PORTLAND PARKS & RECREATION

Healthy Parks, Healthy Portland

Salmon Safe Annual Report
July 2008
Conditions Status

Status Updates

Precondition I (Vermont Creek revegetation plan)
Completed as reported in 2005 Annual Report

Condition I (System-wide, watershed-based strategic restoration plan) *5 years*
As reported in 2005, we have completed a vegetation inventory of all 7,000 acres of natural area parkland in the system.

The City's 2005 Portland Watershed Management Plan identifies strategies for improving watershed health throughout the City, especially within aquatic and riparian zones.

An interbureau team working with outside experts is continuing to develop a Terrestrial Enhancement Strategy for the City.

Portland Parks & Recreation (PP&R) is coordinating the effort to complete the restoration plan for the park system by 2009.

Condition II (IPM water quality monitoring peer review)
Completed as reported in 2006 Annual Report

Condition III (Fish habitat field inventory) *5 years*
Completed as reported in 2007 Annual Report

Condition IV (Impervious surface estimates, stormwater mitigation projects) *1 year*
Completed as reported in 2005 Annual Report

Condition V (Ponds and wetland contamination) *5 years*
Completed as reported in 2006 Annual Report

Condition VI (Irrigation data collection and reporting) *5 years*
PP&R received $154,000 in one time money to purchase equipment to connect additional parks to the Maxicom system. PP&R has upgraded and connected 10 additional parks and have supplies for approximately 25 more parks that will be connect throughout 2008-2009. There has been a water cost savings of approximately 20% by

having the systems managed centrally and tied to weather stations. This is based on the cost per acre of Maxicom sites versus stand alone controllers. Parks connected to the Maxicom system this year include Earl Boyles, Fernhill, McCoy, Sewallcrest, Lillis-Albina, Lincoln, Portland Heights, George, and Harrison.

Condition VII (Alternatives to herbicides) *5 years*

Funding was continued to carry out the trials begun in spring 2005. The trials include six different parks with up to 17 treatment regimens per park. Willamette and Gabriel Parks were chosen for treatments to tree wells and fence lines. Ladd's Addition East Rose Garden was chosen for the formal shrub bed trials. The natural area park sites were chosen to allow study of two of the major urban weeds in our region: Himalayan blackberry and English ivy. Powell Butte was chosen for blackberry control studies and Hoyt Arboretum is being studied for ivy control comparisons.

Control methods to be compared include manual or mechanical weed control, traditional and non-traditional herbicides, and physical control using landscape fabric and/or mulch as a weed barrier. Manual methods of control consist of hand weeding, hand digging, line trimmers, flame weeding, and using mulches. The synthetic herbicides used in the trials were chosen from current PP&R approved materials that are typically used for vegetation control purposes within the IPM program. The IPM trials will also test some of these herbicides in reduced concentrations to investigate their effectiveness at lower rates for certain weeds.

Data for the majority of the sites has been collected, with final results to be obtained on the remainder. Data analysis and project reporting will take place in 8/07 through 12/07 with release of findings at the conclusion. Reporting will include time involved, cost, carbon generation and efficacy, as well as recommendations for PP&R's IPM program.

PP&R completed the IPM Enhancement Trails in the fall of 2007; the report was completed in August 2008 (see attached).

Condition VIII (Education plan related to Gabriel Park revegetation)

Completed as reported in 2005 Annual Report

Condition X (Balch Creek trail culvert improvements)

Completed as reported in 2006 Annual Report

IPM Enhancement Trial

A summary of 3 years of field trials in Portland Parks

Document prepared by:
Portland Parks and Recreation City Nature Division
Astrid Dragoy, Zone Manager
John Reed, Integrated Pest Management Program Coordinator
Martin Nicholson, IPM Enhancement Trial Coordinator

Portland Parks & Recreation
1120 SW Fifth Avenue, Suite 1302
Portland, Oregon 97204
(503) 823-PLAY
www.PortlandParks.org
Portland Parks & Recreation City Nature
6437 SE Division
Portland, Oregon 97206
(503) 823-1636

Dan Saltzman, Commissioner
Zari Santner, Director

http://www.portlandonline.com/parks/index.cfm?c=38296

Contents

Executive Summary

In the fall of 2007, PP&R completed their IPM Enhancement Trials, a three-year weed management program that evaluated and compared existing successful weed management practices and materials with some recently developed products. Use of reduced rates of current materials, new application methods and varying kinds of weed suppressing mulches were also evaluated in the trials. Funding for these trials came from the City of Portland's Science fish and Wildlife Program (formerly known as the Endangered Species Act program).

The vegetation control target sites in the trials included shrub beds, tree rings, and fence lines in developed parks as well as control of two invasive weed species in natural area park land. Trial plots were located at Gabriel Park, Willamette Park, Ladd's Addition Rose Gardens, Hoyt Arboretum and Powell Butte. A range of weed control methods and materials were used on each of the sites. Cost and control efficacy were evaluated throughout the three year period on replicated plots. While treatment scheduling and replication did not allow for an exceptional level of scientific rigor, the results are meaningful in refining PP&R's IPM program and are based on an accurate representation of real world weed management methods.

The invasive weed targets in the trials were Himalayan blackberry (*Rubus armeniacus)* and English ivy (*Hedera helix*). Particularly useful information was obtained from the ivy control plots. The newer, natural ingredient based herbicides (*Natures Glory Weed and Grass Killer* and *Blackberry Brush Blocker*) did not show any efficacy on ivy with a single application. Strong support was shown for the efficacy of using reduced rate methods of some of the current synthetic based herbicides used in the PP&R IPM program. The most effective treatments were: 1. A combination foliar spray of *Rodeo* (glyphosate) + *Garlon 3A* (triclopyr) + *Syl-Tac* surfactant, 2. A 2% *Rodeo* foliar spray after pretreatment with string line trimmer or leaf rake, 3. A 4% *Roundup Pro* (glyphosate plus POEA surfactant) foliar spray. The rates used in these successful treatments were considerably lower than rates typically used for English ivy control. These results suggest that it will be possible to reduce overall herbicide rates while still achieving equivalent control of ivy.

