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Weed Biology

Weeds, by definition, are plants out of place. A plant that is desirable in one setting may be considered a pest elsewhere. A red oak is a perfectly desirable tree in many landscapes and along city streets. However, a red oak too close to a country road or highway causes sight distance problems, and is a collision hazard.

Roadside managers must be able to distinguish between desirable and undesirable plants. The objective is to encourage plants that provide benefits to the roadside while discouraging plants that hinder roadside safety and function.

To most effectively control weeds we must know what they are and how they grow. By knowing how a plant grows, you know when a plant is most vulnerable to control measures. There are over a thousand species of plants growing along PA roadsides, and each is unique. However, to make managing vegetation easier, we can place plants into a few categories that describe traits we need to know to control them. Two common methods are to describe plants by their *life cycle*, and their form, or *anatomy*.

Plant Life Cycles

The life of a plant can be divided into a *vegetative* phase, and a *reproductive* phase. During vegetative growth, a plant produces new stems, leaves, and roots. Reproductive growth is the production of flowers and seeds. Preventing reproduction is a primary goal of weed management, so preventing weeds from flowering and producing seeds is a high priority.

Some weeds are more difficult to control because they can reproduce by seed and *vegetatively*. Vegetative reproduction describes forming new plants from a vegetative part of an existing plant, such as the roots or stem.

Plant life cycles are described as *annual*, *biennial*, or *perennial*. These labels describe the lifespan of the plant and also provide some information on how they reproduce.

Annuals

Annual plants complete their life cycle in one growing season, and reproduce only by seed. Annuals

Figure 1: The remains of the summer annual plant kochia in winter. The seed matures at the end of summer and drops from the plant during the fall and winter.

are commonly described as being summer or winter annuals. However, some species can behave as either, and could be described as 'anytime annuals'.

Summer annuals

These plants germinate in spring, grow vegetatively through summer, and then set seed in the late summer. Most summer annuals die with the onset of hard frosts. Examples of summer annual weeds include common ragweed, crabgrass, giant foxtail, and kochia (Figure 1).

Winter annuals

Winter annuals germinate in late summer or fall, and overwinter as a *rosette*. In the rosette stage, the stem of a plant does not elongate so all the leaves are close to the ground (Figure 2). Early the next spring the plants 'bolt' (the stem elongates), flower and set seed, then die. Common winter annuals include yellow rocket and downy brome.

Biennials

Biennials need to overwinter to complete their life cycle, and they reproduce solely by seed. The difference between a biennial and a winter annual can be indistinct sometimes, and it is not uncommon to see some plants listed as being either, or both. A plant considered to be a biennial will usually germinate in the spring or early summer, overwinter as a rosette, then

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Figure 2: The overwintering rosette form of the winter annual yellow rocket. In the early spring the central stem will elongate (bolt), and the plant will flower, set seed, and die.

bolt and flower in late spring or summer.

Biennials live longer than annuals, grow bigger (Figure 3) and can produce more seed.

Common examples of roadside biennials include wild carrot, burdock, bull thistle, poison hemlock, and white sweetclover.

Perennials

Perennial plants live for more than two growing seasons. The difference between a perennial plant and an annual or biennial is a *perennating structure* - a plant part that allows the plant to regrow after it has completed its annual growth cycle or been injured. A common example of a perennating structure is the taproot of the common dandelion. New rosettes form from buds on the crown at the top of the taproot, and - as almost everyone has experienced - if the plant is pulled but a piece of the taproot remains, new shoots form from the top of the remaining root piece.

Like annuals and biennials, perennials reproduce by seed, but many can also reproduce vegetatively. Plants that can reproduce from root or stem pieces can be more difficult to control because quite often the part of the plant that needs to be controlled is underground.

Perennial plants can be divided into three groups: herbaceous perennials, brambles, and woody plants.

Herbaceous perennials

Plants with non-woody shoots are called *herbaceous*. Herbaceous perennials take many different forms, with different strategies for overwintering.

Canada thistle and Japanese knotweed (Figure 4) are examples of plants where the shoots arise from roots or rhizomes each season, and there are no overwintering stems aboveground.

Dandelion and chicory are examples of herbaceous perennials that have a perennial taproot, and produce new rosettes from crown buds.

