Selected Characteristics of Some Herbicides Used in Forestry

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Primary mode of action

- Growth regulators (systemic herbicides)
  1. Phenoxy acetic acids
     2,4-D
     2,4,5-T
  2. Phenoxy propionic acids
     dichlorprop
     silvex
  3. Benzoic acid
     dicamba (Banvel)
  4. Picolinic acid
     picloram (Tordon)

- Inhibitors of oxidative phosphorylation
  1. Dinitrophenols
     dinoseb
  2. Organic arsenicals
     MSMA (Silvisar)
     cacodylic acid (Silvisar or Phytar)

- Photosynthetic inhibitors
  1. Chloro-s-triazines
     atrazine (AAtrex)
     simazine (Princep)

- Soil-applied inhibitors of seedling root and/or
  shoot growth
  dichlobenil (Casoron)
  diphenamid (Ende)

- Chlorophyll inhibitor
  amitrole

- Free radical formation
  paraquat (Paraquat)

- Disrupt cell membranes
  herbicide oils

- Interfere with protein metabolism
  dalapon (Dowpon)

- Miscellaneous (modes of action not clear)
  glyphosate (Roundup)

Characteristics of some organic herbicides

- Growth regulators
  1. All herbicides acting as growth regulators
     affect plant growth in a similar way and appear
     to act at the same site as the natural plant
     auxin, IAA (indole acetic acid). However, all
     are much more active than IAA.
  2. All are translocated in both the phloem and
     xylem and, therefore, will control several
     perennial weeds. However, there are large
     differences in degree of translocation of dif-
     ferent compounds in this group. Also, trans-
     location of the same compound may vary in
     different species.
  3. Because their effect on the plant is “systemic”
     rather than “contact,” they are effective when
     only part of the plant is treated.
  4. As a result of systemic effect, low pressure and
     low volume sprays can be used.
  5. Effects on plant growth may be seen at doses
     far below the lethal dose. This creates a poten-
     tial problem with spray drift to susceptible
     crops.
  6. Quite mobile in soil.
  7. With the exception of dicamba and picloram,
     they do not persist long in the soil.
  8. All have low mammalian toxicity.

- Photosynthetic inhibitors
  1. Photosynthesis is stopped rapidly in suscep-
     tible plants. In resistant plants the effect on
     photosynthesis is much less and is temporary.
  2. They have no direct effect on root growth.
  3. Both move primarily in the xylem. Therefore,
     weeds are controlled principally by root ap-
     plications, not by foliage sprays. Atrazine does
     have some foliage activity.
4. In general, these compounds are moderately to highly resistant to movement in the soil, but this varies with the compound, soil, and rainfall.
5. Persistence in the soil varies from a few weeks to more than two years, depending upon the herbicide, amount applied, climate and soil.
6. All have very low mammalian toxicity.

- Soil-applied inhibitors of seedling root and/or shoot growth (other than mitotic poisons)
   Included here are several chemical groups, the modes of which are not known. However, they are all soil-applied herbicides that inhibit the growth of roots and/or shoots of seedling plants. Some of them also inhibit the buds of certain perennials. They all have low mammalian toxicity.

- Chlorophyll inhibitor (amitrole)
  1. Very soluble in water.
  2. Translocated in both xylem and phloem and moves throughout the plant.
  3. It interferes with pigment formation in the leaves and new growth becomes almost white.
  4. In some perennial plants it persists for several months and new buds produce white leaves.
  5. It is not very selective in that all plant species are injured.
  6. It is rapidly inactivated in the soil, and, therefore, it is used entirely as a foliage spray.
  7. Acute mammalian toxicity is very low. However, it has been reported to have carcinogenic properties. At one time this herbicide was important for weed control in cranberries.
  
  Amitrol-T: a mixture of amitrole and ammonium thiocyanate. Apparently the ammonium thiocyanate improves the translocation of amitrole in plants, making it much more effective in the control of several kinds of weeds.
  
  Amizine: a mixture of amitrole and simazine which gives residual weed control for several months in addition to controlling the weeds present at time of spraying.

- Free radical formation (paraquat)
  1. Very soluble in water.
  2. Strong cation.
  3. Enters the foliage very rapidly (rain after 30 minutes does not affect results).
  4. Plants are killed quickly, usually within 1 or 2 days.
  5. Shows very little true selectivity.
  6. Action is much more rapid in bright light than in weak light or in the dark.
  7. Usually plants are killed so rapidly there is little translocation.
  8. Strongly adsorbed by clay colloids and therefore has little or no activity in the soil.
  9. Mammalian toxicity is high for paraquat; fish toxicity is low.