While plots and treatments were established for Himalayan blackberry controls, changes in trial management and other factors resulted in no meaningful results. Future trials to address blackberry control methods and materials are being planned.

Tree rings: Tree rings are a weed free area established around the bases of trees in developed parks to protect them from damage, enhance their growing conditions and maintain a safe area for park users. Weed pressure and control needs vary depending on many factors, including tree size, age, irrigation presence, canopy type and density. The most effective weed control methods for tree rings were combination spray applications of a systemic post emergent *Roundup Pro* herbicide combined with a preemergent herbicide *Surflan AS* (oryzalin), mulch, and hand weeding. These methods vary greatly in cost. Questions about frequency and timing of applications as they relate to efficacy need to be explored further.

Shrub beds: Mulching with proper materials was an effective long term weed management strategy for shrub bed weed control, although applications of Roundup Pro + Surflan AS were less expensive and also as effective. Alternative weed control products were variable in their efficacy. *Corn gluten meal*, which is used as a natural based preemergent herbicide, provided no weed control. *Natures Glory Weed and Grass Killer*, a natural based plant desiccant herbicide, was a marginally effective product but requires monthly application, an expensive regimen. *Eco Exempt EC* a clove oil based desiccant herbicide was only effective when temperatures were above 50˚F degrees. This severely limited its ability to control weeds early in the spring when

effective control is essential. Hand weeding was more effective and cheaper than the natural based alternative products as long as weeding occurred at least monthly.

Fence lines: Weed management in these areas is important since weed growth quickly overtakes fence lines. Unchecked growth allows establishment and spread of difficult to control woody species and noxious weeds. It also creates fire and safety hazards, as well as traps litter and results in an untidy appearance. Fence lines at Gabriel park were the setting for the testing of eight weed control methods. Weed control at these sites was difficult due to the constant encroachment of the turf grass. Several of the methods that provide top kill of weeds, such as thermal treatments or desiccant herbicides were effective though their usefulness was limited by the need for multiple applications. Propane burning was effective at removing vegetative matter though was restricted to the spring and fall as the fire hazard their use creates in the summer is unacceptable in a park setting. Line trimming removed tall vegetation but did not affect weed number, so this method needed to be repeated on a monthly basis. Sprays of the naturally based desiccant herbicide products only removed the green tissue and need to be repeated on a monthly basis. With up to 6 applications being required each year these products became very expensive due to labor and materials costs. Spray application of the systemic post emergent *Roundup Pro* herbicide combined with a preemergent herbicide *Surflan AS*, provided acceptable weed control with two applications per year though even this method got weedy in between applications. Further investigation into long term solutions to fence line weed control is recommended. Pricing and the desirability of permanent barrier type controls such as concrete underlayment should be investigated.

All sites: Some reduced rate procedures were found to be effective. There was good evidence that additional use of mulch is justified in certain park sites. For many sites, herbicides are an essential part of a responsible and efficient weed control strategy. In all the trial plots the alternative natural based herbicides were less effective than was expected. Cost of their use was also prohibitive due to product cost, product rate required, and the need for multiple applications. The labor cost of hand weeding and the top kill alternative herbicides was also high. The labor to place mulch at appropriate sites once every 1½ to 2 years showed that the increase in labor requirement for the application was offset by labor being available at other times. In most cases labor cost to travel to and from the site was the biggest expense. Reducing the number of trips or combining trips saves labor cost and also reduces fuel usage and subsequent pollution of air and water.

The PP&R IPM program is designed to minimize negative environmental impacts and reduce potential hazards to park staff and the public while remaining responsible stewards of park land. This complete trial report identifies in more detail the various impacts of the different options and the limitations of the trial treatments.

Background and Objective

Portland Parks and Recreation (PP&R) has a refined, well established and effective Integrated Pest Management (IPM) program that provides oversight for all pest management activity on its land. This program has been used as a model for responsible land stewardship and environmentally sound pest management. Judicious procedures and guidelines are in place to evaluate products for potential inclusion into the program. The IPM Enhancement trial provides park specific information useful in the refining of the IPM program.

To satisfy safety, financial, efficacy and feasibility concerns it can be valuable to conduct field trials before accepting new products into the program. The IPM enhancement trials were designed to screen potential available weed control methods and products and then provide a framework for evaluating these tools in the field. A series of criteria were established which were:

Efficacy: Does the product or method show any merit as a weed control tool? Is there any documented evidence of this efficacy? Have good use patterns for the product been established?

Safety and environment concerns: If the product or method was used regularly would it create an acceptably safe environment for the public and for the employees applying the product. What is the fate of the product once applied, or long term consequence of the method if used? Are there any environmental concerns? Does the product have, if required, a label and MSDS?

Application issues: How is the product applied? Does it require any specialized equipment? Are there methods of application that make this more or less safe for the public, applicators and the environment?

The study time frame was set at three years from initial product and methods evaluation through data gathering from field trials through reporting on the results for park staff and public use.

Overview

Before any fieldwork was initiated a literature search was conducted to sample the current Best Management Practices (BMPs) for traditional and non-traditional herbicides and also the literature concerned with manual and other control methods. The park sites were then chosen on the basis of having adequate areas to study and ready access by the study team. The study included six different parks with up to 17 treatments per park. Coordination and cooperation between the study team and park staff was crucial for program success.

Control methods to be considered for trial inclusion included manual and mechanical weed control, traditional and non-traditional chemicals, and physical control using landscape fabric and/or mulch as a weed barrier. The synthetically derived herbicides used in the trials are those already approved for use within the PP&R IPM program, and are typically applied at various park sites. In some cases these chemicals are being tested in the trial at application rates below typical concentrations to investigate effectiveness.

The focus of the developed area study is the invasion and establishment of weed seeds (0-100 % cover) in developed park planting areas. Gabriel and Willamette Parks were chosen as the sites to study various treatments involving tree wells and fence lines. The east block of Ladd's Addition rose gardens was chosen for the shrub bed study. Because of the unkempt appearance of control plots where weeds are uncontrolled can detract from the park aesthetic it was necessary to inform and engage the support of park staff and the public during the trials. To aid in communicating these issues, special informational signage was installed at Ladd's Addition.