The roots and stems of common perennial grasses such as tall fescue or Kentucky bluegrass may live less than one year, but the plant lives from year-to-year by continually giving rise to a new generation of daughter-plants from buds on the stem base of the current plant.

Brambles

Blackberries and raspberries are common examples of brambles. These plants have perennial root systems, and stems (canes) that live two seasons. Cane growth the first season is vegetative. During the second season new growth initiates from buds located on the existing canes. These buds produce new foliage, flowers and fruit. After flowering and fruit set, the cane dies.

Woody perennials

Woody perennials, as the name implies, have persistent, woody stems that do not die back to the ground every winter. They resume growth each season from buds on their stems (*primary growth*, see Figure 5). All but a few woody species also undergo *secondary growth*, which is an annual increase in diameter. Secondary growth produces the annual growth rings you see when you look at a cross-section of a cut log or stump.

Figure 3: A patch of rosettes of the biennial poison hemlock in the spring, with 7-foot tall dead stems from the previous growing season still present. Biennials usually grow for most of two growing seasons, and generally grow bigger and produce more seed than annual plants.

Figure 4. New shoots arising from a rhizome of Japanese knotweed, an herbaceous perennial. The large central shoot died back at the end of the previous growing season. Small pieces of knotweed rhizome will give rise to new plants.

Woody plants are usually categorized as trees or shrubs. Trees are typically taller and grow from a single trunk, or a few trunks. Shrubs are shorter and have multiple stems or branch very close to the base of the trunk, producing a shorter, rounded form.

Trees and shrubs can be described as *deciduous* or *evergreen*. Deciduous plants shed their foliage at the end of each growing season. Trees such as red oak and red maple are deciduous. Evergreens retain green foliage for more than one year, so that last year's foliage is still present when new growth begins in the spring. White pine, Eastern hemlock, and rhododendron are common examples of evergreen plants.

Grouping Plants by Form

Another way to categorize plants is by *anatomy*, or form. We will review the scheme that taxonomists use to classify plants, and then use these groups to describe the plants that have an impact on roadside management.

Taxonomic Classification of Plants

Taxonomists compare the form of organisms to classify them into different levels of similar groups, or *taxa*. A familiar taxonomic grouping is the *kingdom*. At the kingdom level, we separate plants from animals. For the purpose of describing distinct organisms, the basic taxonomic level is the *species*. Generally, a species is defined as a group of organisms that have a characteristic form and can interbreed to produce offspring that share the same form as the parents. The next level of grouping is called a *genus*, where species with similar characteristics are grouped together. At the genus level, we distinguish oaks (*Quercus*) from maples (*Acer*). At the species level, we distinguish between a white oak (*Quercus alba*) and a red oak (*Quercus rubra*).

Table 1 lists terms often used to distinguish plants. Though not everyone's cup of tea, taxonomy is a fluid, dynamic science, and subject to much debate and change. If you read six different plant science books, you may encounter six slightly different taxonomic schemes to organize the plant kingdom.

Figure 6 provides a simplified version of plant taxonomy, showing how we distinguish the familiar categories of plants.

Vascular Plants

Below the kingdom level, plants are divided into the vascular and non-vascular plants. Vascular plants have distinct parts - leaves, stems, and roots - and a conducting system to move water and nutrients throughout the plant. Non-vascular plants, such as mosses, do not really factor into roadside management. They are certainly present, but they do not impact roadway function.

Seed Plants

Vascular plants can be divided into those that reproduce by external spores, such as ferns and the horsetails, and those that form seed. The seed is an embryonic plant, with preformed root and shoot, with reserve energy in its fleshy seed leaves (*cotyledons*), all contained in a protective shell. The seed is a survival structure. It allows plants to survive winter and periodic harsh growing conditions.

The seed plants are divided into groups that have flowers (the *angiosperms*) and those where the seed-forming organ is exposed (*gymnosperm*, which means 'naked seed'). The most common gymnosperms are the conifers - or cone-bearing plants. Familiar conifers

Figure 5: New foliage emerging in the spring from the buds of Tartarian honeysuckle, a woody perennial.

include pines, spruces, firs, and hemlocks.

