a measurable (usually 5%) yield loss.

| | | | |
|---|---|---|---|
| **Highly competitive weeds** (1 or fewer plants per foot of row result in yield loss.) | | | |
| Common cocklebur | Common sunflower | Common waterhemp | Giant ragweed |
| **Moderately competitive weeds** (5 to 10 plants needed per foot of row to result in yield loss.) | | | |
| Canada thistle | Field bindweed | Switch grass | Velvetleaf |
| Hedge bindweed | Horseweed | Volunteer corn | Giant foxtail |
| Common lambsquarters | Woolly cupgrass | Redroot pigweed | Russian thistle |
| Kochia | Wild proso millet | | |
| **Low competitive weeds** (>10 needed per foot of row to result in yield loss.) | | | |
| Wild buckwheat | Green foxtail | Yellow foxtail | Longspine sandbur |
| Large crabgrass | Witchgrass | Venice mallow | Barnyardgrass |

on investment. Always read and follow product label instructions before tank mixing and application. Add adjuvants at the correct rate and only if recommended on the label. Make sure the sprayer is calibrated so that proper amounts of herbicide are applied. Application at optimal crop and weed growth stages decreases the chances of crop injury and increases product effectiveness and yield potential.

Some herbicide products require incorporation for optimal performance. Herbicides are typically incorporated with some type of tillage, such as disking. A good "rule of thumb" is that a product will be incorporated about half the depth of the tillage. For example, disking at 4 inches incorporates the product 2-inches deep.

A disadvantage of herbicidal weed control is that weeds may become tolerant or resistant to a herbicide that is used continuously. Many producers have been relying on glyphosate-resistant (e.g., RoundupTM) genetics for the basis of their weed control. In 2005, over 73% of South Dakota corn acreage had a glyphosate product applied. The reliance on a single herbicide may result in unwanted and unexpected consequences, such as weed species shifts or herbicide resistance.

Herbicide-resistant weed populations can occur when a single herbicide or multiple herbicides with the same mode of action are used repeatedly over several years. In several Midwestern states, ryegrass, Johnsongrass, common waterhemp, horseweed, and common and giant ragweed have been identified as glyphosate resistant. In addition, densities of tolerant weeds (e.g., those that were never well-controlled with the herbicide) may increase.

Glyphosate-tolerant weeds in South Dakota and surrounding areas include velvetleaf, wild buckwheat, field bindweed, kochia, and Asiatic dayflower. Herbicide resistance and tolerance reduces weed control, leaves the producer with uncontrolled weeds, and may increase costs. In addition, across the United States more than 55 weed species have been documented to be resistant to several commonly used herbicides (including triazines; sulfonylureas and imidiaziliones; and 2,4-D). Resistance to these herbicides has been observed in pigweeds, kochia, and foxtails. Herbicide resistance can reduce 1) the efficacy of herbicides at high rates or 2) the efficacy of other herbicide products with a similar mode of action. The type of weeds in a field should be considered when developing a management plan. Herbicide programs in fields with a large percentage of glyphosate-tolerant plants should include alternative herbicide chemistries.

## Scout and Map Fields to Identify Weed Species, Densities, and Location Changes

Effective field scouting includes identifying weed species and mapping problem areas. Maps can be drawn from scouting activities and can be used to identify species shifts and to assess weed control effectiveness. Scouting also helps determine if shifts in species or changes in control with a herbicide have occurred. This is valuable information for future weed management decisions. Information on mapping can be found in Clay et al. (1999).

Weed management options depend on tillage, corn genetics, and crop rotation. For example, mechanical control is not an option in a no-till system. For no-till corn, some important considerations include the following:

- Consider a burndown application prior to or at planting. Winter annuals such as horseweed and mustards are more difficult to control after they are >6-inches tall.
- For moderate to heavy weed infestations, consider tank mixing a soil-residual herbicide in the burndown application.
- If treating with a foliar-contact herbicide (such as glyphosate products), do not treat too early; the weeds must emerge for effective control.
- Do not apply the herbicide too late, as weeds may cause yield loss as early as the V2 stage. Large weeds are often more difficult to control than small weeds.
- Continue to scout the fields, and use a second application if needed. Some herbicides have no residual activity.
- If environmental conditions are favorable, a second weed flush can occur. Fields treated with herbicides that have residual activity are less likely to have multiple flushes.

In tilled systems, disking and cultivation can be effective weed control strategies. Rotary hoes can be effective to control small weeds in corn up to about the V2 growth stage. Keep inter-row cultivation as shallow as possible to reduce weed seed germination and soil water loss. The total amount of herbicide applied can be reduced by band applying the herbicides in-row and by relying on cultivation for inter-row weed control.

Biocontrol has not been shown to be an effective weed control strategy in corn, but biocontrol may be an option in adjacent non-cropped areas to reduce seed load. The South Dakota Department of Agriculture administers a program that provides assistance for the biocontrol of Canada thistle, leafy spurge, spotted knapweed, purple loosestrife, and musk thistle (http://www.state.sd.us/doa/das/hp-w&p.htm). Documenting the effectiveness of biocontrol efforts is important for future decisions. The success rates of biocontrol efforts are currently inconsistent. If biocontrol is ineffective, alternative control efforts are recommended.

## Use Appropriate Cultural Practices

Good cultural practices can be used to reduce weed problems. For example, split or band fertilizer applications reduce weed growth. Planting when soil is warm results in rapid germination and canopy development. Planting narrow rows (e.g., 22") increases competition and canopy cover.

Cultivation is an option for curtailing weeds between rows. Rotary hoes work well for weed control between germination and emergence. In no-till systems, the importance of chemical control is increased because cultivation is not a viable option. When using Roundup (glyphosate) Ready™ seed in no-till systems, it is important to do the following:

- Consider a burndown application.
- Avoid early applications of glyphosate products (weeds must emerge for effective control).
- Avoid late applications of glyphosate products (the critical weed-free period for corn begins at V2, and early emerging weeds reduce yields).
- Continue field scouting, and use a second application if needed (the critical weed-free period ends between V6 and V8).

## Sprayer Calibration and Maintenance

Applying herbicides at labeled rates is the legal obligation of the applicator. Well-maintained application equipment that applies treatments at the prescribed rate can optimize control and reduce under- or over-application. An investment of time and money for the replacement of worn or faulty parts can be minimal compared to the loss of product or crop yield. Equipment calibration is outlined in FS933, "Calibration of Pesticide Spraying Equipment" (Wilson 2006), which is available either from your county Extension educator or online at http://agbiopubs.sdstate.edu.