The focus of the natural area study is the removal of specific invasive weeds that have become established in these areas. Portions of Powell Butte and Hoyt Arboretum were chosen for the natural area trials.

Thermal Weed control

There are four types of thermal weed control: solarization, directed flame, radiant heat, and steam.

Solarization. The term solarization refers to the use of sunlight to heat soil to a point where weeds and weed seeds are destroyed. For best efficacy the soil must be tilled and irrigated before being covered with clear plastic to trap the heat from the sun. Six weeks of heating is required to kill off most weed seeds. Perennial weed control by this method is variable, with longer covering times needed. This method is sometimes used in organic food production but has many drawbacks for use in public ornamental landscapes and is generally not feasible for use in park sites. The shrub beds within the parks are seldom completely empty as plant replacement most often occurs a few plants at a time thus the entire shrub bed could not be solarized. There is some waste with this method as the plastic is not usually able to be reused and thus needs to be disposed of after the solarization period.

Waipuna Hot Foam. While there are other hot water weed control systems, this system uses a special surfactant to create a hot foam that is applied by a hose from a truck mounted boiler and pump rig. Super heated foam is sprayed onto the weeds, this heats up the plant and disrupts cell membranes. It primarily works to top kill weeds and can be effective at this however repeated applications are required for control of persistent perennials. Woody tissue is more resistant to heat thus control is not effective. The application process is slow and sites need to be within hose reach of the truck mounted equipment. The process is also energy intensive, with a separate diesel powered boiler system required to heat the foam. The system is also expensive to purchase or lease, with current figures over $20,000. According to the Nature Conservancy website, the Waipuna™ system is not available for individual purchase and the cost to lease the system from the company is US$700 per month (minimum lease period is 2 years).Chuck

Fairchild (BLM-Oregon) notes that the foam concentrate costs about the same as RoundUp® herbicide, since a 100-liter (55-gallon) drum of the foam concentrate costs about $900." (Mandy Tu, TNC).
Multiple demonstrations of this, and other hot water weed control systems have taken place in parks. This product, though showing efficacy, was considered too expensive and not feasible for widespread use on the acreage we manage.

Propane driven weeders take two forms: directed flame and radiant heat torches.

Open flame propane weeders are inexpensive but are inefficient users of propane. Several manufacturers exist with wand types starting at $40 without tank. The open flame weed burners can be hazardous in dry conditions as the flame extends up to 18 inches beyond the end of the torch. Weeds need to be heated to a point where cell disruption occurs but not to the point of actually burning. With this in mind, flaming moves reasonably fast and good control of the top portion of the plant can occur at moderate walking speed.

Radiant heat torches use propane flame to heat a ceramic plate which then radiates heat towards the weed target. The advantage over open flame units is that it eliminates the open flame so there is a reduced, but not eliminated, chance of setting a fire, and reduced fuel use as the flame is small and directed at heating the ceramic plate. An entry level hand held unit is $250 but this runs only off small non refillable propane cylinders. A larger unit suitable for parks use is $1,211, the Infra-Weeder Landscaper 100.

Due to low cost of equipment, availability of materials needed and the ease of use, propane flame weeding with a hand held torch was selected as the representative weed control method in this group.

Chemical weed control products

The current IPM program allows for use of a group of carefully screened chemical weed control products. The most commonly used herbicide is Roundup Pro which is a glyphosate based, systemic post-emergent petroleum based herbicide. This product is often used in combination with a pre-emergent oryzalin based herbicide, Surflan AS. Pre-emergent herbicides extend the time an area remains weed free by either preventing seed germination or controlling seedling growth depending on the product selected.

Increasingly, there are many naturally derived weed control products on the market. These herbicides typically use a variety of plant derived oils and acids to desiccate and destroy plant tissue. Many of these products use ingredients that allow for use in organically certified crop systems or are considered exempt from the EPA mandated label standards or registration that conventional products fall under. Due to this there can be problems determining use patterns of some products and there may not be the labeling available to determine worker safety and any storage issues. Safety data and evidence of efficacy may also not be easily determined for some of these products. Future availability is an important issue for some of these products. For example in the early stage of the trial some of the products were available but six months later were not. When selecting trial products from this group, price, packaging size, and a clear label were considered the most important factors. If there was data available on use and efficacy this was also considered important. Many products were looked at and three selected for the trial. Of the three, two were acetic acid based products and the other a plant essential oil based product. The selected products were *Natures Glory Weed and Grass Killer*, *Blackberry and Brush Blocker*, and *Eco Exempt EC*. *Roundup Pro* and *Surflan AS* were selected as the synthetically derived products.

Mulch

Mulches provide weed control through the smothering of existing weeds seeds. A range of materials from newspaper, cardboard, manufactured materials and wood based materials are used as mulches in different systems. Three wood product materials mulches that are already in use by parks staff were selected for evaluation. Mulching has been used widely in the parks system and is common in many horticultural and agricultural settings.

Bark mulch is a by-product of wood processing. Bark can come from many different kinds of trees with the types available often depending on the region of purchase. Bark can be purchased in different particle sizes. Bark chips have moderate particle size (1/5 to ½ inch) bark nuggets have larger particle sizes (1/2 to 2-1/2 inches). Small particle bark dust and shredded bark is popular but breaks down even more quickly than the larger particle sizes.

Chipped wood from both softwood and hardwood trees is another commonly used mulch material. Similar to bark mulch, wood chips form a good barrier and can be less expensive than bark mulch. In many cases arborists will provide this material for free to home owners as they need to dispose of large volumes of this material produced from their work. While sometimes considered less aesthetically appealing than some materials, wood chips can be an excellent long term wed suppressant. Sawdust is less often used as ornamental mulch, but is common in some crop production systems.