Monocots vs. Dicots

The flowering plants are distinguished by the number of cotyledons that the embryonic plant has in the seed. Monocots have one seed leaf, and dicots have two. Mature dicots have net-veined leaves, and include trees and shrubs (except for the conifers and ginkgo) and many of the herbaceous plants we would call forbs, 'weeds', or 'wildflowers'.

Mature monocots usually feature narrow leaves and parallel leaf veins. Examples of monocots include lilies, cattails, sedges, rushes, palms, and bananas. The most important monocots to mankind are the grasses. The grasses are our most important food, feed, and conservation plants, and include crops such as rice, wheat, corn, and barley.

Why Plant 'Form' Matters

From a weed management point of view, the taxonomic scheme leaves us with three groups of plants - grasses, 'broadleaves', and 'others'. We tend to view the entire plant kingdom in these three categories because of which plants are important crops to us, and how plants respond to herbicides.

Herbicide use became one of the primary weed management tools in the late 1940's, with the introduction of synthetic herbicides such as 2,4-D. Since that time thousands of active ingredients have been discovered, and there are hundreds of unique herbicides available for use. Herbicides affect plants at the molecular level, and closely related plants are more similar at the molecular level. Some herbicides are selective - they injure some plants but not others - because of the similarity of related plants at the molecular level. For example, we can remove many non-grass weeds from grass areas because at the dosage used, the anatomical and molecular makeup of grasses prevents them from being injured.

This is why we bother to distinguish what type of plant a weed is. Sometimes it's not enough to know that a plant is an annual or perennial - we often need to know what *kind* of annual or perennial it is.

Grasses

Of the three 'functional' categories described above, the term *grass* has the clearest meaning. The grasses are a specific family (*Poaceae*) of monocots. Grasses feature mature leaves that are narrow with parallel veins, and simple wind-pollinated flowers that lack petals and sepals.

Grasses can be annual, such as crabgrass, foxtail, corn, or wheat; or perennial, such as tall fescue, Kentucky bluegrass, or switchgrass. Most grasses are herbaceous - the only woody grasses are the bamboos.

Table 1. Some common terms used to describe plants.

Taxa - The individual levels of classification in the taxonomic scheme. The order of taxa for plants, from broadest to most specific is Kingdom, Division, Class, Order, Family, Genus, and Species.

Angiosperm - A Division (*Magnoliophyta*) of the plant kingdom. These are seed bearing, flowering plants. The seed-forming organs are enclosed by the ovary. These are the most common plants along the roadside.

Gymnosperm – Translates roughly to 'naked seed'. Encompasses the divisions of seed bearing plants that are not angiosperms. Includes the conifers, cycads, and gingko. Unlike *angiosperm*, the term 'gymnosperm' is no longer used to describe a particular taxa.

Conifer - A division (*Coniferophyta*) within the gymnosperms that produces its seed in cones instead of flowers. Examples include pines, spruces, firs, hemlocks, yews, and junipers.

Cotyledon - Also known as a seed leaf. Cotyledons are fleshy leaves present on the embryonic plant within the seed of angiosperms. They provide energy for the young seedling before it forms new leaves and is able to support itself through photosynthesis.

Dicot – A class (*Magnoliopsida*) of the angiosperms distinguished by two cotyledons. Usually characterized by broad leaves with net-like veins. Most plants we think of as wildflowers, shrubs, and (non-coniferous) trees are dicots.

Monocot – A Class (*Liliopsida*) of the angiosperms distinguished by a single cotyledon. Many monocots are ‘grass-like’ – they have narrow leaves and parallel veins. Examples of monocots include grasses, sedges, and lilies, and most of the spring flowers that grow from bulbs.

Grass – Refers specifically to a single monocot family (*Poaceae*). Arguably the single most important plant family to mankind, due to our reliance on grasses for food, feed, ornamental and conservation purposes.

Broadleaf –The most precise (and most limited) definition equates broadleaf with *dicot*. Looser definitions add plants that can be injured by 'broadleaf' herbicides. The looser definition could be said to include trees, shrubs, wildflowers, vines, and ferns.