Anyone who applies pesticides (including herbicides) to an agricultural commodity that has a value greater than $1,000 is required to be a certified applicator (SDCL § 38-21-38). There are 2 classes of certification: private and commercial. Contact your local Extension educator or the South Dakota Department of Agriculture for more information on certification.

Certified applicators that handle and apply any pesticide are required by rule to have a written "pesticide handling and discharge response plan." A template for developing this plan is available from your local Extension educator or from the South Dakota Department of Agriculture at http://www.state.sd.us/doa/das/hp-pest.htm#handling. The plan can serve as a reference for action in the event of an emergency.

Herbicides are a regulated material and must be stored, handled, and applied in compliance with federal and state law. Some general safety suggestions are presented in Table 10.4. Questions regarding regulatory compliance should be directed to the South Dakota Department of Agriculture, Office of Agronomy Services, at (605) 773-4432.

**Table 10.4. Safety tips for the transport, storage, and mixing of herbicides**

**Transport**

- Place small containers (2.5 gal. or less) in watertight totes.
- Insure that loads do not exceed weight limits of trailers.
- Tie down tanks with load straps strong enough to secure the load.
- Avoid transportation on vehicles or trailers where the load can cause a rollover.

**Storage**

- Store herbicides away from sensitive areas such as wells, populated buildings, animal feed, and so on.
- Avoid storing herbicides in unheated storage over the winter – freezing may break containers or compromise the integrity of the product.
- Avoid storing or transporting near direct heat (e.g., furnaces or exhaust).
- Triple rinse containers, store in appropriate locations, and dispose as labels direct.
- Lock doors to avoid accidental opening or vandalism.

**Usage**

- Use secure hoses, containers, and pumps.
- Lock valves to avoid accidental opening or vandalism.
- Load and mix herbicides 150 feet from wells, lakes, or wetlands.
- Have an anti-back-siphon device when filling equipment.

## Recordkeeping

The 1990 Farm Bill initiated the Pesticide Recordkeeping Program (PRP) and requires certified private applicators to keep records of all applications of federally registered restricted-use pesticides (RUP). Essentially, producers are required to record what RUP was used, and when, where, and to what crop it was applied. Instructions and recordkeeping forms are available by contacting county Extension educators, the South Dakota Department of Agriculture, or online from the USDA–Agricultural Marketing Service at http://www.ams.usda.gov/science/prb/Prbforms.htm. More information is provided in Chapter 13 ("Recordkeeping") of this publication.

## Weed Identification: South Dakota Weeds of Importance

Weed control practices rely on the accurate identification of weeds. The weeds presented here (the images primarily are of seedlings and small plants) are common in many corn fields. Small weeds are controlled more easily with herbicides or tillage than larger weeds. Seedlings may be more difficult to identify than small plants. Rotation of crops, rotation of chemicals, and rotation of control methods are recommended to minimize weed problems.

**Volunteer corn (*Zea mays*)**

**Time of emergence:** Typically emerges early—before or just after planting—depending on soil temperature and moisture conditions.

**Life cycle and reproduction:** Annual, reproducing from seed lost during or before harvest.

**Areas of infestation:** Typically occurs in localized areas (fig 10.1). Can be problematic in corn monoculture systems or when a herbicide-resistant variety was planted the previous year.

**Yield loss potential:** Volunteer corn may cause yield losses up to 15%.

**Effective management:** Use techniques that minimize harvest loss discussed in Chapter 11 ("Corn Grain Harvest"). If a glyphosate-tolerant variety was planted, rotate to a broadleaf crop and use a grass herbicide or cultivate inter-row areas.

**Herbicide resistance:** Resistance depends on the transgenic traits of the hybrid from which the volunteers originated. Volunteers originating from hybrids resistant to glyphosate (Roundup Ready® varieties), glufosinate (LibertyLink® varieties), or sethoxydim will also be resistant to these herbicides.

**Figure 10.1. Volunteer corn**

*(Photo courtesy of Mike Moechnig, South Dakota State University)*

**Woolly cupgrass (*Eriochloa villosa*)**

**Time of emergence:** When soil temperatures are favorable, woolly cupgrass emerges before or just at planting. Germination season is short (all seedlings emerge within 2 weeks after initial emergence).

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.2)**:** The cotyledon and the first true leaf are very wide. Leaves are covered in fine, soft hair (hence the name "woolly"), and one of the leaf margins generally is crinkled. This plant is often confused with foxtails but typically does not tiller as much as a foxtail plant. The seed head is a distinctive panicle with compressed rows of seed. The seeds are oval and vary in color from tan to brown to green.

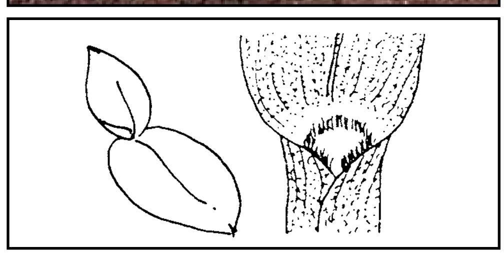
**Areas of infestation:** Found in fertile loam to clay loam soils.

**Yield loss potential:** Moderately competitive, especially plants that emerge early in the season.

**Effective management:** Typically not controlled by pre-emergence grass herbicides in the acetanilide family, though early suppression may be seen.

**Herbicide resistance:** None has been reported.

**Figure 10.2. Woolly cupgrass**



*(Photo courtesy of Weed Science Society of America. Illustration courtesy of Iowa State University)*

**Longspine sandbur (*Cenchrus longispinus*)**

**Time of emergence:** Non-native warm-season grass, emerging after planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.3)**:** Sandbur has stems that are flattened with hairs and leaves that may be rough to the touch. The plant has a short, fringed, and hairy ligule. Seeds are enclosed in sharp, spiny, hairy burs that give the plant its name.

**Areas of infestation:** Found in sandy soils, though may be found in fertile loam to clay loam soils.

**Yield loss potential:** Yield loss is often low. Its sharp spurs make it a nuisance plant.

**Effective management:** Tillage is effective when sandbur is small. Competition with shading reduces growth. Chemical control is often effective.