Compost is the decomposed remains of organic material. Whether made at home from plant material and kitchen scraps or purchased from commercial sources, compost can be quite variable depending on the source material. Usually of fine texture, compost is very good at holding moisture and is often considered the best amendment for improving soil. These characteristics also make it less effective as a weed barrier compared to some other mulch. Weed seeds may find the compost mulch layer a good place to germinate and establish, and compost tends to break down quickly. However, the benefits compost provides landscape plants may override these drawbacks. It is important to use compost that was properly managed during the composting process, so that any weed seeds in the source material were destroyed. Compost that has not been made properly may introduce many new weed seeds that could add to the problem.

Grass clippings are readily available to those that have lawns to mow. While many gardeners now use mulch mowers that leave the clippings on the lawn to decompose, collecting cut grass is still common. This material can be used as mulch, but such a layer can be dense and may become somewhat impervious to water and air. Clippings also tend to break down quickly, and may not provide long term weed control.

Hay and straw are often used in vegetable gardens. Hay is higher in nitrogen than other mulch so nitrogen supplementation is usually not required. Use hay with caution because it can contain weed seeds. Straw is less likely to contain weed seeds and it lasts longer than hay, but the organisms that break down straw will use nitrogen in their immediate vicinity. Nitrogen supplementation may be required when straw mulch is used.

Leaves are readily available in the fall, leaves can be used as mulch, but a good layer may be difficult to keep in place. Leaves make better mulch if composted into leaf mold first. Certain types of tree leaves may also affect soil properties when used fresh. For example, black walnut leaves possess natural chemicals that can make it difficult to grow desirable plants where they fall and accumulate.

Agricultural by products such as hazelnut and other nutshells, cocoa bean husks, and coir fibers have recently become more available. Offered in bulk or packaged forms, or sometimes pressed into mats, their availability often depends on local crop and orchard types. These materials can function well as soil or path covering mulches but individual characteristics vary.

Within PP&R many products are available and used. “Forestry chips” which are chipped wood from mixed species from the Urban Forestry unit’s tree crew, are used either fresh or aged as a shrub bed mulch. Forestry chips are a coarse ground product and loads can differ significantly in the amount of fine material and the amount of unchipped twigs and sticks. PP&R horticulturist Steve Maki has developed a successful composting strategy for mixing and aging this wood waste product to produce a high quality end product that provides extended weed control. (more detail on this method follows in selected products section)

Another PP&R waste product which is used extensively is referred to as “Beast grindings”, produced from a large grinding machine (called the Beast) that processes all of the organic waste generated in parks. This machine crushes material into very small pieces and creates a lot of fines. The material is stockpiled and rests until it is used. The stockpiles generate a lot of heat as they decompose but are not formally composted. Much of the heating occurs under anaerobic conditions and some areas of the pile do not heat up at all. The material that goes into the beast is a mix of weeds, dead plants, branches, hedge clippings and any other organic waste. The kinds of plant material vary greatly depending on time of year and location and nature of the various sources. The resulting pile is variable in the amount of decomposition, coarseness, and the level of viable weed seeds. Some horticulturists are cautious about using Beast grindings because they suspect it contains many viable weed seeds.

Parks also purchases hemlock and fir bark mulch from outside vendors to mulch shrub beds in parks. On some sites compost is purchased to improve soil conditions during shrub bed renovation. All PP&R play grounds have a deep layer of shredded wood mulch as a safety pad and a weed barrier, this weed free consistent grade wood mulch product is also purchased.

For the trials the three mulches most commonly used in parks are being used these are the forestry chips, Beast grindings and hemlock bark.

Barriers

Barriers can be artificially spun or woven ground fabrics or organic materials such as cardboard used to create a layer impervious to weeds. Often mulching material is laid above the barrier to make it more aesthetically attractive. Ground clothes may be made of plastic material and be impervious to air and water, made of various woven synthetic material which do not break down but allow water and air to pass through. Organic material such as cardboard newspaper or coconut husks may be used in this manner also though they will break down more quickly than synthetic barrier cloth. Barriers can be expensive, not very practical to install into existing landscapes and can create maintenance problems when they start to fail. They can however provide many years of weed suppression and sheet mulching with organic material can improve the soil over time. For the trial a woven synthetic barrier cloth was selected and used in tree rings.

Ground cover plants.

This is the use of competitive plants that cover the ground completely and reduce suitable habitat for weeds or introduction of new weeds. Planting density and plant selection are key to establishing and maintaining shrub beds while reducing weed competition. Research on the use and selection of plant material for this use specifically was limited but horticulturist experience was valuable in determining species that had the most chance of survival in the trial designated site, a tree ring planting, and would potentially be competitive with weeds. For the trial, 3 plant species were inter-planted and mulched. Species selected were F*ragaria , Arctostaphylos uva-ursi* “Massachusetts”, *Sedum spathulifolium.* It is important that designated ground cover plants be competitive so that they can establish well, but not present a problem as an invasive species.

English ivy is a good example of a good weed suppressing ground cover, but its invasive tendencies in our natural areas precludes its use in this way.

Mechanical

Mechanical control is the physical removal of weeds either with the use of hand tools or motorized equipment. It takes on many forms from large rippers used to pull weeds from the ground, large motorized or tractor mounted flail mowers that cut down established weeds, to the simple act of hand pulling. In agricultural systems mechanical control is the preferred method used by many who choose organic production systems. Within the parks system mechanical weed removal takes many forms, with hand removal of ivy and other plants occurring, use of hand held tools such as hoes, rakes and shovels to pull and cut weeds, and tractor mounted mowers and choppers that cut weeds to the ground. Line trimmers are used extensively to cut tall vegetation in rough areas and along fence lines. There are limitations to mechanical controls and especially motorized equipment in that damage to the landscape and desirable plants can occur. Injuries to workers who use hand tools for long periods of time can be an issue with fatigue and repetitive motion injuries being the main concern. Almost all mechanical weed control only removes the top of the plant and leaves the root either entirely or fragments of it in the ground to grow back therefore the control must be repeated over time to reduce the weed burden. In many cases the weeds are just groomed so that they are not a visual nuisance but are never completely removed.
Hand removal using a hula hoe and line trimming with a motorized trimmer are common methods used in parks and are most suitable for the trial format.

