Lecture

Herbicide x Plant Interactions
Absorption and Translocation of Herbicides Applied to Soil

Herbicides are applied to soil to control seedling weeds as they emerge. Many herbicides have only soil activity, i.e., they do not affect plants when applied to the foliage.

To be effective, the herbicide must enter the plant. This lecture will address absorption of herbicide from soil.

1. Herbicide contact plants via: (in soil)

   - interception - as the root or underground shoot of the plant grows it intercepts herbicide molecules in the soil

   - mass flow - herbicide moves to the root or underground shoot of the plant in the soil aqueous solution. Most important for non-volatile herbicides; this could be referred to as herbicide activation

   - diffusion - the herbicide moves along a concentration gradient either in the aqueous solution or vapor phase.

     Movement from an area of high concentration to a area of lower concentration. Very important for volatile herbicides e.g. Treflan (trifluralin).

2. Sites of absorption (in soil)

   - seed absorption - herbicide moves to the seed via mass flow or diffusion; herbicide passively absorbed from the soil solution during imbibition. This is **not** a major means of absorption of herbicide

   - root absorption - major mode for broadleaf plants (will discuss later)

   - shoot absorption - major mode of soil absorption by grasses (will discuss later)

3. Root absorption of herbicide (from soil)

   - major mode for broadleaf plants

   - hypocotyl and shoot absorption can occur in broadleaf plants, but much less important

- see Figure 4.4 (Comparison of the germination and early development of a broadleaved plant and a grass plant; page **6**)

- penetration of root hair first step - via mass flow and diffusion; this process is easy since no cuticle is present on the root surface

4. Route of herbicide movement in root

- apoplast - represents non-living portions of the plant - xylem mobile herbicides (transpiration driving force)

  apoplast is more or less a continuous system of cell walls, intercellular spaces, and xylem (the water conducting tissue)

  discuss transpiration process

  xylem mobile herbicides move through the apoplast

  pathway: root hair ≡ intercellular spaces ≡ cell walls of cortical cells ≡ endodermis ≡ diffuse casparian strip (suberized barrier) ≡ enter xylem (moved upward)

- See Figure 4.5 (Cross section of root; page 7)

  casparian strip - impermeable barrier in the root

  endodermal cells are covered with suberin wax (casparian strip) - function is to protect root from dehydration. Roots do not have a cuticle like leaves.

  The function of the casparian strip and leaf cuticle are the same - to prevent dehydration

  The casparian strip also delays herbicide movement across the endodermis. Herbicides must diffuse through the casparian strip or go around it which slows down movement.

  Sencor (metribuzin) herbicide used in soybeans is soil-applied and apoplastically translocated; this herbicide inhibits photosynthesis

  YSince the herbicide inhibits photosynthesis then the weed would have to emerge from the soil and receive sunlight for photosynthesis to begin. The chemical must get into the xylem to move upward.

- symplast - represents living portions of the plant - phloem mobile herbicides (mass flow of solutes driving force with source-sink relationship)

  phloem mobile herbicides move through the symplast

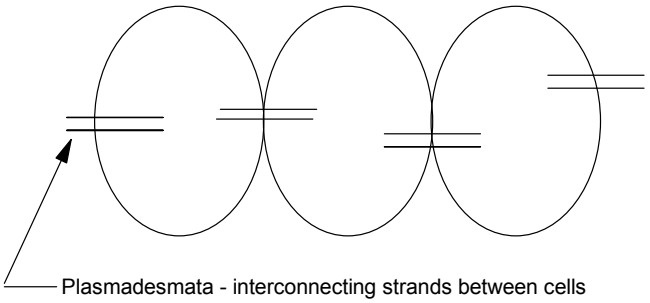
  pathway: root hair ≡ enter cell ≡ cell to cell through plasmodesmata ≡ enter phloem (will not move out of root) - this pathway avoids the problem with the casparian strip

  Source-sink relationship:

  source - any area in a plant that generates carbohydrates (e.g. mature leaves)

  sink - any area in a plant that requires energy source (carbohydrates) to include roots, growing points, very young leaves.