**Herbicide resistance:** None has been reported.

**Barnyardgrass (*Echinochloa crus-galli*)**

**Time of emergence:** Warm-season grass, emerging late in the season after planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.4)**:** This warm-season grass has flattened, smooth, and branched stems without an auricle or ligule. This grass has broad leaves and typically is reddish or purple at the base of the plant. Barnyardgrass size can vary from 2-inches tall with only one tiller, to over 4-feet tall with 50+ tillers. Larger plants are found around field edges or in areas with poor canopy cover.

**Areas of infestation:** Found in wetter areas.

**Yield loss potential:** Yield loss is often low.

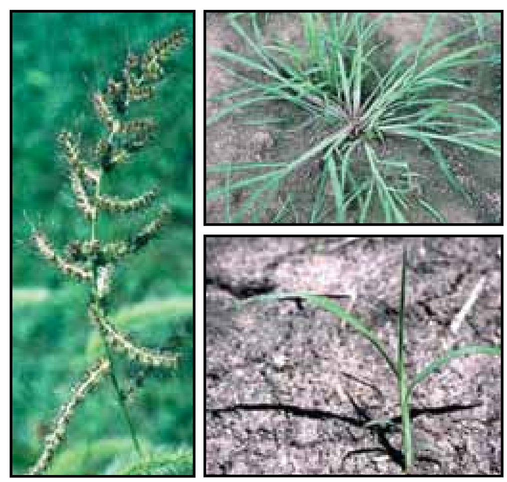
**Effective management:** Tillage is effective when plants are small. Shade under a crop canopy reduces growth. Chemical control is often effective.

**Herbicide resistance:** Biotypes resistant to photosynthetic inhibitors (e.g., atrazine), lipid synthesis inhibitors (e.g., sethoxydim), and other chemicals.

**Figure 10.3. Longspine sandbur**

*(Photos courtesy of California Department of Food and Agriculture)*

**Figure 10.4. Barnyardgrass**



*(Photos courtesy of Pacific Northwest Weed Handbook)*

**Wild proso millet (*Panicum miliaceum*)**

**Time of emergence:** Typically late in the season, after corn planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.5)**:** This warm-season grass has a round stem with a membranous ligule tipped with a fringe of hair. Seedlings look like corn but are hairy. Leaf blades are flat. Hairs may or may not be on the blade and sheath, but hairs are present at nodes. This grass can grow up to 6-feet tall. Seeds are large, shiny, and white, green striped, olive-brown, or black, and often remain on the root of seedlings, which helps in identification. Non-black seeds are usually not viable after two seasons; black seeds can remain viable for up to 4 years.

**Areas of infestation:** Tolerates sandy, dry soils and high temperatures.

**Yield loss potential:** Yield loss is moderate to high.

**Effective management:** Tillage is effective when plants are small. Shading by the crop canopy reduces growth. Chemical control often is effective. Sanitation of equipment is suggested to prevent spread.

**Herbicide resistance:** None noted at this time.

**Figure 10.5. Wild proso millet**

*(Photos courtesy of Steve Dewey, Utah State University)*

**Giant foxtail (*Setaria faberi*), Yellow foxtail (*S. pumila*), and Green foxtail (*S. viridis*)**

**Time of emergence:** Giant foxtail emerges just before or at corn planting. Yellow and green foxtails emerge toward the end of planting.

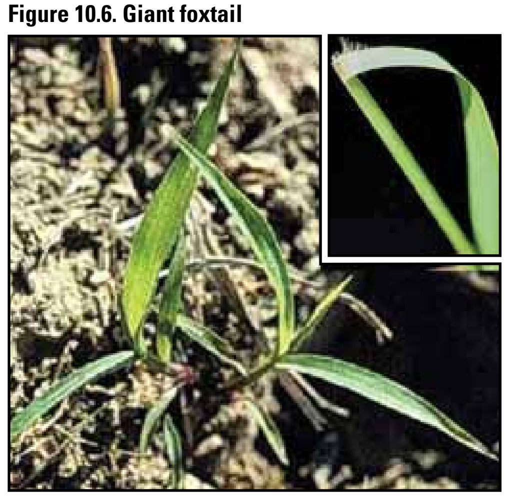
**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (figs. 10.6, 10.7)**:** Giant foxtail is infrequently found in South Dakota. Soft, short hairs are found on the leaf blade, and the plant has a hairy ligule. Plants can grow up to 7-feet tall. Yellow and green foxtails infest most eastern South Dakota fields. Yellow foxtail has long yellow hairs near the ligule, a flattened stem, and large seeds. Green foxtail has no or few hairs on the leaf blade, a round stem, and its seeds are small.

**Areas of infestation:** Common in several soil types and in many climates.

**Yield loss potential:** Depending on density, corn yield losses can approach 50%. The potential for yield loss is greater with giant foxtail compared to yellow or green foxtail at similar densities.

**Figure 10.6. Giant foxtail**



*(Photos courtesy of Weed Science Society of America)*

**Effective management:** Tillage, crop rotation, and post-emergence cultivation are effective control measures.

**Herbicide resistance:** Biotypes of these foxtails have shown resistance to a number of herbicides with different modes of action. Giant foxtail has been reported to be resistant to photosynthetic inhibitors (atrazine), ALS inhibitors (sulfonylureas and imidiazilinones), and lipid inhibitors (sethoxydim). Yellow foxtail has been reported to be resistant to ALS and photosynthetic inhibitor herbicides. Green foxtail has been reported to be resistant to dinitroanailine (trifluralin), ALS, lipid synthesis inhibitors, and photosynthetic inhibitors. Yellow foxtail is more tolerant to atrazine than are giant or green foxtail.

**Large crabgrass (*Digitaria sanguinalis*)**

**Time of emergence:** This warm-season grass emerges after corn emergence.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.8)**:** Hairs found everywhere on plant, and it has a flattened stem. Membranous ligule and seedhead finger-like spikes. This grass can grow from 6-inches to 2-feet tall.

