Non-Selective Weed Control in Non-Crop Areas

PENN STATE

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Mention of products is for purpose of illustration. Inclusion of a product does not imply endorsement, nor does exclusion of a product imply lack of endorsement.

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Section One

Introduction

Non-selective weed control in non-crop areas, often referred to as Industrial Weed Control, or a variety of phrases including the term 'bare ground', or total vegetation control, is the practice of maintaining vegetation-free areas during the course of the growing season. Examples of sites where this is practiced include railroad ballast, highway shoulders and guiderails, fencelines, electrical substations, refineries, storage tank areas, pipelines, parking lots, tower bases, lumber yards, around signposts- any place where vegetation can grow, but function or maintenance is improved in the absence of vegetation.

The reasons to control vegetation are many and varied. Examples include reduction of fire hazard, improved access and visibility, reduction of vermin habitat and cover, ease of maintenance, improved surface drainage, and aesthetics.

Industrial weed control is most often accomplished with herbicides. The art of industrial weed control is being able to apply herbicide treatments potent enough to prevent the growth of vegetation for the entire growing season, yet limit the activity of these treatments to very specific areas without affecting nearby non-targets. This is best accomplished through knowledge of the site to be treated and characteristics of available herbicides. This common sense approach is the basis of **Integrated Pest Management**, or **IPM**.

Section Two

Integrated Pest Management

IPM is a means to take a structured, holistic approach to common sense pest control. IPM stresses using all methods that are practically available, in a coordinated, or integrated manner, to manage pests. IPM also includes setting pest thresholds, or the amount that can be tolerated before control action is taken, and careful monitoring of pest populations and effectiveness of treatments.

Introduction to IPM

The stress is on the concept of *management*. Any ecosystem, whether it is a electric right-of-way, a corn field, a dairy barn, or a flower production greenhouse, has many natural forces interacting in a constantly changing manner. Nature does not stand still - it is a constant, inter-connected chain of action and reaction. IPM stresses encouraging the natural forces that work to our benefit, and acting to enhance these processes. IPM is not warfare - its goal is to be a series of gentle nudges to allow natural processes to assist us in producing a natural commodity, whether it's livestock, food or fiber, a hazard-free right-of-way, or a pleasing landscape.

Methods available to manage pests can be grouped into the following categories:

Cultural

Mechanical

Biological

Chemical

Cultural methods are practices to enhance the growth and vigor of the desirable species, whether it is a crop, turf, or livestock. When the desired species is more vigorous, it can withstand more pest pressure before there is a negative effect. Examples include practices such as fertilization, liming, proper planting dates, mowing heights and frequencies, and crop rotations for plant species; and practices such as proper feeding, housing, and waste management for animal species.

Mechanical controls physically remove or harm the pest species. Pulling, cutting, or digging weeds are examples of mechanical methods.

Biological control is the use of other organisms to control pest species. Predator and parasitic insects, as well as diseases are often used against insect pests. Insects have been introduced to feed on specific plant pests. Soil bacteria have been used to inhibit plant fungal diseases. Companion planting in the garden often pairs a plant that repels certain insects with a plant that is susceptible. These are just a few of the almost countless examples of biological control.

Chemical control is the use of pesticides. Examples of pesticides include insecticides, fungicides, herbicides, rodenticides, and nematicides. Pesticides are an extremely useful, but potent tool. It is essential to understand how a pesticide works to use it most effectively. Effective pesticide use must complement other control measures, not replace them. The use of chemicals to manage pests is the practice that really forces us to think about a coordinated approach to pest management, because poorly considered use of pesticides can have a detrimental effect on the efficiency of other methods, and can lead to the 'one step forward, two steps back' syndrome.

The proper coordination of the different control practices is what makes IPM. It is not enough to be able to list several practices that you are using to manage a pest. It is important to understand how these practices work together. For example, when managing insect pests, insecticides should be selected and applied in a manner that affects the pest, but preserves beneficial predaceous and parasitic insects. This can be a matter of material selection, application placement, or application timing. When managing vegetation with herbicides, it is important not to mow or mechanically disturb treated plants soon after treatment, so that the herbicide has an opportunity to move through the plant. Another example of method integration would be cut-surface herbicide treatments to control brush. When non-coniferous brush species are cut, they resprout vigorously with multiple stems. Within a few seasons, the brush is much denser and more problematic than it was before cutting. By simply adding the step of treating the cut surface with an herbicide to kill the roots, the process of cutting the brush becomes effective.

IPM and Total Vegetation Control

It may seem that IPM has no practical application in creating bare ground for the entire growing season. Although there are fewer elements of IPM involved in total vegetation control, there is ample need for an IPM approach. An IPM approach stresses using the proper material at the proper rates based on the conditions at the site. The less material you can use to achieve the goal of bare ground, the less likely you are to have off-site movement.

An application of IPM in total vegetation control is dividing treatment sites into three categories, based on vegetation present: normal, sensitive, and difficult. 'Normal' areas would be those where a typical industrial treatment including herbicides with considerable soil activity could be used with little risk, and would be effective on the vegetation present. 'Sensitive' areas would be those areas where non-targets are in close proximity to the treatment area, and the risk of causing damage with highly soil-active herbicides is unacceptable. Sensitive areas would be treated with herbicides that would control weeds coming from seed, but with little or no activity against nearby desirable plants. Areas designated 'Difficult' would contain plant species that would not be controlled with a typical bare ground herbicide mix, such as brush, or herbaceous species such as Japanese knotweed (*Polygonum cuspidatum*). Rather than treating the entire site with a mixture potent enough to control extremely difficult species, it is better to spot-treat the difficult species, and use a less potent mixture on the bulk of the area.

Site mapping will be covered in more detail after we have discussed site characteristics, the properties of available herbicides, and application techniques.

Section Three

Site Characteristics

Effective total vegetation control is a combination of efficient utilization of available resources, and knowledge of the site to be treated and of the properties of the available herbicides. This section will discuss characteristics of the site that affect vegetation control. For this discussion, site characteristics will be categorized as vegetation, climate, soil, water movement, and proximity to non-targets.

Vegetation

The nature of the vegetation present at a site is one of the most important factors in determining the most appropriate herbicide treatment. A site populated by well-established perennial vegetation would require a much different herbicide treatment than the same site that was free of well-established vegetation and required only control of seedlings and preventing weeds from seed.

In terms of control measures, vegetation can be functionally grouped into the following categories:

Established

Seedling

Seed

Before discussing these categories of vegetation, we should review a few points of basic plant biology that play a role in our control practices. Plants are classified as annual, biennial, or perennial, based on their life cycles.