Trial Site selection

Site selections were focused on areas in developed parks where weed management has been historically practiced and natural areas where invasive plants need to be removed. Pest Management program staff worked with PP&R ecologists and horticulturists to determine the best locations to establish the trial plots. Coordination and cooperation between the study team and park staff was crucial in setting up these trial areas. The sites were chosen on the basis of having adequate target areas to study, good access for the study team, and good coexistence with other park management needs. The trials include six different parks with up to 17 treatment regimens per park. Meetings were held involving district staff and IPM personnel throughout the site selection and treatment selection process.

Developed park area targets included in the study are tree wells, fence lines, and established shrub beds. Willamette and Gabriel parks were chosen for treatments for tree wells and fence lines. Ladd's Addition East rose garden was chosen for the formal shrub bed trials. Because the appearance of certain trial plots may not meet normal developed park standards, it is very important to gain the support of the park staff and the park visitors. Park staff was informed of the importance of the study to our IPM program and its long-range goals. Informational signage was designed and installed at the Ladd's Addition site to help explain the project and its goals to park users.

The natural area park sites were chosen to allow study of two of the major urban weeds in our region: Himalayan blackberry, *Rubus armeniacus* and English ivy, *Hedera helix*. Powell Butte was chosen for blackberry control studies and Hoyt Arboretum for ivy control comparisons. The blackberry study was intended to examine the effectiveness of control methods on "pure" stands (100 % cover) and the ivy trial to compare method of ivy control in a natural area looking at control efficacy as well as impact on native plants present.

Gabriel Park

Trials at Gabriel Park occupied two sites. One site included the fences surrounding the tennis courts. The current pesticide use pattern in this area is one or two applications per year of Roundup Pro with or without Surflan AS. The treatment swath extends 12 inches from the edge of the concrete area under the fence. The fence line that prevents volleyballs from rolling down the slope was also included.

Treatments for the fence lines were;

1. EcoEXEMPT HC
2. Blackberry and Brush Blocker.
3. Corn Gluten Meal A-maiz-N
4. CGM and BBB
5. Trimmer
6. Control - no weeding
7. Flame
8. Roundup Pro and Surflan AS treatments were replicated 4 times, 32 plots were required. Plots were 20 ft long. The red areas of the photo indicate the fence lines used.

The second control area involved tree rings. Trees rings used in the trial were adjacent to SW 45th and within the traffic circle shown above. Currently weeds under trees are controlled by twice yearly applications of Roundup Pro and Surflan AS. Maintaining a clean area under trees is a park practice for three reasons: to protect them from damage, especially from mowers, enhance their growing conditions and maintain a safe area for park users.

The treatments for the tree rings were
1. EcoEXEMPT HC
2. Natures Glory weed and grass killer
3. Corn Gluten Meal A-maiz-N
4. CGM and Natures Glory W&G Killer
5. Weed Barrier
6. Control - no weeding
7. Mulch
8. Roundup Pro and Surflan AS
9. Ground cover
10. Hand, using hand tools

Each tree ring measured 3ft in diameter. The plots were replicated 3 times with 10 treatments thus requiring 30 tree rings. The tree rings at Gabriel Park represent mixed age deciduous and evergreen trees typical of most Portland parks.

Willamette Park

Willamette Park was used to replicate tree ring treatments used at Gabriel Park. There were 48 trees available for treatment. 40 trees to the north and south of the parking lot were included. The trees are mixed evergreen and deciduous aged 10 to 30 years. The ring size under the tree was 3 ft in diameter, the same as at Gabriel.

Ladd's Addition Rose Garden

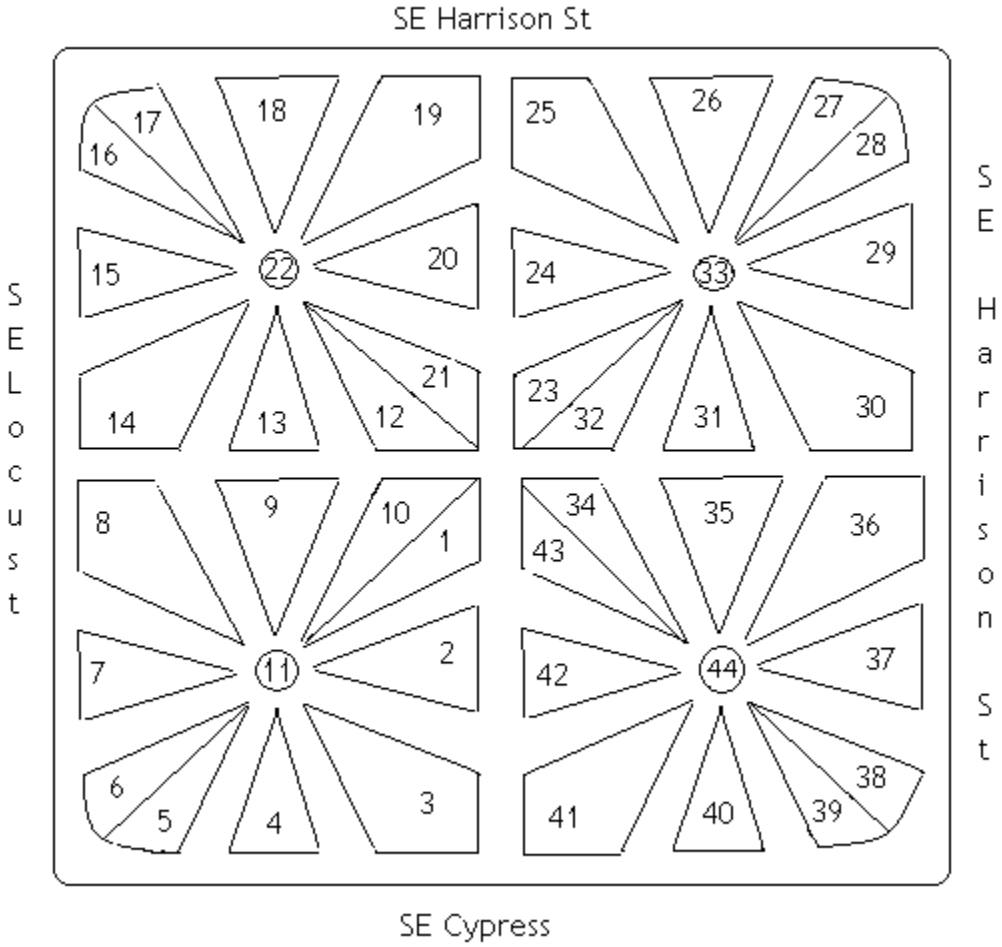
Ladd's Addition East Rose Garden was the site used for the ornamental bed trial. The site had a reasonably heavy weed pressure and weed control is important as it is a popular rose garden and receives considerable scrutiny from visitors. Weed control used at the site were Round Pro and Surflan AS herbicide applications and medium grind bark mulch. It also received hand weeding carried out by Alternative Community Service work crews. The herbicide treatments were carried out twice yearly and mulching frequency depended on how fast the material breaks down. The last mulching took place 2 years before the trial. Hand weeding occurred in the winter of 2004/05. The site is ideally suited for the trials as there are 4 replicated quadrants in the design of the beds and each quadrant contains 9 beds; the larger two of which were split to create 11 plots.