**Areas of infestation:** No specific growing requirements.

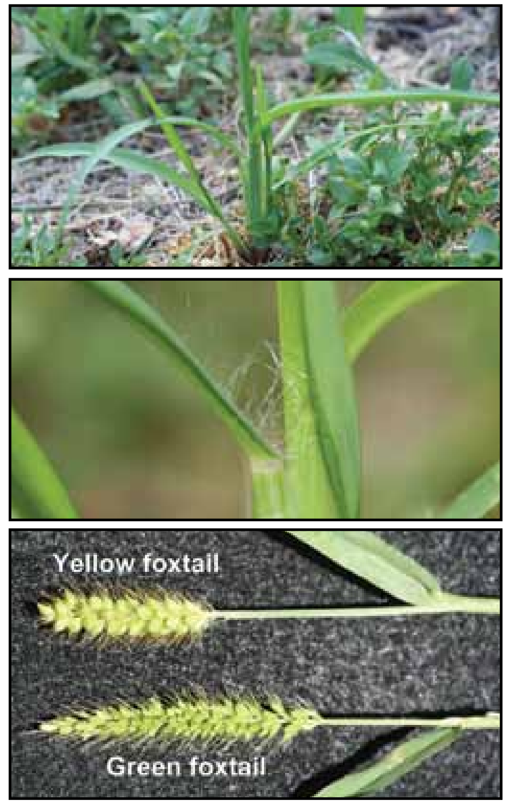
**Yield loss potential:** Low, even at high densities.

**Effective management:** Tillage, crop rotation, and post-emergence cultivation may be effective management tools.

**Herbicide resistance:** Herbicide resistance has been reported to lipid synthesis inhibitors (e.g., sethoxydim) in Wisconsin.

*(Photo courtesy of Pacific Northwest Weed Handbook)*

**Figure 10.7. Yellow foxtail**




*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Figure 10.8. Large crabgrass**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Witchgrass (*Panicum capillare*)**

**Time of emergence:** This warm-season grass emerges after corn emergence.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.9)**:** Witchgrass has a flat stem and long, soft hairs covering most of the plant. The ligule is a fringe of hair. Panicles are an open inflorescence, spreading, hairy, and large. When mature, the panicle can break off and tumble along the ground.

**Areas of infestation:** Grows well in sandy, droughty soil.

**Yield loss potential:** Low, even at high densities.

**Effective management:** Tillage, crop rotation, and post-emergence cultivation can be effective control measures.

**Herbicide resistance:** A biotype of witchgrass that is resistant to photosynthetic-inhibitor herbicides (e.g., atrazine) has been reported in Canada.

**Switchgrass (*Panicum virgatum*)**

**Time of emergence:** This warm-season grass emerges late in the season, after corn has emerged.

**Life cycle and reproduction:** This perennial reproduces by rhizomes and seed, often escaping waterways or other areas. Vegetative stems are sometimes confused with witchgrass.

**Distinguishing characteristics** (fig. 10.10)**:** There is a V-shaped patch of hair on the upper leaf surface near the stem. Plants can grow up to 6-feet tall. Switchgrass is grown in stands for biofuel, but escaped plants can be problematic.

**Areas of infestation:** Switchgrass grows well in sandy or droughty soil types.

**Yield loss potential:** Moderate.

**Effective management:** Pre-emergence grass herbicides other than atrazine.

**Herbicide resistance:** Escaped plants can be difficult to control. Tolerant of atrazine.

**Figure 10.9. Witchgrass**

*(Photo courtesy of Weed Science Society of America)*

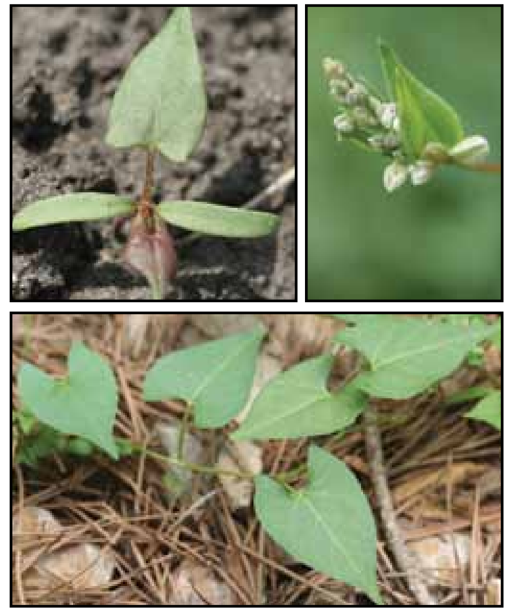
**Figure 10.10. Switchgrass**

*(Photo courtesy of Texas A&M University)*

**Wild buckwheat (*Polygonum convolvulus*)**

**Time of emergence**: Typically early (before or just at corn planting). Late flushes may occur, depending on soil temperature and moisture conditions.
**Life cycle and reproduction:** This annual vining broadleaf reproduces from seed.
**Distinguishing characteristics** (fig. 10.11)**:** An ocrea (white to brown sheath) is located at the base of the leaf on the stem. This plant is often confused with the perennial field bindweed and is known as black bindweed in other regions. Triangular seeds, the ocrea, very small flowers, leaf shape, and root structure help distinguish wild buckwheat from field bindweed.
**Areas of infestation:** Wet areas of fields.
**Yield loss potential:** Yield losses can be as high as 30%. However, low densities may not reduce corn yield. The vines, which twine up corn stalks, can become tangled in harvest equipment. If mixed with corn grain, the high water content of wild buckwheat seeds may cause spoilage.
**Effective management:** Bromoxynil, atrazine, dicamba, clopyralid, and some sulfonylurea-type herbicides can be used for control. Tillage, crop rotation, and post-emergence cultivation may be management tools.
**Herbicide resistance:** No resistance reported but is difficult to control with glyphosate and 2,4-D. The tolerance to glyphosate makes wild buckwheat a problem even in glyphosate-resistant corn hybrids.

