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# Herbicide Mode of Action

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## Herbicide Effectiveness and Mode of Action

For effective weed control, herbicides must 1) adequately contact the weeds; 2) be absorbed by the weeds; 3) move within the weeds to the site of action, without being deactivated; and 4) reach toxic levels at the site of action. The application method used, whether preplant incorporated, preemergence, or postemergence, determines whether the herbicide will contact germinating seedlings, roots, shoots, or leaves of the weeds. The mode of action of the herbicide influences how the herbicide is applied. For example, contact herbicides that disrupt cell membranes, such as aciflurofen (Blazer or Tackle) or paraquat (Gramoxone Extra), need to be applied postemergence to leaf tissue in order to be effective. Seedling growth inhibitors, such as trifluralin (Treflan) and alachlor (Lasso), need to be applied to the soil in order to effectively control newly-germinated weed seedlings.

## Soil-Applied Herbicide Activity in Plants

Because the seeds of many weed species are quite small and germinate within 0.5 to 1.0 inch of the soil surface, it is important that soil-applied herbicides be positioned in the top 1 to 2 inches of soil to be effective. Herbicide positioning can be accomplished by mechanical incorporation or rainfall. Once an herbicide comes in contact with the plant, absorption through the roots or shoots is very important. An herbicide that is absorbed through the roots will be taken up as long as the herbicide-treated soil remains in contact with the absorbing region near the root tips. As the roots grow to greater soil depths, herbicide uptake declines. Therefore, weeds not killed before the root tips grow out of the herbicide-treated soil are likely to survive. Many soil-applied herbicides are absorbed through plant shoots while they are still underground and may kill or injure the shoots before they emerge from the soil. Volatile herbicides such as the thiocarbamates (e.g., EPTC [Eradicane]) and the dinitroanilines (e.g., trifluralin [Treflan]) can penetrate the shoot as gases. Less volatile herbicides such as the acetanilides (e.g., alachlor [Lasso]) are absorbed into the shoot as liquids. Physical and environmental factors that promote rapid crop emergence reduce the length of time that a plant is in contact with a soil-applied herbicide and, therefore, reduce the possibility of crop injury.

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Herbicides differ in their ability to move within a plant. The soil-applied herbicide chloramben (Amiben) and the dinitroaniline herbicides (e.g., trifluralin [Treflan]) are not mobile within the plant. Therefore, their injury symptoms are confined to the site of uptake. Other herbicides are mobile within the plant. For example, soil-applied atrazine is absorbed by plant roots and moves upward within the water transport system of the plant (i.e., xylem) to be concentrated in the leaves. In general, injury symptoms will be most prominent at the site where the mobile herbicides concentrate.

## Postemergence Herbicide Activity In Plants

Effective postemergence herbicide application depends upon adequate contact with above-ground plant shoots and leaves. Therefore, it is important to adjust spray pressure and volume for adequate plant coverage. Also, it is very important to use the proper nozzles. Hollow-cone or flat-fan nozzles are generally recommended. Read the herbicide label for details.

For postemergence herbicides, the chemical and physical relationships between the leaf surface and the herbicide often determine the rate and amount of uptake. Factors such as plant size and age, water stress, air temperature, relative humidity, and herbicide additives can influence the rate and amount of herbicide uptake. Additives such as crop oil concentrates, surfactants, or liquid fertilizer solutions (e.g., 28% UAN) can increase herbicide uptake by a plant. Application of herbicides under hot and dry conditions or application to older and larger weeds or weeds under water stress can decrease the amount of herbicide uptake. Differences in the rate and amount of herbicide uptake influence an herbicide's potential for crop injury and weed control and often explain the year to year variation in an herbicide's effectiveness. Also, the faster a herbicide is absorbed by a plant, the less likely it will be that rain will wash the herbicide off the plants.

Like soil-applied herbicides, postemergence herbicides differ in their ability to move within a plant. Nonmobile postemergence herbicides are called contact herbicides, and, for adequate weed control, they must thoroughly cover the plant. Contact herbicides include the bipyridylium, diphenylether, benzothiadiazole, and nitrile families. Other herbicides are mobile within the plant. Growth regulator herbicides such as 2,4-D and dicamba (Banvel) move both upward and downward within a plant's food transport system (i.e., the phloem) to the growing points of the shoots and roots. In general, injury symptoms will be most prominent at the sites at which the mobile herbicides concentrate.