Treatments for the beds:

1. Natures Glory, Acetic acid
2. Eco Exempt HC clove oil
3. Roundup Pro/Surflan AS
4. Corn Gluten Meal
5. Corn Gluten meal plus Acetic Acid
6. Mulch (Steve's mix, composted forestry chips)
7. Bark mulch, medium grind as received from Mt Scott Fuel
8. Mulch (from Beast grind)
9. No weeding
10. Hand weeding
11. 1/2 rate corn gluten meal plus Natures glory Weed and grass Killer

Applications of the products occurred in the first week in April after first recording the current weed population with weed counts as described for the tree ring trials. Post application weed counts occurred at 7 days, 40 days and 100 days after the initial application. Follow up applications occurred 30 days after the initial application for those products that required follow up applications. For treatments that required multiple visits throughout the year, these were scheduled as required but took place at least bi-monthly. These treatments were hand weeding and top kill herbicide products. If treatments could potentially damage rose plantings due to their density at certain times of the year, they did not take place. Fall applications occurred in October unless weed pressure was high and earlier treatments were required. Follow up weed counts occurred on the same schedule as for the spring applications. Mulch treatments were not reapplied for at least 18 months and then only if weed pressure became significant. The trial continued for at least two full years. Treatments were assigned randomly to 4 replications. Each replication was for 1 quadrant of the circle and consisted of eleven plots per replication.

Ladd's Addition East Block



Plot ID	Size	Treatment	Plot ID	Size	Treatment
Rep 1			Rep 3		
1	350	1	23	350	4
2	300	2	24	300	8
3	500	3	25	500	3
4	200	4	26	200	6
5	350	5	27	350	10
6	350	6	28	350	2
7	300	7	29	300	5
8	500	8	30	500	9
9	200	9	31	200	11
10	350	10	32	350	1
11	314	11	33	314	7
Rep 2			Rep 4		
12	350	1	34	350	9
13	300	4	35	300	3
14	500	11	36	500	1
15	200	6	37	200	8
16	350	5	38	350	2
17	350	2	39	350	10
18	300	7	40	300	7
19	500	3	41	500	11
20	200	8	42	200	6
21	350	10	43	350	4
22	314	9	44	314	5

Powell Butte

Powell Butte Natural Area is cared for by PP&R City Nature and is also home to a City of Portland Water Bureau underground reservoir facility. Unfortunately it is also home to many invasive weeds. The uppermost area of the park is a meadow ecotype, and the lower areas are woodland and transitional woodland areas. PP&R continues to develop Powell Butte Nature Park and a good deal of invasive plant management takes place. The master plan for this site calls for preserving and enhancing the butte's wildlife habitat and providing public access and passive recreation. This includes improving trail surfaces, closing paths into habitat areas, weed eradication, and habitat restoration. These efforts will result in a higher degree of ecosystem health, more observable wildlife and an improved natural area experience.

The vegetation survey of Powell Butte highlighted the degradation of many areas of the park, mainly due to the presence of invasive weeds. The weed species present are English Hawthorn (Crataegus monogyna) , English Holly (Ilex aquifolium) and Himalayan Blackberry (Rubus armeniacus). In areas of heavy blackberry infestation a 4 to 8 ft thicket is present, in other areas plants are smaller but the cover is still dense enough to preclude native plants from the site. Current management methods include cut stump treatment of hawthorn and holly with Garlon 3A (triclopyr). Blackberry is being treated also with Garlon 3A either as they exist or after a prior mowing. Even with these tools available there is a monumental task ahead to reduce the invasive weed burden here and on the thousands of acres under parks management that have invasive weed problems.

The trial on this site addressed control of blackberry. An area adjacent to the forested portion of the park was used. This area was covered in a thicket 3 to 5 foot deep that runs almost continuously along the transition zone from meadow to forest. In this zone there is a risk of fire being transferred into the canopy of conifers. This area has a plan for reduction of the fuel load due to the blackberry thicket and there is a determined desired future condition (DFC) for this site.

Two DFC priorities exist. First, reduce the fire potential, and second, successfully transform the site into a native plant dominated area. To achieve these goals and also the goals of the IPM trial, multiple tools were combined to develop a BMP model for blackberry control. Within the trials, several new plant derived herbicides were evaluated for their ability to control blackberry. As previously mentioned the treatments consisted of regimes of non-synthetic herbicides, synthetic herbicides, mechanical removal, hand removal, and mulching. Each of the individual components was selected based on efficacy claims or research information that suggests them as suitable tools for blackberry control. In all treatments site and native plant disturbance was minimized.

Mowing the blackberry prior to some of the treatments. Note the height of the blackberry.

