# Herbicide Physiology:
# Why do I see what I see?

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Herbicides are an important tool in the production of cranberries. Production statistics show steady increases as herbicides became more available and widely used. Weeds compete with cranberry vines for light, water and mineral nutrients. Left uncontrolled weeds will significantly reduce yields and fruit quality.

Herbicides used on cranberries can be grouped in a variety of ways. For the purposes of this article I'm going to group them as pre-emergence and post-emergence. Simply put, this is a grouping as active against germinating seeds and seedlings or active against mature weeds. Within each group of herbicides the different commercial products control a different range of weeds. Not all pre-emergence herbicides will control all emerging weeds. You need to compare the weed spectrum of the available products and compare that list to the weeds commonly encountered on your marsh.

**Herbicides and plants**

The reaction of plants, both weeds and crop plants, to an herbicide application is determined by both the plant and the soil and the interaction between the two and with the environment (weather). Plant response to an herbicide is difficult to predict exactly because so many variables are involved. These factors may also interact with each other to create even more complexity. Plant responses to herbicides depend on:

1. The uptake and absorption of the material
2. Translocation or movement within the plant
3. Ultimate fate of the herbicide within the plant
4. Effect of the herbicide on plant metabolism

In order to be effective, an herbicide must enter the target plant. Different herbicides gain entry into plants in different ways and different plants are susceptible to herbicide entry at different locations. Herbicides can enter plants through leaves, roots, shoots and stems.

Post emergent herbicides generally are absorbed through the leaves. Leaves are covered with a waxy cuticle layer that prevents water from escaping and, therefore, also prevents aqueous solutions from entering the leaf The cuticle tends to be thinner at trichome bases and that is a preferential site of entry. Also, different plants have cuticles made of different types of waxes, some of which are more penetrable than others. Surfactants also help penetration by allowing greater contact between the herbicide solution and the leaf However, surfactants may also alter the selectivity of an herbicide if the selectivity depends on differences in leaf absorption.

Pre-emergent herbicides or soil active herbicides usually are absorbed by plant roots before they are active. However, some work through vapor action near the soil surface. The primary root region where herbicides are absorbed is 5 to 50 mm behind the root tip. In this area the xylem is functional, but the casparian strip that stops movement of materials into the roots is not completely lignified and therefore is not a significant barrier. Herbicides may be taken up passively by roots while others require the plant to expend energy to take them up. For the most part herbicides enter plant roots passively.

Once an herbicide enters the plant it may move to a location other than where it was absorbed to be effective. Two general pathways exist for compounds to move within plants. These are the xylem (apoplast) and the phloem (symplast). Movement in the xylem is passive and follows the same pathway as water. They enter the xylem and move along with the water to leaves and fruit. The driving force is water evaporating from leaves through transpiration. Movement in the phloem is generally from areas of high sugar concentrations (mature leaves) to areas where sugar is being utilized (developing fruit, growing points, young leaves). If herbicides that are to move through the phloem are applied to too high of concentrations, they kill or disrupt phloem movement and cannot be transported throughout the plant for a "complete kill".

Most plants have no way to rid themselves of materials once they have entered the plant. In order to protect themselves plants must either sequester the foreign materials or metabolize them into something less harmful by adding molecules onto them or splitting them into smaller pieces that may be less harmful. When the phytotoxicity of herbicides is reduced we call it inactivation; when it is enhanced it is called activation. This can be the basis of selectivity as well. If a plant can metabolize or sequester a chemical it won't be toxic. On the other hand, if a plant will metabolize a relatively benign substance the result could be toxic to the plant.

Ultimately to be effective, an herbicide must disrupt some essential plant function in such a way that the plant dies. This is called the "mode of action". One needs only to think of all of the processes that take place in plants to devise approaches to kill plants. Herbicides may interfere with a single process or multiple processes within a plant. Weed resistance is more likely to develop if only a single process is interrupted, but the opportunity for selectivity is greatest then. Often, the exact mode of action of herbicides is not known. A good example is 2,4-D. This herbicide has been widely used for 50 years and yet the exact mode of action is not known.