## Herbicide Selectivity

Plants that can rapidly degrade or deactivate a herbicide can escape the herbicide's toxic effects. Corn is tolerant to the triazine herbicides because it quickly deactivates these herbicides by binding them to naturally occurring plant chemicals. Soybean tolerance to metribuzin (Sencor, Lexone) is at least partially due to the deactivation of the herbicide by its binding to plant sugar molecules.

Situations may occur in which a crop may be injured by a herbicide to which it is normally tolerant. This often occurs because environmental stresses such as hot or cold temperatures, high relative humidity, or hail decrease a plant's natural ability to reduce herbicide uptake or deactivate a herbicide. Postemergence cyanazine (Bladex) injury to corn under cold and wet weather conditions is a good example of environmentally-induced herbicide injury. An excessive application of herbicide, due to misapplication, can also injure a tolerant crop by overwhelming the crop's herbicide degradation and deactivation systems.

# Herbicide Families

An understanding of how herbicides kill weeds (i.e., herbicide mode of action) may be useful in selecting and applying the proper herbicide for a given weed control problem. Understanding herbicide mode of action is very useful in diagnosing herbicide injury complaints. Although a large number of herbicides are available in the marketplace, several have similar chemical properties and herbicidal activity. Herbicides with a common chemistry are grouped into "families." Herbicide families are a convenient way of organizing information about herbicides. In addition, two or more herbicide families may have the same mode of action within the plant and thus express the same herbicide activity and injury symptoms. The following paragraphs describe the characteristics of widely used herbicide families, grouped by their mode of action. These seven major modes of action are as follows: growth regulation, amino acid synthesis inhibition, lipid synthesis inhibition, seedling growth inhibition, photosynthesis inhibition, cell membrane destruction, and pigment inhibition.

## I. Growth Regulators

The growth regulators include the following herbicide families: **phenoxy acetic acids, benzoic acids, and the pyridines**. Growth regulator herbicides can act at multiple sites in a plant to disrupt hormone balance and protein synthesis and thereby cause a variety of plant growth abnormalities. Growth regulator herbicides selectively kill broadleaf weeds; however, they are capable of injuring grass crops. Most of the herbicides in this group can move in both the xylem and the phloem to areas of new plant growth. As a result, many herbicides in this group are effective on perennial and annual broadleaf weeds. Herbicide uptake is primarily through the foliage but root uptake is possible. Injury symptoms are most obvious on newly-developing leaves.

1. **Phenoxy Acetic Acids**
   a. **Use:**
      2,4-D for small grains, corn, pastures, and noncropland
      MCPA for small grains
      2,4-DB for alfalfa and soybeans
   b. **Injury Symptoms:**
      Broadleaf plants exhibit stem twisting (epinasty) and leaf malformations (cupping, crinkling, parallel veins, leaf strapping). Corn plants exhibit rolled leaves (onion-leafing), fused brace roots, stalk bending and brittleness, and missing kernels. Small grains exhibit sterile florets or multiple florets.

2. **Benzoic Acids**
   a. **Use:**
      Chloramben (Amiben) for soybeans, dry beans, and sunflowers.
      Dicamba (Banvel) for corn, wheat, oats, sorghum, pastures, and noncropland.
   b. **Injury Symptoms:**
      Banvel injury is similar to that caused by the phenoxy acetic acid herbicides; however, broadleaf plants may exhibit more cupping than strapping of leaf tissue. Amiben is not a mobile herbicide and primarily causes root malformation. Roots will be stubby but not necessarily swollen.

3. **Pyridines**
   a. **Use:**
      Clopyralid (Stinger) for small grains and sugarbeets
      Picloram (Tordon) for noncropland and pasture
   b. **Injury Symptoms:**
      Similar to the phenoxy acetic acids.