Annuals live one growing season, and reproduce by seed only. Summer annuals germinate in the spring or early summer, and complete their life cycle before winter. Winter annuals germinate in the fall, overwinter, then complete their life cycle in the early spring. The most effective management programs prevent annuals from going to seed, so that the population of viable seed in the soil is not increased. Examples of annual weeds are listed below:

Summer Annual Weeds

horseweed, marestail	*Conyza canadensis*
common ragweed	*Ambrosia artimisiifolia*
common lambsquarters	*Chenopodium album*
pigweed(s)	*Amaranthus* spp.
prickly lettuce	*Lactuca serriola*
giant foxtail	*Setaria faberi*
smooth crabgrass	*Digitaria ischaemum*

Winter Annual Weeds

shepherdspurse	*Capsella bursa-pastoris*
yellow rocket	*Barbarea vulgaris*
common groundsel	*Senecio vulgaris*
Japanese brome	*Bromus japonicum*
downy brome	*Bromus tectorum*

Biennials are plants that live for two growing seasons and reproduce only by seed. Typically, biennials germinate in the spring, grow close to the ground without stem elongation (rosette) the first season, overwinter, then elongate or 'bolt', flower, set seed and die. The distinction between what is a winter annual and what is a biennial is often a gray area. Management of biennials is much like annuals, with the emphasis on preventing seed production. Biennials tend to grow much larger than annuals, so it is much easier to control them during their first season while they are still somewhat small. Examples of biennials are listed below.

common burdock	*Arctium minus*
white, and	*Melilotus alba*
yellow sweetclover	*Melilotus officinalis*
bull thistle	*Cirsium vulgare*
musk thistle	*Carduus nutans*
teasel	*Dipsacus sylvestris*
wild carrot	*Daucus carota*
poison hemlock	*Conium maculatum*
wild parsnip	*Pastinaca sativa*
spotted knapweed	*Centaurea maculata*

Plants that live more than two years are considered perennial. Perennials can be woody, or herbaceous (non-woody). Some perennials reproduce only by seed, such as dandelion (*Taraxacum officinale*). Many species can also reproduce without flowering, or vegetatively. Examples of vegetative propagation and species are listed below.

Shoots from Spreading Roots

Canada thistle	*Cirsium arvense*
tree-of-heaven	*Ailanthus altissima*
black locust	*Robinia pseudoacacia*

Rhizome (creeping, underground stems)

quackgrass	*Elytrigia repens*
Japanese knotweed	*Polygonum cuspidatum*
Johnsongrass	*Sorghum halepense*
common reed	*Phragmites australis*

Stolon (creeping, above-ground stems)

white clover	*Trifolium repens*
creeping bentgrass	*Agrostis palustris*

Bulb (enlarged stem bases)

wild garlic	*Allium vineale*

Let us reconsider the vegetation categories outlined above, Established, Seedling, and Seed. It should be our goal to manage our sites over time so that each year we are trying to control seedlings and prevent weeds from seed. If we eliminate established vegetation from a site, we can rely much less on the more potent, long-lasting herbicides that have more potential for off-site damage.

In terms of control, a seedling is a seedling, whether it is tree-of-heaven, or giant foxtail. The seedling growth stage of any plant is when it is most susceptible to control measures. When the vegetation on a site is in the seedling stage, an herbicide treatment can be limited to a preemergence material to control weeds from seed, and a relatively low rate of a postemergence material to control the emerged seedlings.

When sites can be brought 'under control', that is, free of established vegetation, your primary decisions deal more with when to start the application season, rather than how to deal with problem vegetation. Starting earlier in the season allows you to finish sooner, and use less postemergence product. Starting later in the season allows you to reduce your preemergence rates because you have essentially shortened the period of time they need to work.

When dealing with established vegetation, knowing *what* the vegetation is on a site will provide an idea of how difficult it will be to actually control. Established perennial species are more difficult to control because they are more capable of regenerating new shoots from roots, crowns, or stem sections than annuals; particularly if they are species that spread vegetatively by the methods listed above. A common example of the regeneration capabilities of perennials is dandelion. If you pull off the top, and even get a large piece of the top of the root, it is capable of regenerating several stems from the root piece left over. Annual species lack this capacity to regenerate, even those with large taproots.

Some perennial species are extremely difficult to control, such a Japanese knotweed (often referred to as 'bamboo', or fleeceflower), or spreading woody species such as sumac or tree-of-heaven. When species such as these are present on a site in isolated areas, it is best to treat them with a separate treatment, rather than treating the whole site with an herbicide combination that is more potent than necessary for most of the site. Simple application options for these spot treatments include granules, spot concentrate, and low-volume applications with a backpack. These will be discussed in more detail in later sections.

Climate

Climate is the average weather conditions for a site, describing temperature, rainfall, and wind. Climate plays a role as a site factor in the planning stages of a contractors application season, particularly if you treat sites in a fairly large region. In Pennsylvania, annual rainfall is similar across the state, so climate as a site factor is probably most important in determining plant growth stage at a given time (Figure 3.1). This is more of a consideration if you treat sites over a large region of the state, and your spray mix is designed for a narrow application window.

Plant development may be two to three weeks different between the warmest and coldest parts of Pennsylvania. Under good growing conditions, two weeks can make a significant difference in plant development, and could require an increase in application rates, or an additional herbicide if the vegetation is beyond the stage the mix was designed for.

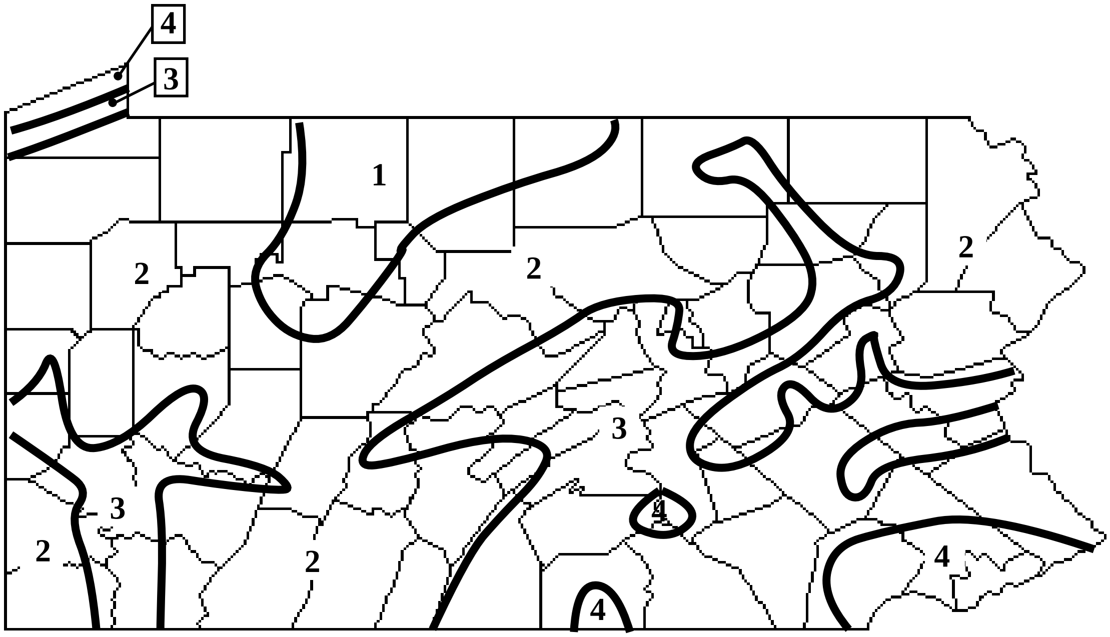

Figure 3.1: Average frost-free days in Pennsylvania.

1 = 84 - 112 days 2 = 112 - 140 days 3 = 140 - 168 days 4 = 168 - 196 days

Soil

The nature of the soil on a site determines how effectively herbicides will stay where they are applied. The composition of the soil will affect how the herbicide interacts with the surface, and how it moves through the soil.

The texture, or particle size of a surface plays a key role in determining how well herbicides can be adsorbed, or held onto the surface. Fine-textured soils have a greater surface area per given volume than coarse-textured soils, and are better able to retain herbicide.

Soil is composed of three size classes of particles - sand, silt, and clay. Listed below are the size ranges of the three types of soil particles, in millimeters (mm):

sand 2.0 to 0.05 mm

silt 0.05 to 0.002 mm

clay <0.002 mm

Consider a cube-shaped stone that is 1.0 inch per side. It has six faces, each with a surface area of 1 square inch (in^2), for a total surface area of 6 in^2. If that same 1-inch cube was divided into sand-sized cubes, 1 mm to a side (approximately 25 mm per inch), it would have a total surface area of 150 in^2. If the 1-inch cube were composed of silt-sized cubes, 0.01 mm to a side, it would have a total surface area of 15,000 in^2 (104 square feet). Finally, if the 1-inch cube were made up of clay sized cubes 0.001 mm to a side, it would have a total surface area of 1,040 ft^2. Table 3.1 summarizes the relationship between soil particle size and surface area.