**Figure 10.11. Wild buckwheat**

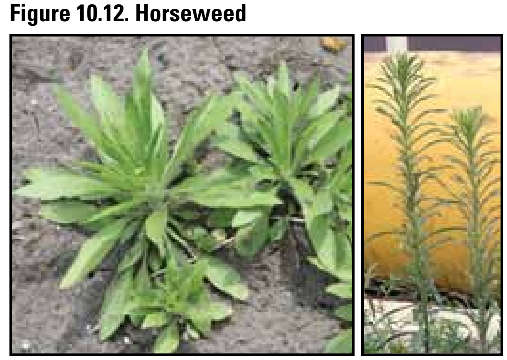


*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Horseweed (*Conzya canadensis*)**

**Time of emergence:** Horseweed may overwinter as a rosette and bolt in the spring or emerge in the spring at or before planting.
**Life cycle and reproduction:** This winter or summer annual reproduces from seed.
**Distinguishing characteristics** (fig. 10.12)**:** The plant has numerous linear, hairy (although some plants have few or no hairs) leaves crowded on the stem. The flowers are very small and are generally white.
**Areas of infestation:** Tolerates drought conditions well.
**Yield loss potential:** Historically, this weed has seldom been dense enough to warrant control. However, high densities in soybean have led to >80% yield loss.
**Effective management:** For control of overwintering populations, auxin-type (e.g., 2,4-D) herbicides in a burndown pre-plant application have been effective. In cases where resistance biotypes are a problem, select an appropriate herbicide or tillage, crop rotation, and post-emergence cultivation.
**Herbicide resistance:** Biotypes resistant to photosynthetic inhibitors (atrazine), glyphosate, amino acid synthesis inhibitors (ALS inhibitors), and paraquat have been observed. Resistance to glyphosate, triazine, and paraquat has been reported in several states (i.e., Indiana and Ohio). Rotating herbicides or using other control methods is necessary to minimize the risk of developing further herbicide-resistant biotypes of horseweed.

**Figure 10.12. Horseweed**



*(Photos courtesy of Mike Moechnig, South Dakota State University and Weed Science Society of America)*

**Common sunflower** (***Helianthus annuus***)

**Time of emergence:** Common sunflower emerges at or just before planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.13)**:** Cotyledons are oval with toothed margins on alternating leaves. Stems become multi-branched, covered with stiff hairs as the plant matures. Has characteristic yellow flowers.

**Areas of infestation:** Typically occurs in drier soils.

**Yield loss potential:** At moderate densities, can reduce corn yields 70%.

**Effective management:** Many different herbicides can be used for common sunflower control. Tillage, crop rotation, and post-emergence cultivation should also be considered.

**Herbicide resistance:** Some biotypes of common sunflower have been reported to be resistant to amino acid synthesis inhibitor (ALS inhibitor) herbicides.

**Figure 10.13. Common sunflower**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Common cocklebur** (***Xanthium strumarium***)

**Time of emergence:** This weed typically emerges after planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.14)**:** Cotyledons of the seedling are linear, thick, and shiny green. Leaves are alternate and large with wavy margins. Seeds are in burs that stick to animal coats.

**Areas of infestation:** Typically occurs in wet areas.

**Yield loss potential:** Highly competitive with corn, causing up to 70% yield reductions at high density.

**Effective management:** Several herbicides are available for control of common cocklebur. Tillage, crop rotation, and post-emergence cultivation may also be effective measures for stand reduction.

**Herbicide resistance:** Biotypes of cocklebur have been reported to be resistant to amino acid synthesis inhibitor (ALS inhibitor) herbicides in some Midwestern states.

**Figure 10.14. Common cocklebur**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

## Russian thistle (*Salsola iberica*)

**Time of emergence:** Typically emerges before or at planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.15): Seedlings resemble small pine trees with threadlike leaves. Older plants become spine-like, with the leaf surface from smooth to hairy with non-showy flowers. The entire plant breaks off at the base and disperses seed as it tumbles in the wind.

**Areas of infestation:** A very drought- and salt-tolerant plant, it can be found in many areas.

**Yield loss potential:** Up to 60% corn yield reductions have been reported, depending on density.

**Effective management:** Pre-emergent herbicides give excellent control. Post-emergent herbicides work best on very young plants. However, little or no control is achieved after the plant becomes spiny. Prevention and cultural control should be implemented in addition to herbicide management.

**Herbicide resistance:** Biotypes in other states have been reported to be resistant to amino acid synthesis inhibitor (ALS inhibitor) herbicides.

**Figure 10.15. Russian thistle**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

## Redroot pigweed (*Amaranthus retroflexus*)

**Time of emergence:** Typically emerges at or during corn planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.16): Cotyledons are thin and linear. Leaves are lance-like with alternate arrangement. The lower surface is hairy. Stems are stout and the lower portion is reddish (hence the name "redroot"). Seeds are black, shiny, and numerous. Large plants can produce over 800,000 seeds. Plants may hybridize with other *Amaranthus* species.

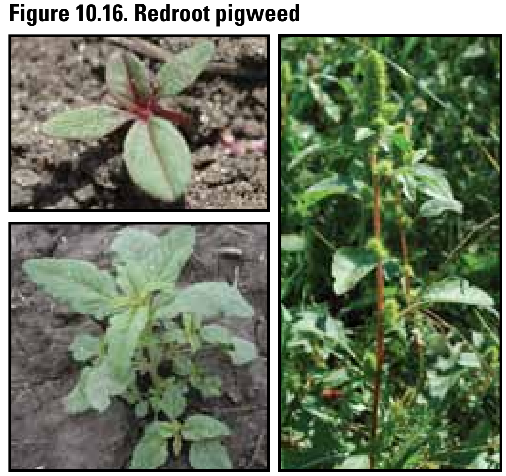
**Areas of infestation:** Disturbed areas, usually with high fertility.

**Yield loss potential:** Up to 55% corn yield reductions reported, depending on density.

**Effective management:** Many different herbicides can be used for redroot pigweed control, though care must be taken because some resistant biotypes have been reported in other states. An integrated program combining cultivation and appropriate herbicides should facilitate effective redroot pigweed control.

**Herbicide resistance:** Biotypes of redroot pigweed in other states have been shown to be resistant to triazine and amino acid synthesis inhibitor (ALS inhibitor) herbicides.

**Figure 10.16. Redroot pigweed**



*(Photos courtesy of Mike Moechnig and Kurtis D. Reitsma, South Dakota State University)*

**Common waterhemp (*Amaranthus rudis*)**

**Time of emergence:** Typically emerges late in the season after corn emergence.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.17)**:** The first true leaves of seedlings are more lance-like than the oval leaves seen on redroot pigweed. Leaf surfaces are not hairy. This species has male and female plants. The inflorescence of the female plant is more highly branched than that of the redroot pigweed. The female waterhemp has been reported to produce over 1 million shiny black seeds.

**Areas of infestation:** Disturbed areas with high fertility.

**Yield loss potential:** Up to 55% corn yield reductions reported, depending on density.

**Effective management:** Common waterhemp is difficult to control and is often seen after layby operations. Some resistant biotypes have been reported in other states. Prevention and cultural control should be implemented in addition to chemical management.