## II. Amino Acid Synthesis Inhibitors

The amino acid synthesis inhibitors include the following herbicide families: **sulfonylureas, imidazolinones, and amino acid derivatives**. Amino acid synthesis inhibitors prevent the production of amino acids, key building blocks for normal plant growth and development. Sulfonylurea and imidazolinone herbicides prevent the production of three branch-chain amino acids by inhibiting one key plant enzyme. The amino acid derivative herbicides inhibit the production of three aromatic amino acids by inhibiting another key plant enzyme. In general, injury symptoms are slow to develop (1 to 2 weeks) and include stunting or slowing of plant growth and a slow plant death. Herbicides in

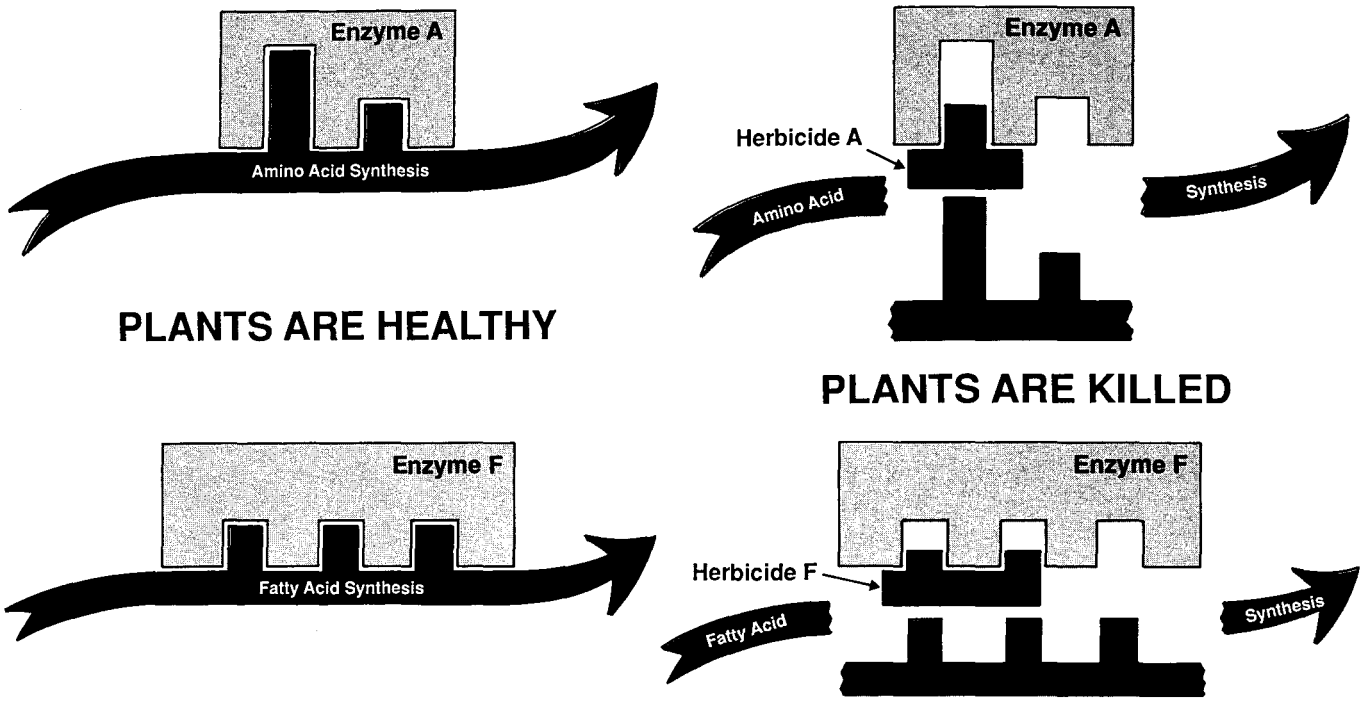


**Figure 1.** **Enzymes**—Enzymes function as steps in biological processes. Enzymes are also extremely specialized in their function. As a result, many different enzymes are involved with the many different biological processes that occur within a plant. Some herbicides can stop specific enzymes from functioning, resulting in a disruption of specific plant processes; this often leads to the death of the plant. This herbicide - enzyme relationship is very specific and any chemical modification of the herbicide or enzyme can eliminate herbicidal activity.

the sulfonylurea and imidazolinone families can move in both the xylem and phloem to areas of new growth and can be taken up through plant foliage and roots. Herbicides in these two families may have activity on annual and perennial broadleaf or grass weeds and may be soil- or foliar-applied. The amino acid derivative herbicides are nonselective and the site of uptake is the plant foliage. Herbicides in this family move via the phloem to all parts of the plant; these are excellent perennial weed control herbicides and are active on annual weeds as well.