Table 3.1: Relationship between soil particle size and surface area. For each example, a 1-inch cube is subdivided into smaller cubes corresponding to particle sizes for sand, silt, and clay. Total surface area of the 1-inch cube composed of these smaller cubes is listed.

Particle Type	Particle Diameter mm	Particle Diameter inches	Total Surface Area in a 1-inch cube (square inches)
Stone	25	1	6
Sand	1	0.04	150
Silt	0.01	0.0004	15,000
Clay	0.001	0.00004	150,000

Table 3.1 provides an illustration of the effect of particle size on surface area, but it does not really reflect the contribution of clay to soil surface area. The calculations in Table 3.1 are based on hypothetical cube-shaped particles. This is not unreasonable for sand and silt, which are usually small fragments of the soil's parent material. Clay particles, however, are not just very small fragments of the parent material. Clay particles are formed as the soil is developing. Its components, silica, aluminum, oxygen, and hydrogen; form into thin, sheet-like particles that behave very differently than sand and silt particles.

Because clay particles are sheet-like, they have much more surface area than if they were more like spheres or cubes. Table 3.2 compares the effect of particle shape on surface area, using a sheet of 8-1/2 by 11 inch paper, 0.01 inch thick as the example. This piece of paper would have a volume of 0.94 cubic inches and a surface area of 187 square inches. A cube and sphere with the same volume would have surface areas of 5.7 and 4.6 square inches, respectively. This tremendous surface area explains why clay particles have such an impact on the physical and chemical properties of soil.

Table 3.2: Effect of shape on the surface area of particles with the same volume. The comparison is based on a sheet of paper, 8.5 by 11 inches, 0.01 inches thick as the 'Flat' particle dimensions.

Particle Shape	Particle Volume (cubic inches)	Particle Surface Area (square inches)
Flat	0.94	187
Cube	0.94	5.7
Sphere	0.94	4.6

A more representative approximation of a clay particle would be to take the 0.001 mm sub-cube from Table 3.1, that was used to approximate a clay particle, and slice it into between 100 and 1000 sheets. This would increase the surface area of the soil in just that cube between 34 and 334 times.

The effect of clay on herbicide is not just increased surface area. Clays are also chemically reactive. Each individual layer of a clay particle is actually made up of a sandwich of positively-charged silica or alumina ions between outer layers of oxygen or hydroxyl (oxygen plus a single hydrogen) ions that are negatively charged. The charges at the edges of these sheets are not balanced, as they are in the center of the sheets, so the edges tend to be negatively charged. In addition, as the sheets are forming, there is occasionally insertion of alumina ions where silica ions should be, or magnesium substitutes for alumina. Alumina has less positive charge than silica, and magnesium has less positive charge than alumina. This substitution reduces the positive charge, and increases the net negative charge.

This net negative charge of clay particles is what creates the **Cation Exchange Capacity**, or **CEC**, of a soil. The CEC is a measure of a soil's ability to adsorb positively charged molecules. This is very important for soil fertility, because nutrients such as potassium, calcium, and magnesium are positively charged.

The other cause of CEC in a soil is organic matter, often referred to as humus. Humus is a general term that refers to a variety of organic molecules that result from the digestion and decomposition of organic residues. Humus is quite resistant to further decomposition, and has a net negative charge. It improves the structure of soil by encouraging the aggregation of smaller soil particles, and improves fertility by providing an adsorption site for positively charged nutrients.

We see then that fine textured soils high in clay, or organic matter have more capacity to bind herbicides in place. In fact, many soil herbicide labels recommend higher rates in fine textured soils because the soils reduce the availability of the herbicides for root pick up. The presence of clay, or particularly organic matter at the surface of the soil will also the slow the rate at which an herbicide can move into the soil, or reduce the overall amount of herbicide that is able to move into the zone where the germinating seeds are.

Most industrial sites, however, have coarse-textured soils, often having gravel surfaces, or even pavement. As can be seen in Table 3.1, stone has very little surface area per unit volume, and therefore very little capacity to adsorb herbicide. Yet, most total vegetation control applications rely on potent soil active herbicides at rates high enough to provide control for an entire growing season. Industrial weed control, then, is often the combination the herbicides most capable of causing off-site damage and the sites least capable of retaining these herbicides.

Therefore, it is critical to evaluate the surface of a site when determining what herbicides to use. If you are treating cracks or seams in asphalt or concrete, be aware that nearly all the herbicide that is deposited on the surface will wash off. Herbicide that does not wash into the cracks or seams will be carried to adjacent areas. The same is true of highway guiderail applications where the guiderail is very close to the pavement, or actually installed in the pavement. If herbicide is applied to the pavement, or to a thin layer of anti-skid material on top of pavement, these sites have little capacity to retain herbicide and much of it can be carried away.

Water Movement

Water is an essential component of total vegetation control. Most herbicides are applied in water. Most herbicides need to be washed off the surface and into the soil with rainfall to be effective. Unfortunately, most herbicides can also be carried away from the application site in water. Therefore, it is important that we have an understanding of the water movement characteristics of a site

Water movement can be categorized as surface movement; or sub-surface movement, which we might normally refer to as percolation, or drainage Whether considering surface or sub-surface movement, water movement is related to the pore space properties of the soil. Water movement in large pores, called macropores, is due to gravity, and is quite rapid. In small pores, called micropores or capillary pores, the attraction of water to the sides of the pore is stronger than the pull of gravity. Movement in micropores is much slower than in macropores, and is due to forces other than gravity.

The ability of water to infiltrate into a soil is dependent on the amount of macropores at the surface of the soil. A soil can have a very high proportion of macropores, but have little water able to move through it because the macropores do not extend all the way to the surface. When water is applied to the soil surface faster than the water can infiltrate, water accumulates at the surface and runoff occurs. If the amount of runoff is great enough, herbicide applied to the soil surface can be re-suspended, and carried with the water.

When evaluating sites, look at the lay of the land. Water that cannot enter the soil will follow the slope. Look for areas where moving water will concentrate, such as drainage swales. Keep the function of the site in mind. Some areas, such as highway shoulders, are designed for runoff. Areas that could have a lot of water moving across them should not be treated with herbicides that are likely to cause off-site damage if they are carried away.

Water movement through the soil can be as much of a concern as runoff. If too much water moves through the soil, herbicide can be leached out. This is a problem because the herbicide is no longer where it should be, so weed control is diminished. It is also a problem because the herbicide may be where it should not be. If the water table is shallow, the herbicide may end up in the ground water. If the site has a subsurface drainage system, the herbicide may end up in the waterways and retention areas.

It may seem that when you consider the potential for off-site movement due to water, there is no safe way to apply residual herbicides the soils typical of industrial sites. However, the vast majority of applications are effective. Losses of herbicide due to water movement happen in extreme cases, usually when very intense storms occur shortly after application. Even in coarse soils, there is a capacity to retain herbicide (see Figure 3.3), if moderate rainfall occurs to move the herbicide from the surface into the upper layers of the soil.

An appreciation for how water movement can affect herbicides should allow you to avoid likely problems; rather than keep you from working in challenging situations.