  Herbicides move from cell to cell through plasmodesmata (interconnecting strands between cells; see illustration below)



  Herbicide would therefore move within the plant through the phloem from sources of carbohydrate production to sinks where energy is needed for cell maintenance and growth

  Would a phloem mobile herbicide move out of the root? No

  YPoints of interest:
  If movement is apoplastic, then movement of a soil-applied herbicide would be upward (from roots to above ground stems. Remember the example of Sencor (metribuzin)

  Herbicide that moves only in the symplast would not be applied to the soil because it will not move out of the root. This is why herbicides that move only in symplast are not soil applied, but rather are foliar applied e.g. Roundup

- both apoplast and symplast - some herbicides can travel in both apoplast and symplast; these herbicides are more versatile in that they can be applied to soil or foliage (preemergence or postemergence)

- neither apoplast nor symplast (e.g. cell division inhibitors) - trifluralin (Treflan) is applied preemergence and inhibits cell division.

  Therefore it is not necessary that it move at all since root growth and development is by cell division. Once cell division ceases the plant dies.

5. See Figure 4-4 (Diagram representing herbicide absorption into roots; page 7)

6. Shoot absorption of herbicide (in soil)

   - major mode of soil absorption by grasses

   - absorbed by coleoptilar node and crown node not roots - as a grass seed germinates and elongates it penetrates the herbicide zone in the soil

     The coleoptile is the first structure that breaks through the soil as the grass emerges. The herbicide is then absorbed by the coleoptilar node (first node on the stem of grass seedlings) and crown node (at or just below the soil surface).

     Y**Through this means of absorption in grasses the herbicide bypasses the casparian strip, which restricts herbicide movement in the root.**

     Why are herbicides like Dual (metolachlor), Lasso (alachlor), and Treflan (trifluralin) shallow incorporated (1 to 2 inches)?

     Answer: because they are primarily active on grasses and if incorporated too deep (e.g., 3-4 inches), the herbicide would be diluted or not present in the soil where the coleoptilar node would be present

   - See Figures 4.4 (Comparison of the germination and early development of a broadleaved plant and a grass plant; page **6**) and 8.1 (Comparative location of the coleoptilar nodes of wild oat and wheat with respect to a soil layer of shallowly incorporated herbicide (e.g. trifluralin); page **8**)

Would depth of incorporation be as critical for broadleaf weeds as for grasses?

No, since root uptake would occur with broadleaf weeds

7. Route of herbicide movement in shoot (from soil)

   - apoplast - represents non-living portions of the plant - xylem mobile herbicides (transpiration driving force)

     pathway: cell walls ⟩ intercellular spaces ⟩ enter xylem (moved upward)

   - symplast - represents living portions of the plant - phloem mobile herbicides (mass flow of solutes driving force with source-sink relationship)

     pathway: enter cell ⟩ cell to cell through plasmodesmata ⟩ enter phloem (will not move out of shoot)

   - both apoplast and symplast

   - neither apoplast nor symplast (e.g. cell division/elongation inhibitors)

     The same concepts discussed earlier for root absorption apply here as well

8. Points of interest

   - in a root or shoot, herbicide entry into xylem is more important than into phloem - Why?
   - a herbicide that moves only in the symplast would not be applied to the soil
   - herbicides must enter the plant cell to be active