**Herbicide resistance:** Biotypes of this plant have been reported to be resistant to amino acid synthesis inhibitor (ALS inhibitor) herbicides, PS II inhibitors (not used in corn production), glyphosate, and cell-membrane disruptor (PROTOX-inhibitor) herbicides.

**Figure 10.17. Common waterhemp**

*(Photos courtesy of Mike Moechnig and Kurtis D. Reitsma, South Dakota State University)*

**Common lambsquarters (*Chenopodium album*)**

**Time of emergence:** This weed typically emerges at or just before planting.

**Life cycle and reproduction:** Annual, reproducing from seed.

**Distinguishing characteristics** (fig. 10.18)**:** Emerging plants are very small. Leaves are opposite and are covered with a mealy powder, especially on the underside. The stems are erect, may have green or red stripes, and can grow to almost 6-feet tall under certain conditions. The flowers are nonshowy and without petals.

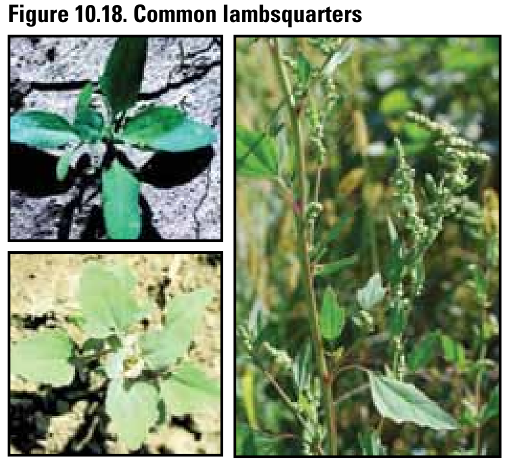
**Areas of infestation:** Found in disturbed sites.

**Yield loss potential:** Up to 40% corn yield reductions reported, depending on density.

**Effective management:** Pre-emergent broadleaf herbicides often give season-long control. Post-emergent herbicides work best on very young plants. This species is difficult to control if taller than 6 inches. Prevention and cultural control should be implemented in addition to herbicide application.

**Herbicide resistance:** Biotypes of this plant have been reported to be resistant to amino acid synthesis inhibitors (ALS inhibitors) and to photosynthesis inhibitors. Reduced sensitivity to glyphosate has been reported in some populations.

**Figure 10.18. Common lambsquarters**



*(Photos courtesy of Mike Moechnig and Kurtis D. Reitsma, South Dakota State University)*

**Kochia (*Kochia scoparia*)**

**Time of emergence:** Emerges at or before planting.
**Life cycle and reproduction:** Annual, reproducing from seed.
**Distinguishing characteristics** (fig. 10.19)**:** Seedlings can be very small—with over 1,000 present in a 1 $ft^2$ area. Leaf margins are fringed with hair. Leaf surfaces range from being without hairs to very hairy. Wind-blown plants will disburse seed in the fall.
**Areas of infestation:** Found in disturbed sites.
**Yield loss potential:** Yield losses of up to 40% have been reported.
**Effective management:** Pre-emergent broadleaf herbicides may provide season-long control. Post-emergent herbicides work best on very young plants. This species is difficult to control if taller than 6 inches. Prevention and cultural control should be implemented in addition to herbicide management.
**Herbicide resistance:** Some kochia biotypes are resistant to atrazine, amino acid synthesis inhibitor (ALS inhibitor) herbicides, and growth-regulator (i.e., auxin) herbicides.

**Figure 10.19. Kochia**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Canada thistle (*Cirsium arvense*)**

**Time of emergence:** Typically emerges before or just at planting.
**Life cycle and reproduction:** This perennial has deep and extensive root systems. It spreads by seeds or pieces of root transported from one location to another.
**Distinguishing characteristics** (fig. 10.20)**:** Leaves have crinkled edges and spiny margins, somewhat lobed and hairless. Stems may be hairy, especially when mature. Plants are diecious (males and females are distinct). Pink to purple flowers are numerous and compact at the top of the plant.
**Areas of infestation:** Found in disturbed sites
**Yield loss potential:** Up to a 40% corn yield reductions have been reported.
**Effective management:** Herbicides can control seedlings, but older plants should be treated with herbicides when in the bud stage or in the fall after the first frost.
**Herbicide resistance:** Biotypes of Canada thistle have been reported to be resistant to growth-regulator (auxin-type) herbicides.

**Figure 10.20. Canada thistle**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Field bindweed (*Convolvulus arvensis*)**

**Time of emergence:** Late spring to early summer.
**Life cycle and reproduction:** Perennial, can grow from rhizomes or seed.
**Distinguishing characteristics** (fig. 10.21)**:** Leaves are arrow-shaped on a twining stem. The root system can be extensive and deep rooted. Flowers are white to pink and bell or trumpet shaped.
**Areas of infestation:** Grows well in dry soils.
**Yield loss potential:** Can reduce yields 50%. Vining nature of the plant can cause problems with harvest equipment.
**Effective management:** Combination of herbicides and competitive crops.
**Herbicide resistance:** This plant is tolerant of glyphosate. Biotypes have been reported resistant to growth-regulator (auxin-type) herbicides.

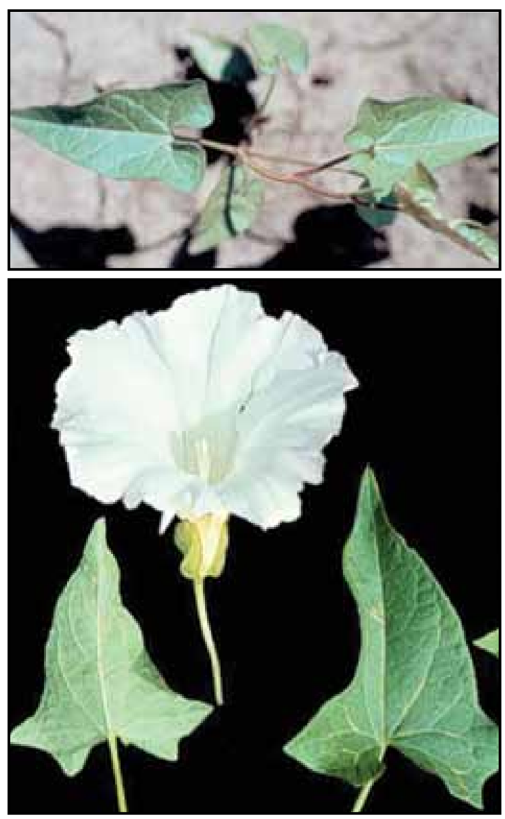
**Hedge bindweed (*Calystegia sepium*)**

**Time of emergence:** Typically emerges before or at corn planting.
**Life cycle and reproduction:** Perennial vining plant, reproducing from seed and rhizomes. It can be confused with field bindweed.
**Distinguishing characteristics** (fig. 10.22)**:** Leaves have a long petiole and have a pointed tip. The flowers are large, funnel shaped, and white to pink in color.
**Areas of infestation:** Found in disturbed sites.
**Yield loss potential:** This plant is not as aggressive as field bindweed, though the vines may cause problems during harvest.
**Effective management:** Prevention and cultural control should be implemented in addition to herbicide application.
**Herbicide resistance:** To date, herbicide resistance has not been reported.