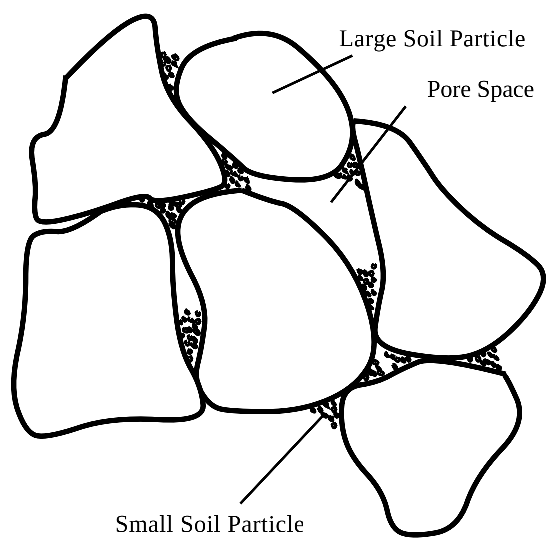

Figure 3.3: Even in coarse-textured soils, there will be finer textured particles present, increasing the surface area of the soil, and its ability to retain herbicides.

Proximity to Non-Targets

To be successful, an industrial weed control application must affect only the targeted area. To achieve a successful result, you must be aware of the potential for the herbicide application to affect non-target areas. Many problems with potential off-site movement or injury can be addressed by properly evaluating the site's soil and water movement conditions. Prevention of spray drift during application is another step that will prevent damage to non-target plants.

Simply keeping the applied herbicides within the boundary of the site is not always enough to prevent off-site damage. The roots of off-site trees and shrubs may extend into the treated area. The root system of trees and shrubs may extend two to three times farther than the drip line (Figure 3.4). Therefore, it is essential to scout the site and identify all the desirable plant material that is near the site to be treated. Where desirable vegetation closely borders the site, a buffer area should be established. This buffer area would not be treated with herbicides that could be picked by the roots of the desirable plants. Treatments in the buffer zone would be limited to postemergence herbicides with little soil activity, and preemergence herbicides that stay near the surface of the soil and control seedlings only.

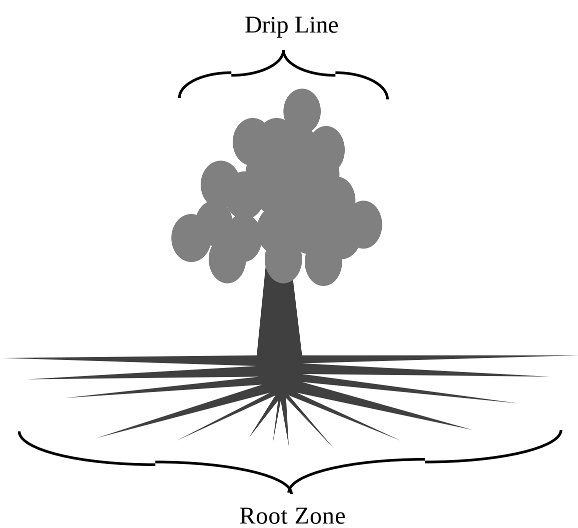

Figure 3.4: The root system of trees and shrubs extends two to three times farther than the drip line. Herbicides that can be taken up by roots and injure trees and shrubs should not be used in areas of industrial sites where roots of non-target plants may occur.

Section Four

Herbicide Characteristics

Herbicides can be classified in many ways. We can classify herbicides into chemical families based on their structure and activity. Though useful to scientists and technicians in the field of weed science, this detailed a knowledge of herbicides is not necessary to use them effectively. It may be more practical to classify herbicides into comparative categories such as soil applied vs. foliar applied, preemergence vs. postemergence, selective vs. non-selective, or contact vs. systemic. Table 4.1 provides a brief definition of each of these terms. A problem with simpler categorizations such as these is sometimes a herbicide can fall into both categories. For example, imazapyr has both soil (root uptake) and foliar activity, and can be used pre- or postemergence. Whether an herbicide is selective or not is often dependent on application rate. The term 'Selective' becomes further complicated because we must distinguish between a selective herbicide, and a selective application - a non-selective herbicide can be selectively applied. The distinction between contact and systemic activity is not always clear cut. In this publication, we will categorize herbicides based on their intended role in a bare ground application.

Table 4.1: A brief definition of terms used to distinguish herbicides. There is considerable overlap between many of the terms.

Soil active - herbicides that are taken into the plant from the soil. Most are absorbed by the roots, some by emerging shoots.

Foliar - herbicides that are taken into the plant after application to the leaves and stems.

Preemergence - soil active herbicides that are applied prior to emergence, and act on weeds as they germinate.

Postemergence - herbicides that control weeds after they emerge. They can be foliar and/or soil active.

Selective - an herbicide that does not control all vegetation. It can be used to control one type of plant, while not harming another. Selectivity is not necessarily an inherent chemical character of an herbicide - selectivity can be due to application rate or timing.

Non-selective - an herbicide that injures all vegetation.

Contact - an herbicide that injures only the portion of the plant it contacts.

Systemic - an herbicide that moves throughout the plant, able to cause injury away from where it contacted the plant.

For industrial weed control applications, we can categorize herbicides as broad spectrum residual, preemergence, and postemergence. The definition of some of the terms is narrower in this scheme. For example, herbicides classed as 'Broad Spectrum Residual', and 'Preemergence' are both effective as preemergence herbicides. For our purposes, however, we use the term 'Preemergence' to describe a group of herbicides that control weeds from seed, but have little or no activity on established weeds - to be effective, these herbicides must be applied prior to (or very soon after) emergence.

Broad Spectrum Residual - non-selective; remain active in the soil after application; active against established vegetation.

Preemergence - remain very close to soil surface; for control of seedlings; not effective on established vegetation.

Postemergence - taken up through foliage, effective against established vegetation.

For our discussion of herbicides, the common names, or active ingredient, will be used. Reference to rates will be in active ingredient, unless specified otherwise.

Broad Spectrum Residual (BSR) Herbicides

BSR herbicides are non-selective, and remain active in the soil after application. These are the herbicides that are sometimes referred to as 'soil sterilants'. This is a poor description of these herbicides for two reasons. First, BSR's do not sterilize the soil. They act on growing plants. They do not kill ungerminated or dormant seeds. They do not kill the other organisms in the soil, such as fungi, bacteria, nematodes, earthworms, and insects. It is soil fumigants such as methyl bromide, metam sodium, and dazomet that are used to sterilize soil. Second, the use of herbicides is a source of concern for many people, and inaccurately characterizing herbicides as being more toxic than they are is poor public relations.

BSR's are useful to control established vegetation and prevent germination of additional weeds. Like most technologies that are very potent, BSR herbicides can cause serious problems if they are misused. Due to their potency and long life in the soil, they can cause considerable damage if they move off-site after treatment. These herbicides should only be used in the amounts needed. When sites are fairly free of established vegetation, BSR use should be reduced or eliminated in favor of a combination of preemergence and low-residual postemergence herbicides.

Examples of commonly used BSR herbicides include sulfometuron methyl, imazapyr, bromacil, tebuthiuron, and prometon. The common name, product example, and mode of action of BSR herbicides is summarized in Table 4.1.

Table 4.1: Examples of broad spectrum residual (BSR) herbicides for non-crop weed control applications, listed by mode of action (italicized type).

Herbicide	Product Example
Enzyme Synthesis Inhibitors	
sulfometuron methyl	Oust
imazapyr	Arsenal
Photosynthetic Inhibitors	
bromacil	Hyvar X
hexazinone	Velpar L
prometon	Pramitol
tebuthiuron	Spike

Sulfometuron methyl and imazapyr are examples of enzyme synthesis inhibitor herbicides. They act on plants by inactivating an enzyme that is required for the synthesis of three amino acids. There are 20 amino acids that serve as the building blocks of all proteins. Proteins are composed of hundreds, sometimes thousands of amino acids. All 20 amino acids are essential to the production of all proteins. When the plant loses the ability to produce any of these amino acids, protein synthesis stops. When protein synthesis stops, growth stops, and the plant slowly dies.