1. **Imidazolinones**
   a. **Use:**
      Imazepyr (Arsenal) for noncropland
      Imazethabenz (Assert) for wheat, barley and sunflowers
      Imazaquin (Scepter) for soybeans
      Imazethaphyr (Pursuit) for soybeans
   b. **Injury Symptoms:**
      Grass plants may be stunted and yellow (chlorotic). Corn plants may show symptoms of root inhibition such as pruning of lateral roots and purpling of lower leaves. Broadleaf plants may be stunted and chlorotic. Soybean injury may mimic potassium deficiency.

2. **Sulfonylureas**
   a. **Use:**
      Chlorimuron (Classic) for soybeans
      Chlorsulfuron (Glean) for small grains and noncropland
      CGA-136872 (Beacon) experimental for corn
      DPX-M6316 (Harmony) for small grains, (Pinnacle) for soybeans
      DPX-V9360 (Accent) experimental for corn
   b. **Injury Symptoms:**
      Same as the imidazolinone herbicides.

3. **Amino Acid Derivatives**
   a. **Use:**
      Glyphosate (Roundup, Ranger, Rodeo) nonselective weed control for burndown and spot treatments in corn, soybeans, small grains, pasture, and noncropland.
   b. **Injury Symptoms:**
      Plant foliage, especially new growth, will first yellow and then turn brown and die within 10 to 14 days after herbicide application.

## III. Lipid Inhibitors

The lipid inhibitors include the following herbicide families: **cyclohexanediones and aryloxyphenoxy-propionates.** These herbicides prevent the formation of fatty acids, components essential for the production of plant lipids. Lipids are vital to the integrity of cell membranes and to new plant growth. The lipid inhibitor herbicides inhibit a single key enzyme involved in fatty acid biosynthesis. Broadleaf plants are tolerant to these herbicide families; however, almost all perennial and annual grasses are susceptible. Injury symptoms are slow to develop (7 to 14 days) and show up first on new leaves emerging from the whorl of the grass plant. These herbicides are taken up by the foliage and move in the phloem to areas of new growth.

1. **Cyclohexanediones**
   a. **Use:**
      Sethoxydim (Poast) for soybeans and alfalfa
      Clethodim (Select) experimental for soybeans
   b. **Injury Symptoms:**
      Injury is seen on grass plants only. Newer leaf tissue will be yellow (chlorotic) or brown (necrotic) and the leaves in the leaf whorl can be easily separated from the rest of the plant.

2. **Aryloxyphenoxypropionates**
   a. **Use:**
      Diclofop (Hoelon) for small grains and soybeans
      Fluasifop (Fusilade) for soybeans
      Fenoxaprop (Whip, Option) for soybeans
      Quizalofop (Assure) for soybeans
   b. **Injury Symptoms:**
      Same as the cyclohexanedione herbicides.

## IV. Seedling Growth Inhibitors

The seedling growth inhibitors include the following herbicide families: **dinitroanilines, acetanilides, and thiocarbamates.** Seedling growth inhibitors interfere with new plant growth, thereby reducing the ability of seedlings to develop normally in the soil. Herbicides in these families must be soil-applied. Plants take up these herbicides during germination through seedling emergence. Therefore, these herbicides are only effective on seedling annual or perennial weeds. Plants that have emerged from the soil uninjured are likely to remain so. Seedling growth inhibitors are active at two main sites, the developing shoot and the root. Much more is known about how seedling root inhibiting herbicides work than about how seedling shoot inhibitors work. The root inhibitors stop plant cells from dividing, which inhibits lateral root formation. Uptake is through developing roots and shoots. Because herbicide movement within the plant is limited, herbicide injury is confined primarily to plant roots and shoots. Shoot inhibiting herbicides are taken up by developing roots and shoots and can move via the xylem to areas of new growth. There is evidence to suggest that these herbicides can affect multiple sites within a plant, primarily interfering with lipid and protein synthesis.