**Figure 10.21. Field bindweed**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Figure 10.22. Hedge bindweed**



*(Photos courtesy of Weed Science Society of America)*

## Herbicide Damage in Corn

Herbicides can cause predictable symptoms to plants. The purpose of this section is to show symptoms and discuss the mode of action of commonly used herbicides.

**Growth-Regulator Herbicides**

**A. Phenoxy acids**

**Example:** 2,4-D

**Mode of action:** Acts as a synthetic auxin, disrupting nucleic acid metabolism and protein synthesis, which ultimately leads to plant death.

**Appearance of symptoms** (fig. 10.23)**:** Symptoms appear within hours of application on sensitive species.

| Injury symptoms | Injury cause |
|---|---|
| Rolled leaves.<br>Fused brace roots.<br>Stalk bending and brittleness.<br>Missing kernels on ear. | Applied to rapidly growing corn.<br><br>Applied too late in growing season. |

**Figure 10.23. Onion leafing due to 2,4-D**

*(Photo courtesy of Leon Wrage, South Dakota State University)*

**B. Benzoic acids**

**Example:** dicamba (Banvel®)

**Mode of action:** Acts as a synthetic auxin. See 2,4-D above.

**Appearance of symptoms** (fig. 10.24)**:** First appearance of symptoms can come within hours after application on sensitive species.

| Injury symptoms | Injury cause |
|---|---|
| Same as 2,4-D, but may occur at lower application rates than 2,4-D. | Variable hybrid sensitivity.<br>Applied during sensitive growth stage of corn. |

**Figure 10.24. Root pruning due to dicamba (Banvel®)**

*(Photo courtesy of Leon Wrage, South Dakota State University)*

**Lipid Synthesis Inhibitor Herbicides**

**A. Cyclohexanediones**

**Example:** sethoxydim (Poast®)

**Mode of action:** Inhibits the formation of lipids used for membrane development and stops growth of new tissue.

**Appearance of symptoms** (fig. 10.25)**:** Symptoms may first appear 2 to 4 days after treatment. The death of the plant is slow.

| Injury symptoms | Injury cause |
|---|---|
| Yellowing or reddening of new leaves.<br>Stunting of plant.<br>Death of tissue and browning.<br>Growing point dies. | Misapplication.<br>Tank contamination. |

**Figure 10.25. Sethoxydim (Poast®) injury**

*(Photo courtesy of Leon Wrage, South Dakota State University)*

## Amino Acid Synthesis Inhibitor Herbicides

**A. Amino acid derivatives**

**Example:** glyphosate (Roundup®)

**Mode of action:** Amino acid synthesis inhibitor; stops synthesis of aromatic amino acids (those that contain a phenyl ring).

**Appearance of symptoms** (fig. 10.26)**:** Symptoms appear within 3 to 10 days after treatment. Environmental conditions that slow growth (e.g., extreme heat, cold, or drought) reduce the effects of glyphosate. May look like P deficiency, except purpling is first seen on the older leaves.

| Injury symptoms | Injury cause |
|---|---|
| Yellow then brown foliage.<br>Growing point dies.<br>Purpling of foliage. | Misapplied to non-tolerant corn.<br>Tank contamination. |

**Figure 10.26. Glyphosate (Roundup®) injury to non-tolerant corn**

*(Photo courtesy of Leon Wrage, South Dakota State University)*

**B. Phosphoric acid-type**

**Example:** glufosinate (Liberty®)

**Mode of action:** Stops the synthesis of the amino acid glutamine, resulting in buildup of toxic levels of ammonia in the leaves.

**Appearance of symptoms** (fig. 10.27)**:** Symptoms appear within 3 to 5 days after treatment

| Injury symptoms | Injury cause |
|---|---|
| Pale yellow or purple leaves.<br>Water-soaked lesions. | Misapplied to non-tolerant corn.<br>Applied too late in the season. |

**Figure 10.27. Glufosinate (Liberty®) injury to non-tolerant corn**

*(Photo courtesy of Mike Moechnig, South Dakota State University)*

**C. Sulfonylureas and imidiazalinones (ALS inhibitors)**

**Example:** primisulfuron (Beacon®)

**Mode of action:** Inhibits the formation of branched-chain amino acids.

**Appearance of symptoms** (fig. 10.28)**:** The growing point becomes yellow within 2 to 4 days after treatment. Plant death occurs within 7 to 10 days after treatment.

| Injury symptoms | Injury cause |
|---|---|
| Stunted plant, stunted internodes.<br>Yellow translucent leaves.<br>Death of growing point.<br>Bottlebrush roots. | Hybrid sensitivity.<br>Applied too late.<br>Tank contamination.<br>Applied to non-tolerant corn.<br>Corn ears have pinched appearance. |

**Figure 10.28. Primisulfuron (Beacon®) injury to corn**

Top: Bottle brush roots. Bottom: pinched ears.
*(Photos courtesy of Leon Wrage, South Dakota State University)*

## Pigment Inhibitor Herbicides

### A. Isoxazoles

**Example:** isoxaflutole (Balance®); mesotrione (Callisto®)
**Mode of action:** Inhibit enzymes in the carotenoid pigment pathway; these pigments protect chlorophyll from destruction.
**Appearance of symptoms** (fig. 10.29)**:** White areas on plants or albino plants appear during emergence.

| Injury symptoms | Injury cause |
|---|---|
| White tissue.<br>Poor emergence.<br>Stunted plants.<br>Growing point dies. | Applied on cool, wet, or sandy soils.<br>Carryover problem. |