The enzyme synthesis inhibitor BSR's can be taken up through foliage or roots, providing pre- and postemergence activity. Sulfometuron methyl and imazapyr are relatively new compounds, and are used at rates much lower than the older photosynthetic inhibitor herbicides. Sulfometuron methyl is commonly used at rates of 0.09 to 0.19 lbs per acre, or 2 to 4 ounces of product per acre. Imazapyr is commonly used at rates of 0.5 to 1.0 lbs per acre, or 1 to 2 quarts of product per acre, to provide bare ground. Contrast these rates with those for bromacil and tebuthiuron, which will be used at rates from 3 to 6 lbs per acre. Prometon is used at rates starting at 10 lbs per acre.

Bromacil, hexazinone, prometon, and tebuthiuron are photosynthetic inhibitors. Hexazinone can be readily absorbed through foliage, while the other three are taken up primarily through the roots, and are carried with the water stream to the leaves. Once in photosynthetic tissue, they block key steps in the photosynthetic process. Rather than being captured and converted to high energy 'fuel' molecules, light energy is converted into highly reactive molecules called free radicals. These free radicals damage cell membranes, causing death of the cell.

Photosynthetic inhibitors work relatively slowly, as they must move through the soil into the root zone before they can enter the plant. The length of time required to observe control of treated plants varies with size. Seedlings may be killed within a week. Affected trees go through a yellowing, then loss of leaves. They may put out a new flush of leaves several times before they finally use up all their energy reserves and die.

Preemergence Herbicides

Preemergence herbicides are used to prevent establishment of weeds from seed. Some preemergence herbicides will also provide control of seedlings. Preemergence herbicides stay very close to the soil surface. This is due to the low solubility of these herbicides, or their ability to bind strongly to soil particles, or both. Preemergence herbicides do not control established vegetation, which is why many can be used to prevent weeds from seed in landscape beds or turf.

Table 4.2: Examples of preemergence herbicides for non-crop weed control applications, listed by mode of action (italicized type).

Herbicide	Product Example
Photosynthetic Inhibitors	
diuron	Karmex
norflurazon	Predict
Root Inhibitors	
oryzalin	Surflan
pendimethalin	Pendulum
prodiamine	Endurance
trifluralin	Snapshot 2.5 TG
Cell Wall Inhibitors	
isoxaben	Gallery

Diuron and norflurazon inhibit photosynthesis, very much like the BSR's bromacil and tebuthiuron - they are taken up the roots, and move with the water stream up to the leaves. However, they are much less potent, and at label rates do not pose near as much hazard as the BSR's if they move off-site. Diuron will control existing seedlings at the time of application.

The root inhibitor herbicides will not control seedlings that are present at the time of application. To be effective, root inhibitor herbicides must be in place in the soil prior to seed germination. They are taken up by the newly emerging root, and act on the plant by preventing cell division in the growing root tip. Therefore, the root system never develops, and the young plant dies. The root inhibitor herbicides are more effective on grasses than broadleaf weeds.

Isoxaben interferes with the formation of the cell walls in the germinating plant, causing grossly abnormal growth, and death prior to emergence. Isoxaben is used primarily for preemergence broadleaf weed control in ornamental beds and turf, but can be useful in industrial situations where bare ground must be maintained near desirable plants.

Postemergence Herbicides

Postemergence herbicides provide relatively quick control of existing vegetation, particularly if it is well established. Postemergence herbicides provide quicker activity because they enter primarily through the foliage. They enter the plant within minutes or hours after application, compared to the much longer time required for a soil active herbicide to move through the soil and be taken up by the roots. Many postemergence herbicides have very little, if any, soil activity. This allows you to control well established vegetation, and avoid the risks associated with herbicides that remain active in the soil for long periods.

There is a wide array of postemergence chemistry available for non-crop usage. We will categorize these materials by first distinguishing between **contact** and **systemic** herbicides, then examine the different types of systemic herbicides available. A summary of postemergence herbicides is listed in Table 4.3.

Table 4.3: Examples of postemergence herbicides for non-crop weed control applications, listed by mode of action (italicized type).

Herbicide	Product Example
Contact Herbicides	
pelargonic acid	Scythe
diquat	Reward
glufosinate	Finale
Enzyme Synthesis Inhibitors	
glyphosate	Roundup Pro
imazapyr	Arsenal
chlorsulfuron	Telar
metsulfuron methyl	Escort
Growth Regulator (Broadleaf) Herbicides	
2,4-D	many
dicamba	Vanquish
clopyralid	Transline
triclopyr	Garlon 3A
picloram	Tordon K
Lipid Biosynthesis Inhibitors (Grass Herbicides)	
fluazifop-p-butyl	Fusilade II
quizalofop-methyl	Assure II
sethoxydim	Vantage
Photosynthetic Inhibitors	
hexazinone	Velpar

The activity of contact herbicides is limited to where they are applied - they do not move through the plant. Contact herbicides are useful for controlling seedlings, and may control some annuals throughout the season. Contact herbicides will not control biennials and perennials, and even well established annuals will often regrow. Because they do not move in the plant, adequate coverage is essential for control.

Systemic herbicides move through the plant, or translocate. Herbicides that are truly systemic are transported through the plant's vascular system. The plant vascular system has two types of conducting tissue, xylem and phloem. The xylem is responsible for water and mineral nutrient transport from the roots to the leaves. Movement in the xylem is upward. The phloem transports the sugars and other complex organic molecules synthesized in the plant. Movement in the phloem is described as 'Source-Sink'. Sugars are transported from where they the synthesized - the source - to where the sugars are needed - the sink. The source of sugars are mature leaves. Strong sinks in a plant are the roots, newly opening leaves, and flowers and seeds. Herbicides that are phloem mobile can move throughout the plant, and can kill the entire plant, including the roots.

To be effective, whether contact or systemic, postemergence herbicides should be applied to actively growing plants. Plants growing slowly due to temperature stress, or suffering drought stress, are less likely to be controlled.

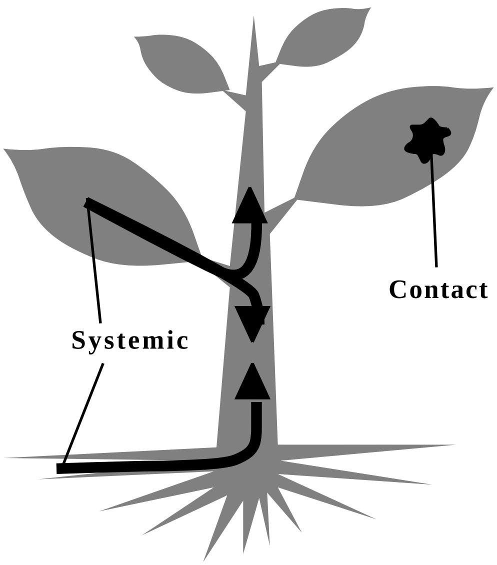

Figure 4.1: Contact vs Systemic Herbicides. Contact herbicides only affect the tissue where they are applied. Systemic herbicides can move throughout the plant. Systemic herbicides that move in the phloem are transported with photosynthetic products, and move up and down in the plant. Systemic herbicides that are striclyt xylem mobile move upwards with the water stream.