A. **Root Inhibitors**
   1. **Dinitroanilines**
      a. **Use:**
         Benefin (Balan) for alfalfa
         Ethalfluralin (Sonalan) for soybeans
         Pendimethalin (Prowl) for corn (preemergence only) and soybeans (preplant incorporated only)
         Trifluralin (Treflan) for soybeans
      b. **Injury Symptoms:**
         General symptoms include stunted plants that do not fully emerge from the soil and short, thick lateral roots. Grass shoots are short and thick and may appear red or purple in color. Broadleaf plants may have swollen and cracked hypocotyls (the area below the cotyledons). Following preemergence treatments, callus tissue may appear at the base of soybean stems.

B. **Shoot Inhibitors**
   1. **Acetanilides**
      a. **Use:**
         Alachlor (Lasso) for corn, dry beans, sorghum, sunflowers, and soybeans.
         Acetochlor (Harness) experimental for corn
         Metolachlor (Dual) for corn, dry beans, sorghum, and soybeans
         Propachlor (Ramrod) for corn, flax, and sorghum
      b. **Injury Symptoms:**
         General symptoms include stunting of roots and shoots, resulting in abnormal seedlings that do not emerge from the soil. Grasses may leaf out underground or leaves may not properly unfurl. Broadleaves may have crinkled leaves and/or a shortened mid-vein, which produces a "drawstring" effect.

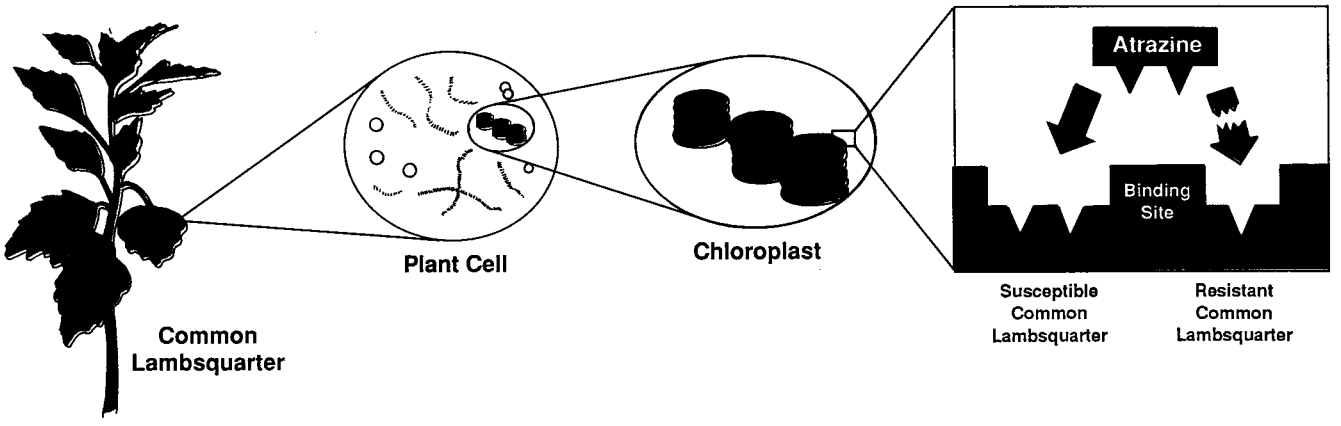


**Figure 2. Photosynthetic Inhibitors**—The photosynthetic process occurs within a plant cell's chloroplasts. Certain herbicides can inhibit photosynthesis by binding to specific sites within the chloroplast. The relationship of a herbicide to the chloroplast binding site is very specific and any modification of the herbicide or binding site can eliminate herbicidal activity.

2. **Thiocarbamates**
   a. **Use:**
      EPTC (Eptam, Genep) for alfalfa, dry beans, flax, sugarbeets, and sunflowers.
      EPTC plus Safener (Eradicane, Eradicane Extra) for corn
      Butylate plus Safener (Sutan+ and Genate Plus) for corn
      Triallate (Fargo) for wheat and barley
   b. **Injury Symptoms:**
      General symptoms include stunting of shoots and poor emergence from the soil. Grasses may fail to emerge from the coleoptile or leaf-out underground. Leaf tips may not unfurl from the coleoptile properly, which results in the "buggy whip" effect. Broadleaves may have crinkled or puckered leaves or leaf buds may not open.