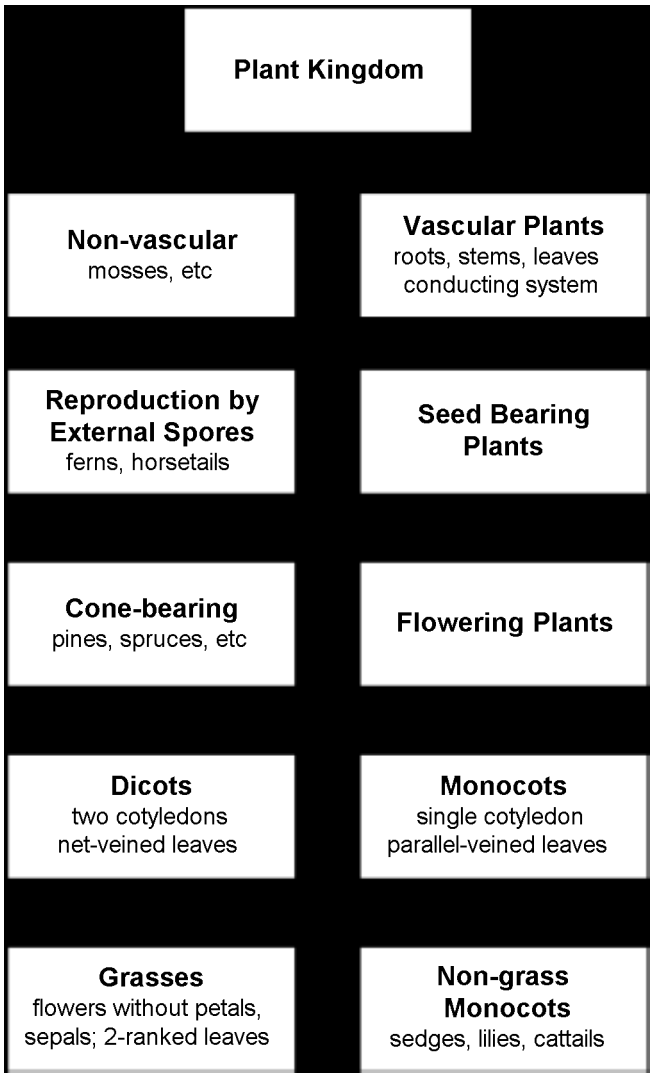

Figure 6. A simplified version of a plant taxonomic scheme, showing the common characteristics used to divide the plant kingdom into the plant groups we are familiar with.

Grasses are a category by themselves because of their agricultural and ornamental importance, and because there are many herbicides that will selectively injure non-grass weeds.

'Broadleaf herbicides' are those that can be used to selectively remove many weed species from grasses. To further enforce the idea that grasses are a unique plant group, there are herbicides that injure *only* grasses, leaving all other types of plants uninjured.

Broadleaves

The term 'broadleaf' has more than one definition. 'Broadleaf' is often equated with the *dicots*, which are a distinct taxonomic class (*Magnoliopsida*) of the angiosperms, or flowering plants. This is the narrowest, most precise definition.

The advent of synthetic, growth-regulating herbicides helped define 'broadleaf', because many of the commonly used herbicides, such as 2,4-D, could be applied at dosages that would control target weeds but not injure grasses. Plants that fall into the broadleaf category based on response to herbicides expands the list of 'broadleaves' to include the ferns and horsetails, the cone-bearing trees such as pines and spruces, and many non-grass monocots such as lilies and greenbriers. Based on this list, we could describe broadleaf plants as ferns, trees, wildflowers, and vines.

'Other' - Not Broadleaves, Not Grasses

If 'broadleaf' can include non-seed plants (ferns and horsetails), non-flowering seed plants (conifers), and monocots that are 'wildflowers' (lilies, etc), all that is really left for the 'other' category are the grass-like monocots such as sedges, rushes (rush, bulrush, beak-rush, spike-rush, etc), or cattails. Many of these plants are wetland plants, and with the exception of cattails, are less likely to be noticed on the roadside. Despite the fact that we regard these plants as less common, they are quite numerous in terms of species. The genus *Carex* (sedges) has more species than any other in Pennsylvania.