Diquat and pelargonic acid are examples of contact herbicides. They act very quickly. On a warm day, when plants are actively growing, the effects of pelargonic acid can be seen within minutes. Diquat often provides complete activity within 2 days. These materials work by damaging plant cell membranes. The fluid within the cell leaks out, and the tissue quickly desiccates and dies. This activity is limited to where the herbicide actually contacts the plant. These materials are effective when plants are small enough to be adequately covered by spray solution. Where dense canopies occur, these materials will burn off the top layer only.

Contact herbicides in combination with preemergence herbicides are an effective combination for early season application on sites that are free of biennial and perennial plants. The contact herbicides will effectively control seedling vegetation, and the preemergence herbicides will prevent further establishment of weeds from seed. Where well established annual vegetation, or biennials and perennials are present, systemic postemergence herbicides should be used instead of contact herbicides.

Systemic postemergence herbicides can be grouped as enzyme synthesis inhibitors; growth regulator, or hormone herbicides; fatty acid synthesis inhibitors; and photosynthetic inhibitors. The growth regulator herbicides provide selective control of broadleaf weeds, while fatty acid synthesis inhibitors selectively control grasses.

Examples of postemergence enzyme-inhibitor herbicides include glufosinate, glyphosate, imazapyr, chlorsulfuron, and metsulfuron methyl. Just as described for the enzyme synthesis inhibitor BSR herbicides, these herbicides prevent the synthesis of specific amino acids, resulting in the death of the plant.

Glufosinate would be best described as a locally-systemic herbicide. It does not move in the xylem or phloem, so its activity is limited to the leaves and stems where it is applied. Glufosinate will control vegetation that is more well established than the contact herbicides, and may control some perennial species. Generally, glufosinate provides less control than the truly systemic postemergence herbicides. Activity is fairly quick, with full symptoms often developing within 4 to 5 days. Glufosinate has no soil activity, and is quickly broken down in the soil.

Glyphosate, imazapyr, chlorsulfuron, and metsulfuron methyl are mobile in the plant's vascular system, and move throughout the plant. Glyphosate and imazapyr are non-selective, while chlorsulfuron and metsulfuron methyl are more active on broadleaf species. Glyphosate has no soil activity, as it is tightly bound to soil particles and unavailable for root pick up.

Imazapyr has considerable soil activity, and was previously discussed as a BSR herbicide. At much lower rates, imazapyr can be used to increase the control spectrum of herbicides such as glyphosate, without providing persistent soil activity. Chlorsulfuron and metsulfuron methyl have soil activity, but not enough to be used alone to maintain bare ground. They are chemically similar to sulfometuron methyl, and are also used at very low rates.

Growth regulator, hormone, or broadleaf herbicides are widely used for broadleaf weed control in turf and brush control applications, but have limited use in industrial weed control. Due to its low cost and quick activity; 2,4-D may be used occasionally to enhance the knockdown of broadleaf weeds on a site. Selective grass herbicides, the fatty-acid synthesis inhibitors, have labeling for non-crop uses, but have limited usefulness in industrial weed control. Control of grasses is almost always accomplished with non-selective materials such as glyphosate or imazapyr. The selective grass herbicides are most used in row crops, landscape beds and nurseries, and in wildflower plantings.

Hexazinone is a photosynthetic inhibitor, and is chemically similar to atrazine and simazine. It has both postemergence and preemergence activity. At lower rates it provides burndown of many species. Hexazinone can also be used as a spot concentrate application to control woody vegetation. Hexazinone moves in the xylem, so it will translocate upwards after root uptake.

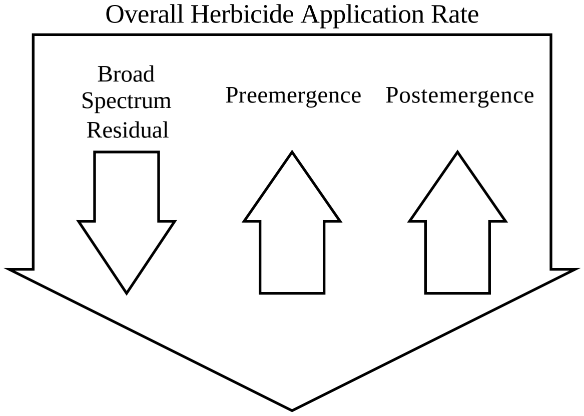

Figure 4.2: Herbicide combination scheme for industrial weed control applications. The overall goal is to minimize the amount of herbicide applied while maintaining control. This is done by reducing the amount of BSR herbicides, and relying more on preemergence and postemergence herbicides. BSR herbicides have the greatest potential for off-site damage.

Herbicide Combinations

There are wide variety of herbicides, which we have funneled into the categories 'Broad Spectrum Residual', 'Preemergence', and 'Postemergence'. These three categories provide us a means to put together herbicide mixtures. An herbicide mixture allows us to combine the strengths of several materials. Instead of using a high rate of a single product, we use lower rates of several products. By using multiple active ingredients, we affect the target plant in multiple ways, making control more likely. The goal of an herbicide mixture is to minimize the amount applied, while maintaining necessary control levels (Figure 4.2). This is an application of IPM to industrial weed control.

There are several herbicide pre-mixes available for industrial weed control applications. Table 4.4 lists examples of some of these products. The products listed in Table 4.4 include a BSR component, and a preemergence component.

Table 4.4: Examples of premixed herbicide combinations for industrial weed control, featuring a BSR and preemergence component.

	Herbicide Component	
Product	BSR	Preemergence
Krovar I	bromacil	diuron
Pramitol 5PS	prometon	simazine
Sahara 70DG	imazapyr	diuron
SpraKil S-13	tebuthiuron	diuron
Topsite 2.5G	imazapyr	diuron

The composition of an herbicide mixture will depend upon the site. Sites that are under control, free of biennial and perennial vegetation, require little or no BSR herbicides. The other extreme would be an overgrown site that included woody vegetation. Such a site would best be treated with two mixtures - one to address the brush, the other to provide the soil residual activity to prevent regrowth. In Section Five of this publication, we will discuss how to develop herbicide combinations, based on the site, and ways to tailor applications to address different types of conditions within a single job site.

Weed Resistance to Herbicides

Another way in which herbicide mixtures are an IPM practice is that we are managing resistance to herbicides by weeds. There are many examples where populations of weeds have become resistant to herbicides that were previously effective. This occurs because over time, the repeated use of an herbicide will eliminate the weeds susceptible to it. Many times a population of weeds contains small sub-populations, called *biotypes*, that are not affected by an herbicide. In the case of triazine herbicides such as atrazine and simazine, these resistant plants were not as vigorous as the 'regular' susceptible plants, so they made up a very small part of the population. With repeated use of these herbicides, the susceptible plants were reduced, and the less-vigorous, but resistant plants became more common. The increasing amount of resistant plants made the once-effective herbicides ineffective, and weed control failures resulted. It seemed to occur suddenly, but actually occurred over many years. Table 4.5 illustrates how a resistant population can build up, and seem to become a problem suddenly. A resistant biotype that comprises only 0.1 percent of the population of a species, could grow to comprise 50 percent of the species after 10 years of using the same herbicide. This example is strictly hypothetical.

Table 4.5: Hypothetical growth of a population of herbicide resistant plants. The resistant plants are less vigorous than the susceptible plants, and make up only 0.1 percent of the population initially. For this example, use of the herbicide that the small population is resistant to allows it to double in size each year. After 10 years, the product is ineffective.