Selectivity to herbicides is not entirely dependent on herbicide chemistry. The plant also plays a significant role. Young plants generally have a thinner cuticle than older plants so more herbicide can enter young plants. Young plants also have more actively growing tissues, thus are more susceptible to growth interruption than older plants. In general, fast growing plants are more susceptible to injury than slow growing (mature) plants. Also, seedlings making the transition from stored reserves to surviving on their own are very susceptible.

## Herbicides and soils

Soils also play an important role in determining herbicide activity and longevity in the soil. Important soil properties include soil texture, temperature, moisture content, oxygen content, soil micro-flora and fauna, and exchange capacity.

The persistence of an herbicide in the soil is important. Too short of persistence and weeds come back quickly, too long of persistence precludes planting susceptible crops the following year. For cranberry production, persistence is desirable to provide long term weed control. Herbicides are broken down in the soil by these processes:

- **Degradation processes:**
  a) Biological decomposition
  b) Chemical decomposition
  c) Photodecomposition

- **Transfer processes:**
  a) Adsorption onto soil particles
  b) Leaching through soil
  c) Volatility
  d) Surface runoff
  e) Removal in harvested plants

Herbicides can be degraded by soil microorganisms or by the metabolic systems of higher plants. When an organic (carbon containing) herbicide is applied to the soil, some microorganisms can use it as a food source. These microbes then multiply and hasten the degradation of the herbicide. Once the herbicide is gone they generally decrease in number. Optimal environments for microbes are warm, moist and have an adequate supply of oxygen and mineral nutrients.

Chemical decomposition is the process of decomposition through chemical means without any organism being involved. Some herbicides break down in the presence of water. Others are sensitive to low or high soil pH.

Photodecomposition is the degradation of herbicides by light. Most herbicides absorb ultraviolet light. The absorption of light energy may allow bonds to be broken or new bonds to be made. This may activate or deactivate a given molecule.

Besides decomposition, herbicide activity may be lost as the active ingredient is moved out of the rooting zone. This can happen in a number of different ways. Herbicide can be lost with soil as soil erodes. Herbicide can leach through the soil as water from rainfall or irrigation moves downwards or laterally. This depends on the nature of the soil (sand > silt > clay > organic matter), the water solubility of the herbicide and the amount of water put through the system. All chemicals have a vapor pressure and a certain amount of material will be lost through volatilization into the air. Herbicides can be lost along with surface runoff water. This can be a big problem if runoff ends up in non-target areas. Herbicide that has been absorbed by plants will be removed from the field in the harvested product. This may not be a significant issue for cranberries since such a small portion of the biomass is harvested.

**Herbicide application**

Application technology is the final variable to-cover in this article. Regardless of the biological activity of an herbicide or the susceptibility of a weed or the tolerance/resistance of the crop, weed control will be inadequate if the herbicide is not applied correctly. Application factors to consider include:

- Calibration
- Even application
- Timing

In order to be effective, the correct amount of material must be applied to a given land area. This amount is always specified on the product label. Poor calibration of application equipment is a primary reason for poor weed control. Calibrate your equipment often to assure the correct amount of product is being applied.

Not only must the correct amount of material be applied, it must also be applied evenly over the surface area (soil or leaf) to be effective. This is a consideration for both ground and air applications. Overlap and misses are of constant concern with air application (along with off target application). Cantilevered booms are inherently unstable and instability increases with boom length. While moving along a dike the boom arm may move up and down and forwards and backwards resulting in uneven application. For liquids, if the nozzles are not evenly spaced or if they are spaced too widely striping of the field will occur.

Timing of application is the last area of concern. If pre-emergent herbicides are applied after weeds have germinated and begun to grow poor control will result. Timing of post-emergent herbicide applications is even more important: For crop safety, 2,4-D granular applications can only be made in the spring before growth begins. On the other hand, Roundup (glyphosate) will provide best control when application is made later in the season when more nutrients are translocated to the roots.

Herbicides are an important component of cranberry cultivation. Using these tools wisely will allow their use for a longer period of time and will provide better weed management. Most problems of non-control are related to improper use of a product.