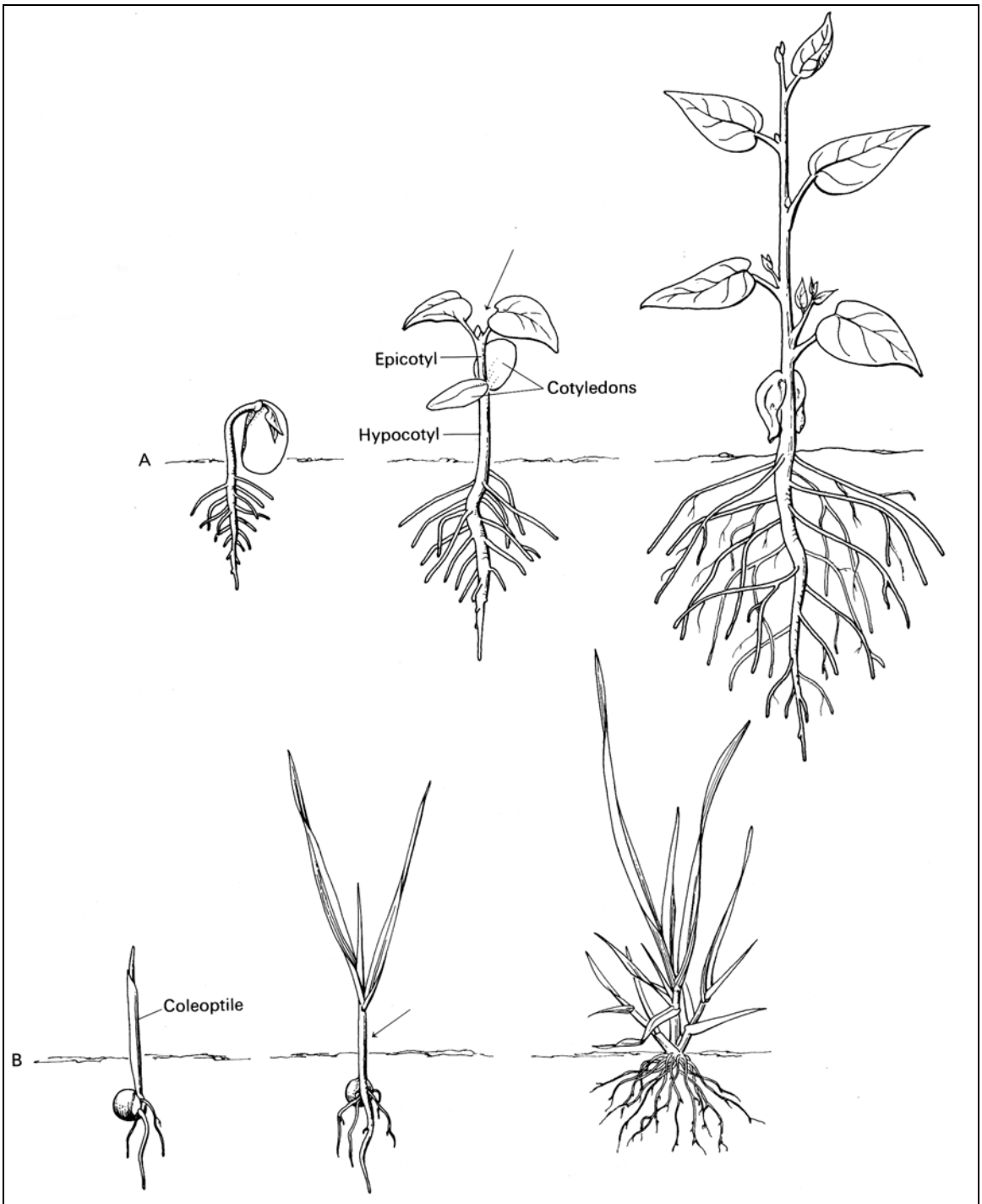


Figure 4.4. Comparison of the germination and early development of (A) a broadleaved plant and (B) a grass plant. Left: Germination. Middle: 1 wk after emergence. Right: A well-established young plant. Arrows point to location of shoot tips.