Years of Herbicide Use	Resistant Population	Susceptible Population
	(%)	(%)
1	0.1	99.9
2	0.2	99.8
3	0.4	99.6
4	0.8	99.2
5	1.6	98.4
6	3.2	96.8
7	6.4	93.6
8	12.8	87.2
9	25.6	74.4
10	51.2	48.8

In the example in Table 4.5. the resistant biotype is less vigorous than the susceptible biotype, and comprises a very small portion of the population. Recently, species in western part of the US, such as kochia have shown resistance to the herbicides chlorsulfuron, metsulfuron methyl, and imazapyr. The resistant biotypes were not less vigorous, and made up a large portion of the existing population. They were able to increase their population to levels rendering herbicides ineffective much more quckly than the less vigorous biotypes that were resistant to atrazine and simazine. In this situation, the weed control failures occured after a few seasons.

In addition to using a mixture of herbicides, you should occasionally change your mixture. This rotation of herbicide mixes is a further step to prevent allowing a resistant weed population to increase. When changing mixtures, it is important to know which herbicides work differently than the ones you are currently using. The herbicides sulfometuron methyl, metsulfuron methyl, chlorfulfuron, and imazapyr all target the same biochemical site in plants. In this example, then, even though switching from sulfometuron methyl (Oust) to imazapyr (Arsenal) may change the spectrum of species controlled, it is not resistance management. It is quite possible that any weed species that develop resistance to sulfometuron methyl may also be resistant to imazapyr.

Section Five

Matching Herbicides to the Site

The key to effective and economic control of vegetation on industrial sites is matching the capabilities of your herbicide mixture with the needs of the site. This is IPM for non-selective weed control.

This is not to suggest that every site should be treated with a different herbicide combination. Instead, you will probably develop one or two basic mixes to address most of your sites. In addition to your basic mix, you will occasionally need to rely on products for sensitive areas, and products for extremely difficult to control vegetation. Both of these needs can be met with products formulated as granules, or applied with a backpack sprayer, so that your equipment needs to apply these additional materials are minimal. This allows you to dedicate your primary sprayer to your basic mix, and maintain productivity.

A common 'basic mix' might contain a low to moderate rate of a BSR herbicide, a full-season rate of a preemergence herbicide, and a moderate rate of a postemergence herbicide. The combination of the BSR and the postemergence herbicides will control established vegetation. A systemic postemergence herbicide will provide quick control of the existing species, and the BSR will provide residual activity to limit re-establishment of difficult to control species from perennial structures such as rhizomes or stolons. The preemergence herbicide would have little or no activity on perennial species regrowing from perennial structures, but will keep the site free of weeds from seed.

Table 5.1 lists herbicides labeled for non-crop applications, and rates that would be suitable for use in a mixture. The herbicides in Table 5.1 are listed by herbicide type, based on the scheme we have already outlined. With this information, you can assemble different mixes based on the conditions of your sites. The next section of this text will outline a basic approach to evaluating each site, and selecting the best materials to apply.

Site Mapping

The range of site conditions you observe between your sites, or sometimes even within a single site, can be very wide. Add to this the selection of herbicides at your disposal, each with its own unique characteristics, and you see that industrial weed control could be very complicated. Actually, it is, and doing it successfully is an art, as well as a science. However, through careful selection of a primary herbicide mix, and taking the time to evaluate your sites, the process can be simplified.

Your primary, or basic, herbicide mix should be one that will provide control of *most* vegetation on a site, and have minimal potential impact on nearby non-targets. Combining a BSR herbicide with a preemergence herbicide, and adding a postemergence herbicide to the mix later in the season, at the rates listed in Table 5.1 will provide such a mix. You then need to account for sensitive areas, and hard to control vegetation.

Sensitive areas will usually be near desirable non-target vegetation such as screen plantings; and areas of a site where there is a higher possibility of off-site movement of the applied herbicide. These sensitive sites should be treated with a combination of preemergence and postemergence herbicides. The preemergence herbicides are much less likely to harm the exiting plants, or to move off-site. Postemergence herbicides such as glyphosate, glufosinate, or diquat have essentially no soil activity and would pose no threat to the existing plants through root pickup. If part of the application is treating underneath desirable vegetation, such a an evergreen screen planting, you can use preemergence herbicides labeled for landscape ornamental applications. There are many of these products that are formulated as granules, so that the only equipment needed would be a spreader.

There are herbaceous perennial and woody species adapted to industrial sites that will not be controlled by many basic mixes. Examples include Japanese knotweed, and tree-of-heaven. These are both large plants that spread rather aggressively. They grow to sizes that make them difficult to adequately spray.

When these species make up a small portion of a site, they can be spot treated with granular herbicides, or a backpack sprayer. There are several granular tebuthiuron products available. These would be slow, but usually effective on difficult species. You must be certain, however, that the roots of desirable species do not extend into the treatment area. Foliar mixes containing higher rates of imazapyr, alone or in combination with other systemic herbicides, are quite active on many difficult species. These foliar treatments could be applied at low carrier volumes, so that a backpack could cover a significant area.

Figure 5.1 shows an example of an industrial site where both sensitive, and difficult-to-control areas occur. The key point to remember about dividing your site into different treatment areas is that it can be done without interfering with the use of your primary sprayer to apply your basic mix. There are many products available, as shown in Table 5.1, so that both sensitive and difficult areas can be treated with simple techniques such as by hand (pellets), backpack sprayer, and granular spreader.

This approach is economical, and effective. You are putting only the herbicide needed to get the desired control. Potent, soil-active herbicides are used only where they are needed. The potential for off-site damage is reduced, but difficult species are controlled. This is how IPM can be practiced in non-selective weed control.

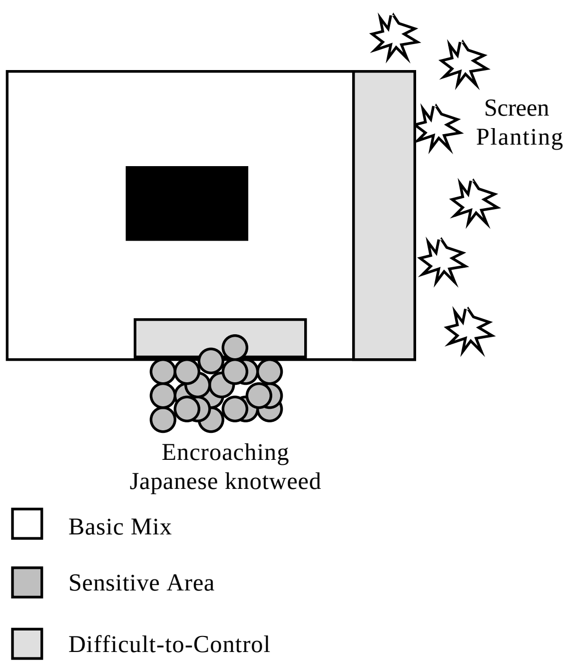

Figure 5.1: Hypothetical electrical substation, where a screen planting borders the treatment area; and a patch of Japanese knotweed from off-site is encroaching. The sensitive area should be treated with a mixture that does not include BSR herbicides, to avoid the possibility of root uptake by the screen plants. The difficult-to-control area could be easily treated with a low-volume backpack application, or a granular product. There are many products available so that both the sensitive and difficult area can be treated with minimal equipment costs, and keep your primary spray equipment dedicated to applying your basic mix.