## Cell-Membrane Disruptor Herbicides

### A. Bipyridiliums

**Example:** paraquat (Gramoxone®)
**Mode of action:** Destruction of cell membranes.
**Appearance of symptoms** (fig. 10.30)**:** Symptoms are often observed within hours. Contact herbicide symptoms primarily seen on treated leaves as speckling. Untreated and new leaves may not show symptoms.

| Injury symptoms | Injury cause |
|---|---|
| Limp leaves.<br>Water-soaked appearance (looks like frost damage).<br>Brown tissue in water-soaked areas. | Drift.<br>Tank contamination. |

### B. Aryl triazolinones (PROTOX inhibitors)

**Example:** carfentrazone (Aim®)
**Mode of action:** Inhibits the protoporphyrinogen oxidase, resulting in cell membrane destruction.
**Appearance of symptoms** (fig. 10.31)**:** Appearance of necrotic (dead tissue) speckling on leaves within a few days after exposure. Symptoms are most often observed during emergence or in seedling plants.

| Injury symptoms | Injury cause |
|---|---|
| Yellowing or reddening of new leaves.<br>Stunting of plant.<br>Death of tissue and browning.<br>Growing point dies. | Misapplication.<br>Tank contamination. |

**Figure 10.29. Isoxaflutole (Balance®) injury**

*(Photo courtesy of Iowa State University)*

**Figure 10.30. Paraquat (Gramoxone®) injury**

*(Photos courtesy of Mike Moechnig, South Dakota State University)*

**Figure 10.31. Carfentrazone (Aim®) injury**

Corn seedlings have chlorotic to white veins (tiger stripping), and the lower leaves may droop.
*(Photos courtesy of Mike Moechnig, South Dakota State University)*

## Photosynthetic Inhibitor Herbicides

### A. Triazines

**Example:** atrazine (Aatrex®)
**Mode of action:** Stops electron flow in photosynthesis.
**Appearance of symptoms** (fig. 10.32)**:** Symptoms are observed within a few days. If due to soil application, older leaves show the most damage. If applied to leaves, treated leaves and outer margins of treated leaves show the most damage.

| Injury symptoms | Injury cause |
|---|---|
| Yellow and brown leaves. Crop oil synergy if applied as a post emergence. | Cool wet conditions slowing corn growth. |

**Figure 10.32. Atrazine (Aatrex®) injury**

*(Photo courtesy of Iowa State University)*

### B. Benzonitriles

**Example:** bromoxynil (Buctril®)
**Mode of action:** Stops electron flow in photosynthesis.
**Appearance of symptoms** (fig. 10.33)**:** Symptoms are observed within a few hours. Contact-type herbicide-speckling of treated areas first observed.

| Injury symptoms | Injury cause |
|---|---|
| Yellow and brown leaves. | Crop oil with the post-emergence application. |

**Figure 10.33. Bromoxynil (Buctril®) injury**

*(Photo courtesy of Leon Wrage, South Dakota State University)*

## Seedling Growth Inhibitor Herbicides

### A. Dinitroanalines

**Example:** trifluralin (Treflan®); pendimethalin (Prowl®)
**Mode of action:** Inhibits the growth of roots or shoots of seedlings.
**Appearance of symptoms** (fig. 10.34)**:** Symptoms are apparent during or soon after plant emergence. Roots shortened with few fine root hairs.

| Injury symptoms | Injury cause |
|---|---|
| Stunted plants.<br>Roots short and thick. | Carryover.<br>Misapplication.<br>Over-application. |

**Figure 10.34. Root clubbing from pendimethalin (Prowl®)**

*(Photo courtesy of Leon Wrage, South Dakota State University)*

*Seedling Growth Inhibitor Herbicides continue on pg. 90*

Seedling Growth Inhibitor Herbicides continued

**B. Acetanilides**

**Example:** metolachlor (Dual®); acetochlor (Harness®)

**Mode of action:** Growth inhibitor that affects roots or shoots of seedlings.

**Appearance of symptoms** (fig. 10.35)**:** During or soon after plant emergence. Leaves do not unfurl.

| Injury symptoms | Injury cause |
|---|---|
| Poor emergence.<br>Stunted plants.<br>Leaf out underground before emergence. | Over-application.<br>Cool, wet soils. |

**Figure 10.35. Metolachlor (Dual®) injury**

*(Photo courtesy of Greg Stewart and Mike Cowbrough, Ontario Ministry of Agriculture and Food)*

**C. Thiocarbamates**

**Example:** EPTC + safener (Eradicane®); butylate + safener (Sutan®)

**Mode of action:** Inhibits the growth of roots or shoots of seedlings.

**Appearance of symptoms** (fig. 10.36)**:** Symptoms appear during or soon after plant emergence. Leaves show buggy whipping.

| Injury symptoms | Injury cause |
|---|---|
| Buggy whipping (leaf entrapment).<br>Stunted plants. | Over-application.<br>Cool, wet soils. |

**Figure 10.36. EPTC + safener (Eradicane®) injury**

*(Photos courtesy of Leon Wrage, South Dakota State University )*

## Documenting Suspected Herbicide Drift Damage

Herbicide drift to non-target plants can result in significant economic losses. Careful attention to application techniques can help minimize drift. At some point it may be necessary to document drift. The following guidance is provided to document losses:

- Record information related to the suspected problem.
  - Date, rate, and name of herbicide used.
  - When damage occurred/was noticed.
  - When adjacent fields were sprayed.
  - The crop in neighboring fields.
  - Herbicides used in neighboring fields (if possible).
  - Wind speed, application type, and speed of travel.
  - Cultural practices in the damaged field.
- Consider all possible causes of the injury.
  - Diseases, nutrients, herbicide carryover, growing conditions, and flooding.
  - Possible tank contamination.
  - Plant samples may need to be submitted to a disease or nutrient laboratory.
- Make a map of the area.
  - Include the legal land description of the field.
- Collect quality photographs.
  - Include tops, roots, and close-ups of affected portions.
- Estimate yield losses.
  - In many situations, it is not possible to calculate yield losses until 10 to 20 days after damage.
  - Visual estimation is not reliable.
  - Compare yields in damaged and undamaged areas during or just before harvest.
- Promptly contact all parties suspected of being involved.
  - Insurance companies may need to be contacted for inspections.
  - It may be necessary to file a complaint with the South Dakota Department of Agriculture.

## Additional Information and References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