Hoyt Arboretum

English ivy is a highly invasive weed that has a degrading effect on the sites where it has become established. Ivy negatively impacts the soil ecosystems, harms existing plant and animal communities and reduces species biodiversity. Because of these factors and the enormous area already covered by this weed it is a priority species for removal from both natural area and developed park sites.

Removal practices for ivy include both chemical and mechanical controls. Choice of controls used on each site varies with the ivy density, presence of natives, expected restoration activities, and preferences of the site manager. Herbicide use is the most widely used control particularly for large areas. Successful hand removal programs exist although they typically rely on volunteer programs in order to make them feasible and affordable. There are some new naturally derived herbicides that may be perceived as having reduced environmental impacts, however the efficacy of these on ivy is unlikely and not well tested. And their actual environmental and safety impacts can be more problematic than current synthetic choices. There are many differing opinions on the most effective rates of herbicides to use for best efficacy on English ivy. Various combinations of herbicides are used as well but their efficacy is not well documented. It is well known that the addition of certain chemical additives such as surfactants can enhance the efficacy of a herbicide or provide an opportunity to reduce the rate of chemical used. Their use for ivy control is known, but hard data is not widespread. Ivy has a thick waxy cuticle that protects the plant. Herbicidal penetration through this cuticle is one factor greatly aiding control. A mechanical method of reducing or removing the waxy layer or removing leaves altogether and applying the herbicide as a cut stem application may be effective.

The goal of the trial was to evaluate some new products against current practices while quantifying other control methods such as hand pulling. We also looked at the herbicide rates currently used to ascertain if reductions in rates can reduce our overall pesticide use and cost while still retaining efficacy.

The Nature Conservancy has explored some reduced rate herbicide combinations but much of their work focused on glyphosate herbicides plus LI-700 surfactant, a combination approved for use near fish bearing waterways by various regulatory bodies. Much of the ground in parks with ivy presence is well removed from streams and thus other options could be explored by the trial for inclusion in the IPM program.

Hoyt Arboretum is located in an area with large portions completely overrun with ivy. The task of removal is a monumental one, yet to do nothing allows the ivy to spread to uninfested areas. Various controls have been used over the years from hand removal to use of herbicides and some mulching. The site available for the trial is typical of many ivy infested sites. Ivy made up about 80 to 90% of the plant material in the site. There are mature trees and some natives struggling to grow through the ivy. Impact on the native plants on site was minimized through timing and directed treatments to preserve materials as possible. Some unavoidable loss of native plant material is always likely during control activities, however the gains in diversity due to native establishment after ivy removal far outweigh any loss. Much of the Hoyt Arboretum site is sloped and ivy removal will be evaluated as to whether it would contribute to erosion problems. It is heartening to note that in other areas at the arboretum where ivy has been removed, native plants present under the ivy have quickly reestablished once freed from competition. For this reason a replant program will not be part of the trial. The plots will be evaluated for species diversity a year after initial treatments.

Ivy control usually occurs in two stages. The first is the removal of the bulk of the material using the desired method. The second is revisiting the site several times to remove any re-growth. Many ivy control strategies fail to recognize the importance of the follow up visits to the site.

For all of the trial treatments, follow up hand removal or spot spraying will be an essential part of the treatment success.

Mulch was to be used in several of the treatments however this did not occur due to difficulty accessing the site with equipment to haul mulch. There are indications that when applied at least 4 inches deep mulch can smother some weak ivy seedlings and effectiveness was evaluated at depths of up to 12" on more mature ivy. Mulch may also add important bio-diversity of soil microbes which helps revitalize the soil and slow erosion while native plants become established.

The treatment list for the ivy trial was extensive to in an attempt to address many areas of interest. There were 16 treatments replicated 4 times, plot size was 10' by 10'. Two were non chemical methods, five qualify as certified organic treatments and the remaining nine were various rates of currently used herbicides.

1. Line trimmer: Repeat visits to deplete energy reserves
2. Hand removal: A tried technique included for a cost comparison.
3. Line trimmer with herbicide application: Spray cut stems with 2% Rodeo
4. Line trimmer with herbicide application: Spray cut stems with 1% Garlon
5. Line trimmer with mulch
6. Rake foliage to damage leaf area then apply 2% rodeo
7. Brush Blocker with mulch
8. Natures Glory with mulch
9. Eco exempt with mulch
10. Garlon 3A 2% plus LI700
11. Garlon 3A 1% plus LI700
12. Garlon 3A 1% plus Syl-Tac
13. Roundup Pro 4%
14. Roundup Pro 2% plus LI700
15. Roundup Pro 2% plus LI700 plus Mulch
16. Roundup Pro 1% plus Syl-Tac
17. Rodeo 2% plus Syl-Tac
18. Rodeo 4% plus LI700
19. Rodeo 1% plus Triclopyr plus Syl-Tac
20. Roundup Pro 1% plus Garlon 3A plus Syl-Tac

Ivy at Hoyt arboretum

Selected products for IPM Enhancement trial

Product List

1. EcoEXEMPT HC
2. Natures Glory weed and grass killer, and Blackberry and Brush Blocker
3. Corn Gluten Meal A-maiz-N
4. CGM and Natures Glory W&G Killer
5. Propane Flaming
6. Weed Barrier
7. Control - no weeding
8. Mulch. Sheet Mulch
9. Mulch. Steve Maki's forestry chip mulch
10. Roundup Pro and Surflan AS
11. Ground cover
12. Line Trimmers, Motorized
13. Hand, using hand tools
14. Garlon 3A