Table 4.1: Examples of products available for industrial weed control, listed by herbicide type and active ingredient. Product rates are examples of commonly used rates, and reflect the use of the product in a mixture. Therefore, the rates are mostly in the low to moderate range of the labels. **Always consult the label prior to use.**

Herbicide[1/] Type	Active Ingredient	Product	Formulation[2/]	Product Rate/Acre	Comments
BSR	bromacil	Hyvar X Hyvar X-L	80 W 2 S	4 to 8 lb 1.5 to 3 gallons	Use caution near desirable trees
BSR	hexazinone	Velpar L Velpar DF Velpar	2 S 75 DF 90 SP	1 to 3 gallons 2.7 to 8 lbs 2 to 6 lbs	Will burn down existing vegetation when applied early postemergence. Velpar L can be used undiluted as a spot soil treatment for brush control.
BSR	imazapyr	Arsenal Arsenal 0.5 G	2 S 0.5 G	1 to 2 qt 200 to 300 lb	The rates for the granular product reflect preemergence rates for using the product alone
BSR	prometon	Pramitol 25E	25% EC	4 to 8 gallons	Do not apply near roots of desirable species
BSR	sulfometuron methyl	Oust	75 DF	2 to 4 oz	Use lower rates for maintenance applications. For postemergence applications where quick burndown is desired, mix with a foliar herbicide.
BSR	tebuthiuron	Spike 80 W Spike 20 P SpraKil S-5	80 W 20 P 5 G	2.5 to 5 lbs 10 to 30 lb 40 to 120 lb	Use with extreme caution around desirable trees and shrubs. The 20 P and 5 G formulations will usually be used alone, so the listed rates are higher in active ingredient than for the 80W. The pellet and granular formulations can be very useful for spot brush control.
PRE	diuron	Karmex DF	80 DF	6 to 8 lb	Will provide burndown when applied early postemergence
PRE	isoxaben	Gallery	75 DF	0.66 to 1.33 lb	Effective primarily on broadleaf weeds. Can be used under trees and shrubs planted near industrial sites.
PRE	norflurazon	Predict	80 DF	2.5 to 5 lb	Will not control established vegetation. If germination has occured on site, tank mix with a postemergence herbicide.
PRE	oryzalin	Surflan	4 AS	2 to 4 qt	Will not control established vegetation. Can be used under desirable trees and shrubs planted near industrial sites. More effective on grasses than broadleaves
PRE	pendimethalin	Pendulum WDG	60 WDG	3.3 to 6.6 lbs	Will not control established vegetation. Can be used under desirable trees and shrubs planted near industrial sites. More effective on grasses than broadleaves
PRE	prodiamine	Endurance	65 WDG	1 to 2.3 lbs	Will not control established vegetation. Can be used under desirable trees and shrubs planted near industrial sites. More effective on grasses than broadleaves

1/ Herbicide types: BSR - broad spectrum residual, PRE - preemergence, POST - postemergence, MIX - commercial premix

2/ Formulations: AS - aqueous suspension (flowable); DF, DG, WDG - water dispersible granule; EC - emulsifiable concentrate; G - granule; P - pellet; S - soluble concentrate; SP - soluble powder; W - wettable powder.

Table 4.1 (continued): Examples of products available for industrial weed control, listed by herbicide type and active ingredient. Product rates are examples of commonly used rates, and reflect the use of the product in a mixture. Therefore, the rates are mostly in the low to moderate range of the labels. **Always consult the label prior to use**.

Herbicide[1/] Type	Active Ingredient	Product	Formulation[2/]	Product Rate/Acre	Comments
POST	diquat dibromide	Reward	2 S	1 to 2 quarts	Provides burndown in 2 to 3 days. No residual activity. Well established vegetation will regrow.
POST	glufosinate	Finale	1 S	3 to 6 qts	Localized systemic. Effective on annuals, some perennials. Faster activity than glyphosate
POST	glyphosate	Roundup Pro	4 S	1.5 to 4 qt	Systemic. No soil residual. Active on all weeds.
POST	hexazinone	Velpar L Velpar DF Velpar	2S 75 DF 90 SP	3 to 4 pt 1 to 1.3 lb 0.8 to 1 lb	Lower rates than BSR application. Will burn back actively growing vegetation
POST	imazapyr	Arsenal	2 S	4 to 16 oz	Reduced rates, compared to BSR use. Very effective as tank mix partner for glyphosate for controlling brush and vines.
POST	metsulfuron methyl	Escort	60 DF	0.5 to 1 oz	Primarily broadleaf activity. Very active on multiflora rose.
POST	pelargonic acid	Scythe	60% EC	5 to 10 gallons	Symtoms develop rapidly. Apply in at least 100 gal/acre. No residual activity. Well established vegetation will regrow.
MIX	imazapyr + diuron	Sahara DG	70 DG	6.5 to 13 lbs	1:8 ratio of imazapyr:diuron. Can be tank mixed with other materials.
MIX	imazapyr + diuron	TopSite 2.5 G	2.5 G	200 to 300 lb	1:4 ratio of imazapyr:diuron. Less postemergence activity than spray applications of imazapyr
MIX	tebuthiuron + diuron	SpraKil S-13 SpraKil S-26	4 G 8 G	150 to 400 lb 75 to 200 lb	Both products are 1:3 mixes of tebuthiuron:diuron.
MIX	prometon + simazine + sodium chlorate + sodium metaborate	Pramitol 5PS	95.75 P	200 to 400 lb	Contains 5% prometon, 0.75% simazine, 40% sodium chlorate, and 50% sodium metaborate.
MIX	bromacil + diuron	Krovar I DF	80 DF	10 to 15 lb	1:1 mix of bromacil:diuron. For postemergence applications where quick burndown is desired, tank mix with a foliar herbicide.
MIX	benefin + oryzalin	XL 2G	2 G	200 to 300 lb	1:1 mix of benefin:oryzalin. Provides control of broadleaves and grasses from seed. Can be used under trees and shrubs planted near industrial sites.
MIX	isoxaben + trifluralin	Snapshot 2.5 TG	2.5 G	100 to 200 lb	1:4 mix of isoxaben:trifluralin. Provides control of broadleaves and grasses from seed. Can be used under trees and shrubs planted near industrial sites.

1/ Herbicide types: BSR - broad spectrum residual, PRE - preemergence, POST - postemergence, MIX - commercial premix

2/ Formulations: AS - aqueous suspension (flowable); DF, DG, WDG - water dispersible granule; EC - emulsifiable concentrate; G - granule; P - pellet; S - soluble concentrate; SP - soluble powder; W - wettable powder.

Section Six

Summary

Although typically portrayed as a complex system of monitoring and management for use on high-dollar commodities, IPM can be applied to any pest control situation. Using IPM for non-selective weed control in non-crop areas is a matter of matching the characteristics of your site with the herbicides available.

By taking into account the type of vegetation present, the soil's capability to retain applied herbicides, potential water movement, and the proximity of non-targets, you will know enough about your site to choose the proper herbicides.

There are many herbicide products available for industrial weed control. By grouping these herbicides as broad spectrum residual (BSR), preemergence, and postemergence, we can develop combinations to match the conditions of the site, and apply only the amount of active ingredient needed to provide bare ground.

Although there are a dizzying array of herbicide combinations you could come up with for different sites, you can treat the majority of your areas with one or two basic mixes. These mixes would include a moderate rate of a BSR herbicide, a full season rate of a preemergence herbicide, and a postemergence herbicide to account for the type of vegetation present. This basic mix would be complemented by a herbicide combination to apply to sensitive areas, and to vegetation that is very difficult to control. Sensitive areas are those where the use of a BSR herbicide poses a risk of non-target injury or off-site movement. Difficult to control species include brush species such as tree-of-heaven and sumac, and herbaceous perennials such as Japanese knotweed. By using granular products, or backpack applied spot treatments, you can treat sensitive and difficult areas on a site with a minimum investment in additional equipment, and maintain efficiency by dedicating your primary sprayer to one mixture.

By surveying your site, and applying the proper herbicide for the situation, you are practicing IPM. You are providing effective weed control in an environmentally sound, economical manner.