- Interfere with protein metabolism (dalapon)
  1. Very soluble in water.
  2. Dalapon enters plant through either the roots or foliage, but action takes place in the foliage.
  3. Dalapon is translocated in both the xylem and phloem.
  4. Because of the characteristics listed under 2 and 3 above, dalapon is used mainly for foliage sprays.
  5. Used primarily to control annual and perennial grasses.
  6. Not adsorbed by soil colloids and leaches readily in all soils.
  7. Normal soil life is limited to a few weeks under warm, moist conditions.

Penetration and translocation of herbicides in plants
To be effective, a herbicide must enter the plant and move to the site of action.

- Penetration
  Herbicides usually enter the plant through the leaves, the roots, or the seedling shoot before emergence. However, the above-ground stem may be an important site-of-entry in certain cases (i.e., basal bark treatment of trees with 2,4-D, 2,4,5-T or related compounds in oil).
  1. Leaves. The leaf surface presents many barriers to the entry of herbicides.
    - Cuticle. This is more easily penetrated by various oils and organic solvents than by water sprays. However, the latter do not enter through the cuticle, but rather through the stomata.
    - Wax. In addition to the wax in the cuticle, many plants have wax deposited on the leaf surfaces making them difficult to wet and reducing penetrability of water sprays. Spray additives and carriers greatly influence the penetration of the leaf surface by herbicides. Penetration through the open stomata can be an important mode of entry. However, stomata are usually on the under surfaces of leaves and the degree of opening varies greatly. Both factors reduce the importance of stomata as points of entry.
  2. Roots. Entry of herbicides into roots is not so difficult as entry into foliage since no wax layer or cuticle is present in the areas of absorptivity. There may be resistance to absorptivity and
differences between species may exist but little is known about this. The major problem with root uptake is getting the herbicide through the soil and into contact with the roots.

3. **Seeding shoots before emergence.** This is an important site of entry for many soil-applied herbicides that are active on germinating seeds or small seedlings. Before emergence, the shoot has a poorly developed cuticle and probably no wax layers, making the shoot more easily penetrated by herbicides.

4. **Stems.** Young stem tissue of herbaceous plants may be penetrated by herbicide solutions in much the same way as leaves. However, they are not so important as leaves because they have a much smaller surface. Older stems and even the bark of trees can be penetrated by herbicides applied in oil carriers.

- **Translocation**
  Once an herbicide has penetrated the leaf cuticle or the root epidermis, there are still many barriers to its movement to the site of action. A number of herbicides are conjugated (chemically bound), adsorbed or otherwise inactivated in the roots or leaves and do not move to other parts of the plant. Forms of 2,4-D conjugate in the roots of many plants.
  Assuming the herbicide is not immobilized in the leaf or root, it moves in the plant primarily by one or both of two routes.

1. **Xylem.** Herbicides that enter the roots or foliage may move upward in the xylem with the transpiration stream. The pattern of xylem movement of an herbicide applied to a leaf is toward the leaf tip only, if there is no phloem movement.

2. **Phloem.** Some herbicides move in the phloem. One of the important features of 2,4-D and most of the growth regulators, as well as amitrole, dalapon, and glyphosate, is their ability to be transported in phloem. Herbicides applied to the leaves can be translocated to the roots of perennial plants. Phloem movement is associated with sugar transport and light conditions. Also, it is very important not to kill the leaf and stem tissues rapidly since transport is via living tissue. Rapid foliage kill will result in poor transport and poor root kill. Sometimes two or three small doses of an herbicide of this type will give better results than a single large dose that kills too rapidly.

**General translocation patterns of several herbicides. (All will vary with species.)**

- **Applied to foliage**
  1. Movement in phloem and xylem
     2,4-D
     2,4,5-T
     simazine
     amitrole
     dalapon
     glyphosate
     MSMA
  2. Move only in xylem
     atrazine
  3. Little or no movement
     dinoseb
     parquat

- **Applied to soil**
  1. Move readily in xylem
     atrazine
     simazine
     amitrole
     dalapon
     picloram
     dicamba
  2. Movement in xylem restricted
     2,4-D
     2,4,5-T

**Relative leaching of herbicides in soil**

- **Readily leached in all soils.**
  dalapon
- **Readily leached in low organic sandy soils but some resistance to movement in others.**
  dicamba
- **Readily leached in low organic sandy soils but considerable resistance to movement in other soils.**
  2,4-D
  picloram
  dinoseb
- **Moderate movement in low organic sandy soils but little or none in others.**
  diphenamid
  atrazine
  simazine
- **Only slight movement in low organic sandy soils and essentially none in others.**
  dichlobenil

Comparative Toxicities of Selected Herbicides
(Acute oral LD₅₀ mg/kg — rodents)


LD₅₀: a lethal dose which kills 50% of a group of test animals when the herbicide is ingested. It is expressed in weight of the chemical (mg) per unit of body weight (kg).