## V. Photosynthesis Inhibitors

The photosynthesis inhibitors include the following herbicide families: **triazines, phenylureas, benzothiadiazoles, and nitriles.** Photosynthesis inhibitors shut down the photosynthetic (food producing) process in susceptible plants. Inhibition of photosynthesis could result in a slow starvation of the plant; however, the plant experiences a more rapid death that is believed to be due to the production of secondary toxic substances. Injury symptoms include yellowing (chlorosis) of leaf tissue followed by death (necrosis) of the tissue. Two of the herbicide families (triazines and phenylureas) are taken up into the plant via the roots or foliage and move in the xylem to plant leaves. As a result, injury symptoms will first appear on the older leaves, along the leaf margin. After foliar application, triazine and phenylurea herbicides are less mobile and do not move out of the leaf tissue. The nitrile and benzothiadiazole herbicide families are not mobile in plants and are classified as postemergence contact herbicides. These herbicides have no soil activity. Contact herbicides must thoroughly cover a susceptible plant's foliage to achieve complete control. Photosynthetic inhibitors may control annual or perennial grass or broadleaf weeds.

1. **Triazines**
   a. **Use:**
      Atrazine for corn and sorghum
      Cyanazine (Bladex) for corn
      Simazine (Princep) for corn
      Metribuzin (Lexone, Sencor) for alfalfa and soybeans
   b. **Injury Symptoms:**
      Photosynthesis inhibitors do not prevent seedlings from germinating or emerging. Injury symptoms only occur after the cotyledons and first leaves emerge. Initial injury symptoms include yellowing of the leaf margins or tips. In broadleaf plants, yellowing between the leaf veins (interveinal chlorosis) may occur. Older and larger leaves will be affected first because they take up more of the herbicide-water solution. Injured leaf tissue will eventually turn brown and die.

Due to the chemical nature of the herbicide/ soil relationship, injury symptoms are likely to increase as the soil pH increases (higher than pH 7.2).

2. **Phenylureas**
   a. **Use:**
   Linuron (Lorox) for soybeans and corn.
   b. **Injury Symptoms:**
   Same as for the triazine herbicides

3. **Benzothiadiazoles**
   a. **Use:**
   Bentazon (Basagran)
   b. **Injury Symptoms:**
   Plant injury is confined to foliage that has come in contact with the herbicide. Effected leaves will become yellow or bronze in color and eventually turn brown and die. Crop oil concentrate and other additives may increase weed control and crop injury symptoms.

4. **Nitriles**
   a. **Use:**
   Bromoxynil (Buctril) for wheat, barley, oats, rye, flax, corn, and alfalfa.
   b. **Injury Symptoms:**
   Plant injury is confined to foliage that has come in contact with the herbicide. Foliage that has been thoroughly covered with the herbicide will turn yellow and soon after turn brown and die. Contact of a low rate of herbicide with leaves may result in spotting or speckling of the leaf surface. Crop oil concentrates and other additives may intensify injury symptoms.

## VI. Cell Membrane Disrupters

The cell membrane disrupters include the **diphenylether and bipyridylium** herbicide families. These herbicides are postemergence contact herbicides that are activated by exposure to sunlight to form oxygen compounds such as hydrogen peroxide. These oxygen compounds destroy plant tissue by rupturing plant cell membranes. Destruction of cell membranes results in a rapid browning (necrosis) of plant tissue. On a bright and sunny day, herbicide injury symptoms can occur in 1 to 2 hours. Because these are contact herbicides, they are excellent for burndown of existing foliage and postemergence control of annual weeds. Perennial weeds usually regrow because there is no herbicide movement to underground root or shoot systems. These herbicides have little soil activity.

1. **Bipyridyliums**
   a. **Use:**
   Paraquat (Gramoxone Extra) for nonselective weed control in corn, soybeans, small grains, and dormant alfalfa. Difenzoquat (Avenge) for barley, winter wheat, and some spring and durum wheat varieties.
   b. **Injury Symptoms:**
   Plant leaves will have a limp, water-soaked appearance, which is followed by browning (necrosis) of the plant tissue. Drift injury will appear as speckling on leaf tissue.