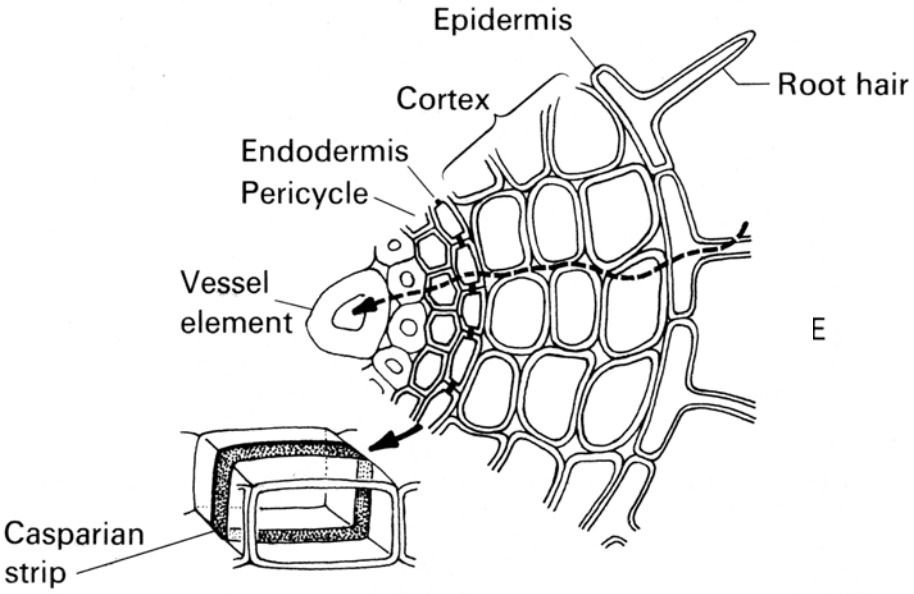


Figure 4.5 – Cross section of root

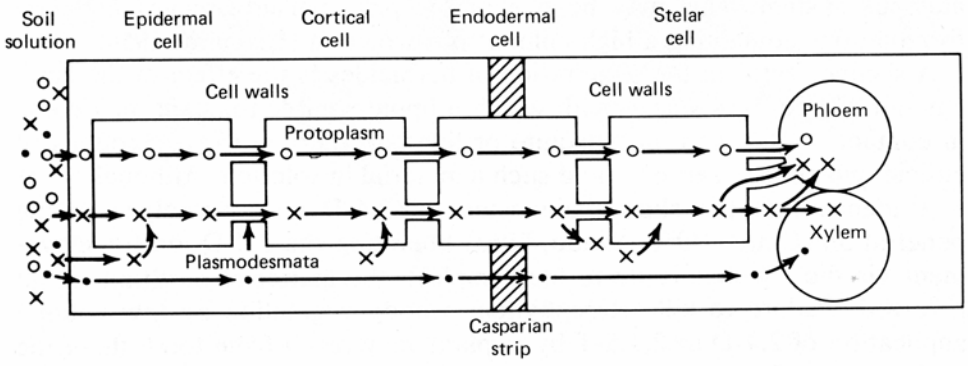


FIGURE 4-4. Hypothetical diagram representing herbicide absorption into roots. (Adapted from E. Epstein, 1973. Roots, *Scientific American* **228** (5):48–58.) • Molecules able to enter cell walls (apoplast), diffuse through casparian strip, and enter xylem. ○ Molecules able to enter protoplasm (symplast), pass from cell to cell through the plasmodesmata, and enter the phloem. × Molecules able to enter both cell walls (apoplast) and protoplasm (symplast), and enter both xylem and phloem.

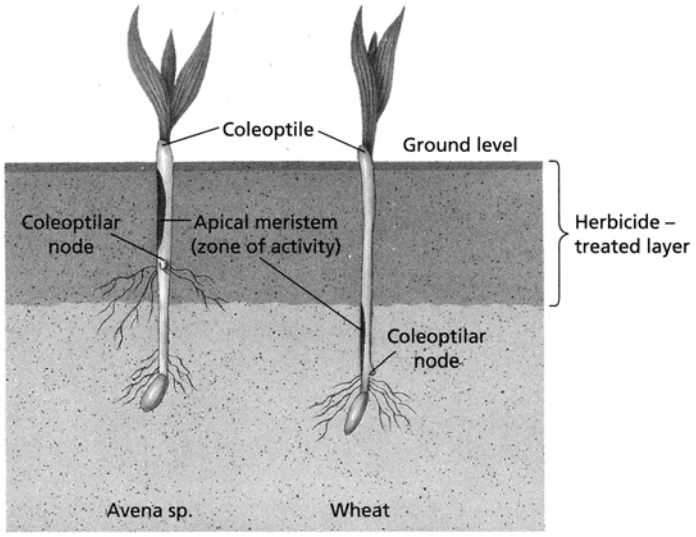


FIGURE 8.1 ■ Comparative location of the coleoptilar nodes of wild oat and wheat with respect to a soil layer of shallowly incorporated herbicide (e.g., trifluralin). The seed of both plants is buried to the same depth. The coleoptilar node is a primary site of entry for some soil-applied herbicides. Their sites of action may be in the apical meristems, depending on the herbicides involved.

SOURCE: J. D. Fryer and S. A. Evans, eds. 1968. *Weed control handbook,* 5th ed. 1:51. Oxford, England: Blackwell Scientific Publications.