Agronomy 317
Principles of Weed Science

Herbicide Selectivity

I. Definition
   A. Differential tolerance between species to herbicides
      1. The rate of herbicide required to kill one species is safe on other species
      2. Basis of modern weed control – herbicides control weeds without damaging crop
   B. Margin of safety
      1. Difference between the rate needed to control weeds and the rate that is safe on the crop
      2. Margin of safety varies widely among herbicides. A 4X margin is considered minimal

II. Selectivity mechanisms
   A. Placement
      1. Herbicide is applied in a manner that minimizes contact with crop
      2. Seed placement – large seeded crops planted below depth where most soil-applied herbicides reach
         a. pendimethalin and corn
         b. isoxaflutole – corn
      3. Post directed applications - specialized application equipment that direct spray so that little herbicide contacts crop. Drop nozzles occasionally used in tall corn – nozzle positioned between rows below the top of the corn canopy so that most of spray misses corn leaves. This type of application was common in early part of chemical weed control because herbicides available at the time had a limited margin of safety.
   B. Timing of application – apply herbicide at a time when crop or other desirable plants will avoid the herbicide or are at a tolerant stage
      1. Dormant applications
         a. Early spring applications of metribuzin to alfalfa prior to new growth
         b. Fall applications of glyphosate in woodland to kill garlic mustard and other invasives without killing spring wildflowers
      2. Between cutting applications of paraquat in alfalfa
      3. Tolerant crop stage
         a. Preemergence crabgrass herbicides in turf – perennial turf species grow from established crowns whereas crabgrass grows from seed
         b. Conifers tolerant to 2,4-D after terminal growth expansion
         c. Several systemic herbicides (2,4-D, nicosulfuron) are safe on corn early in the growing season. However, after the V6 stage of development corn initiates development of reproductive structures (ear/tassel) and these may be damaged by herbicide applications after this time.
   C. Absorption and translocation
      1. Some plants may absorb or translocate herbicide more efficiently than others
      2. Usually will provide minor level of selectivity, not enough by itself to allow selective use in crops
      3. In some high value crops established using transplants, roots of the transplants are dipped in activated charcoal to reduce absorption of soil-applied herbicides
D. Differential metabolism

1. Plants metabolize herbicides to non-toxic compounds.
2. Differential metabolism is the ability of one plant to break down a herbicide more rapidly than another. It is the most common form of selectivity. Rapid degradation of a herbicide can prevent it from reaching the target site at toxic concentrations.
3. Degradation processes
   a. Same enzymes involved that animals use to degrade toxins
      i. Major difference between plants and animals is that plants are unable to excrete toxins via the urinary system like animals
      ii. Compounds converted to forms that can be isolated from sensitive areas of the cell, typically sequestered in vacuole or cell wall
   b. Two or three step process
      i. Phase 1
         a. Herbicide modified to reduce toxicity, increase polarity, or predispose to further degradation
         b. Enzymes involved: cytochrome P₄₅₀, esterases, reductases
         c. This step not required with all herbicides
      ii. Phase 2
         a. Conjugation reactions – components added to herbicide molecule that further reduce biological activity, increase polarity and decrease mobility
         b. Examples: glutathione, sugars, amino acids
         c. In mammals, these conjugates are excreted in urine
      iii. Phase 3
         a. Conjugated herbicides put into ‘permanent’ storage
            i. Placed into vacuoles
            ii. Incorporated into cell walls
         b. Unique to plants
         c. Processes poorly understood
4. Factors influencing metabolism
   a. Rate of metabolism affected by many factors, reduced metabolism can result in significant crop injury
   b. Plants under environmental stress less efficient at metabolizing herbicides
   c. Excessive herbicide rates (misapplication) can overcome plant’s ability to metabolize herbicide
   d. Other pesticides, chemicals
      i. Competition for enzymes – plant has limited capacity to degrade xenobiotics (chemical found in an organism that is not produced by the organism and not needed for any purpose). The enzyme systems that degrade herbicides are involved in degradation of any other xenobiotics found in the plant. If enzymes are tied-up degrading other compounds, the herbicide
      ii. Inhibition of enzymes (insecticides) OP insecticides can disable enzyme
   e. Herbicide safeners
      i. Chemicals used to enhance herbicide metabolism by the crop, therefore increasing crop safety
         a. Target enzymes
            i. Glutathione conjugation (glutathione-S-transferase)
            ii. Cytochrome P₄₅₀
         ii. Must enhance metabolism in crops but not weeds
         iii. Examples
            a. Safener included in herbicide formulation. Ex. - Dual II, Harness, Option, Require Q.
b. Safener applied as seed treatment. Ex. Concep and Screen treated sorghum seeds – allow the use of Lasso or Dual

5. Differential metabolism is the most common form of herbicide selectivity

E. Insensitive target site
   1. Some plants may have a different form of the target site than weeds, therefore preventing binding of the herbicide.
   2. This form of selectivity generally provides the highest margin of crop safety
   3. ACC-ase inhibiting herbicides (clethodim, fluazifop, etc.) gain their selectivity via this mechanism. These herbicides bind to the ACC-ase enzyme in grasses, but other plants have a different form of the enzyme and thus are not affected.

III. Herbicide resistant crops (HRC)
   A. Alteration of a crop to provide resistance to a herbicide that normally would kill the crop
      1. Traditional means of obtaining selectivity was to screen thousands of chemicals hoping to find a herbicide that could be used on a crop without causing injury
      2. HRC involve screening genes for selectivity, rather than screening chemicals
      3. As it has become more difficult to identify selective herbicides (easy ones already discovered), it is less expensive to screen genes

   B. Methods of development
      1. Traditional breeding techniques
         a. Triazine resistant canola – canola was crossed with a weedy mustard (field mustard) that had developed resistance to triazines following repeated use of atrazine (insensitive target site)
         b. ALS-resistant corn – created by mutagenesis of pollen by UV light. A mutation was found that resulted in an insensitive target site for ALS herbicides
      2. Transgenic crops (genetic engineering)
         a. Gene that will provide resistance to a herbicide identified in some other organism and transferred to crop plant
         b. Glyphosate resistant (GR) crops (Roundup Ready)
            i. Most RR crops use a gene for an insensitive target site (EPSPS) found in bacterium. In some GR crops, a gene for an enzyme that metabolizes glyphosate is included along with the modified target site. A second gene for an insensitive enzyme has been identified from mutated corn is used in some GR crops.
            ii. Current RR crops: corn, soybean, cotton, sugarbeet, canola
            iii. Numerous other crops developed, including wheat, creeping bentgrass, Kentucky bluegrass, etc. Registration is pending or on hold
            iv. RR alfalfa was approved in 2006, but a court order in 2007 stopped planting of any new seed and established fields need to be closely monitored. Court decided that the movement of the RR gene into conventional alfalfa could cause loss of market for persons wanting to grow non-transgenic alfalfa
            v. A gene that codes for an enzyme that degrades glyphosate has been identified by DuPont and will be used in Optimum GAT crops. These crops will also contains a gene for resistance to ALS herbicides
         c. Glufosinate resistant crops (Liberty Link)
            i. Gene for an enzyme that degrades glufosinate identified in bacteria and inserted in crops
            ii. Current LL crops include corn, cotton, soybean and canola.