2. **Diphenylethers**
   a. **Use:**
   Aciflurofen (Blazer, Tackle) for soybeans
   Lactofen (Cobra) for soybeans
   Fomesafen (Reflex) for soybeans
   b. **Injury Symptoms:**
   Plant leaves will yellow and then turn brown and die. Reddish-colored spotting on the leaf surface may appear shortly after the herbicide is applied. Plants that do not die may be stunted for a week or more. Crop oils and other additives, as well as extremely cool or warm temperatures, may increase plant injury.

## VII. Pigment Inhibitors

Pigment inhibitors prevent plants from forming photosynthetic pigments. As a result, the affected plant parts become white to translucent. Clomazone (Command), a soil-applied soybean herbicide, is the only member of the **isoxazolidinone** family in use at this time. Command is taken up by plant roots and shoots and can move in the xylem to plant leaves. The newly developed foliage of many plant species is so sensitive to Command that very small amounts can whiten new plant growth.

1. **Isoxazolidinones**
   a. **Use:**
   Clomazone (Command) for soy beans
   b. **Injury symptoms:**
   Plants turn white, often becoming translucent at the leaf tips. In corn, if more than 75% of the plant is white it will most likely die.

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# SOURCES FOR FURTHER INFORMATION

## I. Color Photographs Available from North Central Regional Publications:

Breneman, D. and R. Behrens. *Herbicide Symptoms in Corn.* 1986 (revised). North Central Regional Extension Publication 94, AG-FO-1354.

Coultas, J., *Herbicide Symptoms in Dry Edible Beans.* 1981. North Central Regional Extension Publication 158, AG-MI-1362.

Coultas, J., *Herbicide Symptoms in Sunflower.* 1985 (revised). North Central Regional Extension Publication 163, AG-FS-1367.

Coultas, J., A. Dexter, and G. Schroeder. *Herbicide Drift Symptoms in Sunflowers.* 1981. North Central Regional Extension Publication 162, AG-FO-1366.

## II. Color Photographs Available from University of Illinois Publications:

Curran, W. S., M. D. McGlamery, E. L. Knake, and M. M. Loux. *Injury Symptoms from Selected Herbicides. 1988.* Vocational Agriculture Service, Urbana, Illinois, X899.16.

Curran, W. S., M. D. McGlamery, E. L. Knake, and C. D. Anderson. *Herbicide Injury—Meristematic Inhibitors I.* 1989. Vocational Agriculture Service, Urbana, Illinois, X899.17.

Curran, W. S., M. D. McGlamery, E. L. Knake, and C. D. Anderson. *Herbicide Injury Meristematic Inhibitors II.* 1989. Vocational Agriculture Service, Urbana, Illinois, X899.18.

Curran, W. S., M. D. McGlamery, E. L. Knake, and C. D. Anderson. *Herbicide Injury—Plant Growth Regulators and Pigment Inhibitors.* 1989. Vocational Agriculture Service, Urbana, Illinois, X899.19.

Curran, W. S., M. D. McGlamery, E. L. Knake, and C. D. Anderson. *Herbicide Injury—Photosynthetic Inhibitors and Contact Herbicides.* 1989. Vocational Agriculture Service, Urbana, Illinois, X899.20.

Downs, J. P., M. D. K. Owen, E. L. Knake, M. D. McGlamery, and M. Martin. *Corn Herbicide Injury I.* 1980. Vocational Agriculture Service, Urbana, Illinois, X899.01.

Downs, J. P., M. D. K. Owen, E. L. Knake, M. D. McGlamery, and M. Martin. *Corn Herbicide Injury II.* 1980. Vocational Agriculture Service, Urbana, Illinois, X899.02.

Downs, J. P., M. D. K. Owen, E. L. Knake, M. D. McGlamery, and M. Martin. *Soybean Herbicide Injury I.* 1980. Vocational Agriculture Service, Urbana, Illinois, X899.06.

Downs, J. P., M. D. K. Owen, E. L. Knake, M. D. McGlamery, and M. Martin. *Soybean Herbicide Injury II.* 1980. Vocational Agriculture Service, Urbana, Illinois, X899.07.

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