Managing Weeds

Now that we have described the differences between the weeds on the roadside, we can discuss how to use this information in a vegetation management program. The goal of the management program is to develop a sustainable groundcover, or plant community, that resists weed invasion and is easy to maintain.

Integrated Vegetation Management

Integrated Vegetation Management (IVM) is a way to take a structured approach to practicing preventive maintenance of vegetation. The objective of IVM is to develop a long-term program with well defined weed management priorities. The program works through clear objectives, using all available management tools, accurate records, effective inspection, and periodic adjustments to improve performance.

Defining Weed Targets

The key to developing an effective weed management program is to know why you need to control weeds. Your mission as a land manager determines what is a weed. On the roadside, weeds are plants that interfere with the function, safety, and maintenance of the roadway, degrade the environmental function of the ROW, and cause problems on adjacent properties.

Weed-resistant Plant Communities

The goal of a roadside vegetation management program is developing a groundcover that resists weed infestations, is relatively easy to maintain, and provides the necessary stabilization and erosion control.

The basic approach is to maintain a grass groundcover close to the roadway that can be maintained by mowing and by truck-based applications of selective herbicides. This provides a means to easily manage the vegetation that has the greatest impact on the motorist.

The area beyond this zone would require less maintenance, and could be maintained with selective backpack-based applications or mowing that could be performed much less frequently - perhaps every three to five years. The groundcover could be crownvetch, grass, or a mix of species creating a meadow-like plant community.

When managing specific weeds, it is important to distinguish between annual, biennial, and perennial plants when deciding the best control options. Each type of weed life cycle has specific periods when they are easiest to control (*Figure 7*). However, many roadside herbicide applications target a broad spectrum of weeds, so the operation has to be the best practical fit for many species.

Controlling Annual Weeds

The primary objective when managing annual weeds is to prevent them from going to seed. Treating annual weeds after they have ripened seed is a wasted effort. Summer annuals are best controlled in spring, and winter annuals are best controlled in fall. There is also a brief window of opportunity to treat winter annuals in the spring before they flower and set seed (*Figure 7*).

Weeds are easiest to control before they germinate or when they are young and small. Annual weeds can be controlled with *preemergence* herbicides that are applied to the soil prior to seed germination. Preemergence herbicides remain active in the soil and control weeds as they germinate. This is the primary means of keeping shoulders and guiderails free of vegetation through the season.

Annuals become more difficult to control with herbicides as they get larger. However, compared to perennial plants, even well developed annuals are susceptible to herbicides and are a viable target as long as they have not set seed.

The total vegetation control program is the one roadside program that primarily targets annual weeds. Guiderail areas are bare (and disturbed) by design, and weeds from seed are the most common targets. In areas with established groundcover, annual weeds are less common.

Controlling Biennial Weeds

In terms of control, biennials can be thought of as 'big annuals' (*Figure 7*). Once again, the key is to prevent seed set. It is easier to control biennials before they emerge, or when they are in the rosette stage. However, as long as biennials have not yet produced viable seed, they are a viable target. Because of their large size when they bolt, biennials can hinder sight distance on narrow ROW and intersections. Treating biennials when they have bolted may provide control, but the tall dead stems will remain, and sight distance may still be impaired.

Biennials are common in guiderail areas and also in non-mowed groundcover, especially in gaps and areas of thin stands.

Controlling Perennial Weeds

Perennial weeds are the most difficult to control. Qualities that make perennials more difficult to control include:

- already established – not growing from seed,
- perennating structure – ability to regrow after injury, and
- extensive underground growth.

The most vulnerable life stage of a plant is when it is a seedling. When a perennial species is starting from seed, the approach to controlling it is the same as for annual weeds. However, perennials are often already established when you target them for control. Therefore they are not susceptible to treatments that prevent germination and establishment.

If a control measure only injures a perennial weed, rather than killing it, the presence of a perennating structure allows perennials to regrow. Many perennials can regrow after their topgrowth is completely removed.

Many perennial species feature extensive underground growth of roots or rhizomes. Therefore, much of the plant is not injured when treatment occurs. Any perennial species that can produce new aboveground growth from its roots or rhizomes is almost impossible to control with mechanical methods. These perennials are usually best controlled by using herbicides that are *translocated* to the belowground portions of the plant after application.