**Table 1.** A comparison of pre-emergence herbicides labeled for Cranberry in Wisconsin.

| Herbicide Trade (common) | Solubility in water | Acute oral toxicity | Acute dermal toxicity | Weeds controlled | Degradation | Mode of action |
|---|---|---|---|---|---|---|
| Evital, (norflurazon) | low, 28 ppm @25°C Not easily leached, adsorbed by clay & OM | 8 g/kg | 20 g/kg | Annual grasses and broadleaves | In soil, degraded by soil microorganisms. Also volatilization & photodecomposition. Half life[z] is 45 to 140 days depending on soil conditions. | Inhibits biosynthesis of carotenoid pigments that protect chlorophyll. Susceptible seedlings emerge with yellow leaves and die. Cranberry is not susceptible because it can metabolize Evital. |
| Devrinnol, (napropamide) | 73 ppm @ 20°C Resists leaching | >5g/kg | >4.6 g/kg | Most annual grasses & many broadleaf weeds | Slowly decomposed in soil by microbes. Half life in loam soil of 8 to 12 weeks. | Exact mode of action not known. Inhibits development and growth of roots, particularly grass roots. Metabolized in mature plants. |
| Casoron, (dichlobenil) | 18-25 ppm @ 20°C Attaches tightly to OM, won't leach | 2.4 g/kg | 1.3 g/kg | Many broadleaf, grass and sedge weeds. | Slowly decomposed in soil by microbes. Half life in soil of 2 to 12 months | Inhibits growth of rapidly dividing tissues such as shoot or root tips. Inhibits phloem transport. Translocates quickly in xylem from roots to leaves & tips. Also absorbed in vapor phase by leaves. |
| Princep, (Simazine) Triazine | 5 ppm @ 20°C Adsorbs to clay and OM in soil. May leach, little lateral movement | >5.0 g/kg | >3.1 g/kg | Emerging annual grass & broadleaf weeds. | Persistent and active in soil for extended periods. Sometimes > 1 year | Inhibits photosynthesis by interfering with electron transport. |

z. Half life is defined as the length of time it takes for half of the material originally present to be gone.

**Table 2.** A comparison of post-emergent herbicides labeled for cranberry in Wisconsin.

| Herbicide & class Trade (common) | Solubility in water | Acute oral toxicity | Acute dermal toxicity | Weeds controlled | Soil Degradation | Mode of action |
|---|---|---|---|---|---|---|
| Roundup, (glyphosate) | 1.2% @25°C | 4.3 g/kg | 7.9 g/kg | Any green tissue. Selectivity is by selective application | Degraded by microbes in the soil, nonpersistent. | Inhibits the formation of some essential amino acids. |
| Touchdown (sulfosate) Non-bearing only | miscible | 0.78 g/kg | >2 g/kg | Any green tissue. Selectivity is by selective application. | Degraded by microbes in the soil, nonpersistent. | Inhibits the formation of some essential amino acids. |
| Poast, (sethoxydim) | 48 ppm @25°C | 2.7 to 3.1 g/kg | Little or no reaction | Actively growing grasses | Persistent in soil only 4 to 5 days | Inhibits lipid synthesis by blocking acetyl-CoA carboxylase. As a result treated plants can't repair or create new membranes. |
| Fusilade, (Fluazifop-P-butyl) | 2 ppm @25°C | 3.3 g/kg | >2 g/kg | Actively growing grasses | Some persistence in soil. Half life [z] of about 3 weeks. | Inhibits lipid synthesis by blocking acetyl-CoA carboxylase. As a result treated plants can't repair or create new membranes. |
| Weedar 64 Weed Rhap 20G (2,4-D) | 900 ppm @25°C | 0.3 to 1.0 g/kg | — | Broadleaf weeds | Degraded by soil microbes. Adsorbed onto clay and OM in soils. Persists in soil for 1 to 4 weeks. | Exact mechanisms unknown. At low concentrations growth and abnormal RNA produced. At high concentrations growth and RNA production reduced. |

z. Half life is defined as the length of time it takes for half of the material originally present to be gone.