Timing of Perennial Control Applications

The best time to treat perennials to control their root or rhizome system is when the sugars produced by photosynthesis are being sent to the root system.

Most translocated herbicides move with the sugars through the plants conductive system. This window of opportunity usually occurs after flowering and seed set.

When perennial plants initiate growth in the spring, the energy to produce the initial flush of growth comes from energy stored in the overwintering plant parts. At this stage, the sugars are moving 'up' in the plant to produce foliage. Once the plant has leafed-out significantly, the canopy is able to support itself through photosynthesis, and sugars begin to be diverted back to the roots. This is the growth stage when herbicide application becomes more effective.

There is considerable variation in the timing of perennial growth. Dandelions flower very early in the spring, and grow as a rosette for the rest of the season. Canada thistle often has two flushes of growth. The first flush begins flowering in late May, sets seed, and often dies back. A second flush of vegetative-only shoots appears later in the summer, and serves to recharge the root system until they are killed back by several hard frosts.

'Aboveground' vs. 'Belowground' Perennials

Another characteristic of perennial weeds that affects how to control them is the location of their perennating organ(s). Perennials that regrow from their roots or rhizomes could be called belowground perennials. Effective control of these plants requires killing the belowground organs. When making herbicide applications to belowground perennials, time the application for the part of the growing season when the plant's canopy is diverting the sugars produced by photosynthesis to the root system. The herbicides will move with the sugars, and injure or kill the roots or rhizomes.

Aboveground perennials would be woody plants that cannot produce new shoots from their root system. An example of this type of perennial would be Norway maple. If you treated the stem of a Norway maple with a basal bark treatment, it would be unable to regrow even though the roots would be alive. Norway maple, and many other woody plants regrow after cutting from dormant buds in the stem tissue. This is why it is critical to treat the stump with herbicide after cutting down trees. The stump treatment kills the remaining stem and the dormant buds.

Fitting the Weed Control Program to the Target Species

Roadside management programs cannot be tailored to treat every weed at just the right time. You select the herbicide mixtures and timings that will be most effective against as many of the weeds present on the roadside.

Each herbicide program will usually have a few species that are missed. The bareground program often is not effective at controlling perennial weeds that have only just begun to emerge at treatment. There is not enough leaf area to get effective postemergence activity, so typically the emerging shoots are burned off by the treatment. New growth from the unaffected root system quickly reemerges.

Common milkweed is often unaffected by turf weed control programs because it emerges after the application has been made.

Japanese knotweed is often only moderately injured by weed and brush applications because it is only effectively controlled by a few herbicides, and treatment needs to occur late in the season to be most effective.

When the weed program has species that are missed, you have to decide if special effort needs to made to control them. Knotweed is an example of a problematic species that is worthy of special control efforts.

Summary

You are best able to run an effective weed control program when you know what the weeds are and how they grow. This knowledge helps you develop an efficient program to deal with the weed problems in your area. Just as importantly, knowing the weeds and how they grow helps you figure out why some species break through the program.

Annual and biennial species reproduce only by seed, and the management goal for these species is to prevent further seed set. Control these species by preventing their germination with preemergence herbicides, or treating them with a postemergence application before they go to seed.

Perennial species can be managed like annual and biennials if they are growing from seed. Established perennials are a different story. The herbicides that prevent annuals and biennials from germinating do not prevent new growth from established perennials. You need to treat perennials when they are sending food to their roots or rhizomes for the most effective control.

Figure 7. Weed life cycle determines the best control opportunities. Each life cycle is depicted over the course of two growing seasons, with months shown at the bottom of the figure. The heavy black line under each life cycle indicates control opportunities. Summer annuals are best controlled prior to germination (preemergence) through the period of flowering. Control of annuals is not effective once the seed has ripened. Winter annuals are best controlled preemergence, or postemergence into the fall of the first season, and again when active growth resumes in the spring prior to seed set. Control opportunities for biennials are similar to winter annuals, but occur in a wider window of opportunity. Herbaceous perennials are depicted as growing from seed in the first season. Therefore there is an opportunity for preemergence control in the first season. In the second season, control opportunities begin when active growth occurs, allowing postemergence control.