1. **Product**: Eco Exempt HC 21% clove oil (eugenol)
Application rate: 1 gallon in 5-7gallons of water, spray to wet for spot applications.
Application Frequency: Only top growth is killed so would expect to have to do two applications minimum 30 days apart. Up to 12 applications per year
Details: Clove oil has a detrimental effect on cell walls and results in burning of green tissue. The product has no residual effect and no detrimental breakdown products. Application should target weeds 2in or smaller, larger weeds may require additional treatments. OMRI listed product, is EPA registration exempt.
Specific use pattern: Label rates are 5-7parts water : 1 part eco exempt.
For the trials a 1:5 mix will be used this is the highest rate, the low rate is 1:7 mix ratio. For a tree ring the application would be 130ml of mix (21mls of product). 2 applications, 30 days apart, with evaluations needed to determine any additional applications.
Cost $96.90 for 1gal, material cost for application of 2 gallons of mix per 1000ft2 is $38.76
Hazards: Caution, protective eyewear, long sleeves, and gloves. Possible eye, throat, or skin irritation if direct exposure occurs. Eugenol as been evaluated as a food additive, low rates show no ill effects to 2.5mg/kg body weight. High doses have toxic effects. Carcinogenic property studies not fully completed . CARC health 2, Ingesting as little as 1 teaspoon can cause nausea, vomiting and convulsions
Studies: Evaluation of Alternative Herbicides for Landscape Weed Management.Cheryl Wilen, UC Statewide IPM Program, 5555 Overland Ave. Suite 4101, San Diego, CA 92123, 2005 California Plant and Soil Conference

2A. Product: Natures Glory Weed and Grass Killer
Application rate: Low rate 1 gallon Natures Glory to 3 gallons water
High rate 1 gallon Natures Glory to 2.25 gallons water
Application Frequency: Burn down of top growth only, repeat as required.4-8 applications/year.
Details: An acetic and citric acid mix
Specific use pattern: Natures Glory Weed and Grass Killer will be applied to tree circles. 1:3 mix ratio applying 0.14 gallons to a 27.5ft square tree circle (3ft radius).
Cost: $20 per gallon. At low rate applying 2 gallons dilute per 1000 ft^2 would cost $15
Hazards: Danger Corrosive , causes irreversible eye damage. Harmful if absorbed through skin. Harmful if swallowed. Do not get in eyes, on skin, or clothing. Wear protective eyewear such as goggles or face shield when handling.
Environmental Hazards: Do not apply directly to water or to areas where surface water is present, or to intertidal areas below the mean water mark. Do not contaminate water. Do not apply to roosting birds or during flowering when bees are actively foraging.

Studies / additional Info: Excel Garden Products 1-800-422-7008.
For further information contact Nature's Glory at 1-866-298-2229 Ecoval U.S. Inc.425 King's Hwy. East Fairfield, CT 06432 ph 203-338-9613

2B. **Product**: Blackberry and Brush Block: Chosen for use on fence lines.
Application Rate: Low rate 1quart to 3 quarts H2O to cover 250ft square
High rate 1 quart to 1 quart H2O to cover 100ft square
Application Frequency: The label claims 60 to 90 days control post application. So 4-6 applications per year
Details: Industrial strength acetic acid is a strong enough acid to have burn down efficacy on green plant material. Blackberry and Brush Block claims some root activity when spray is directed at the soil under the plant. Blackberry and Brush Block label warning, "do not apply in a manner to contact nearby plants including the soil within their drip line or root zone". This excludes this product from use in a tree ring. Product is 20% citric acid and 8% acetic acid
Specific use pattern: Use at high rate on fence line 1:1 ratio 0.15 gallons per 20 ft of fence line spraying a 1ft swath. Test pH prior to and within 1 day after application to determine any effect on soil pH.
Cost: 1 gallon $25.00. Cost for 1000ft2 at high rate is $9.40
Hazards: Product has a pH of 2 and goggles are required to prevent splashing causing eye damage. Can cause skin irritation ingestion or inhalation can cause irritation of the mouth and respiratory tract. Wear protective eyewear and gloves when handling. Mixing and applying this product
Environmental impact: Possible negative impact on soil pH and soil microbes.
Studies: Jay Radhakrishnan USDA ARS showed vinegar has potential as a weed control tool
Agrichemical and environmental news, Dr Tim Miller, September 2001, Issue No. 185

3. **Product**: A-maize-N from Wilbur Ellis, $24 / 50lb bag.
Application rate: 40lbs / 1000ft square (1600lbs/ A)
Application frequency: Spring and fall
Details: Corn gluten meal has been shown to have some preemergent weed control efficacy. The meal is a byproduct of the corn syrup extraction process and contains dipeptides, which appear to inhibit seed germination. There are many studies based in agricultural and turf uses of the product. Results from the studies have been mixed with any thing from moderate weed control to actual increases in weed counts. Efficacy appears to be highly dependent on rainfall and irrigation frequency and timing, with consistant precipitation inhibiting the preemergent effect. The product also has some value as a fertilizer being 9% nitrogen.
Specific use pattern: Tree rings: 3ft tree circle covers 27.5 square feet. At 40lb/1000 ft square application rate require 1.1 lb spread over tree ring. Calibrate spreader prior to application. Spring and fall applications will be required at a minimum. Fence line applications to 1.5ft wide strip under fence line. Plots will be 20ft long. 30 Square ft per plot at 40lb/ 1000 ft^2 application rate requires 1.2lb per plot. Application will be made with hand held applicator such as modified Casoron granule applicator.
Ornamental Bed: Based on actual square foot area of shrub beds. The application rate will be 40lb per 1000 ft^2
Cost: $24 / 50lb bag. $19.20 per 1000ft square.
Hazards: Limit exposure to dust. Being a corn product this may attract rodents. No hazardous decomposition products
Studies: Greenhouse Screening of Corn Gluten meal as a natural weed control product for broadleaf and grass weeds. Bingamand and Chistians Iowa State University Hortscience 30(6) October 1995.
Corn Gluten and Corn gluten hydrolysate for Weed control. Melissa McDade Thesis work 1999. Iowa State university.
Crabgrass and broadleaf weed control in turf using corn gluten
meal based fertilizer. K. Carey and E. Gunn, Guelph Turfgrass Institute.

4. Corn Gluten Meal and Natures Glory,
A combination of the products mentioned in 2A and 3 above.

5. **Product**: Red dragon torch. Open flame unit, already own one for pesticide free park.
Application: Rate is difficult to quantify, depends on time taken for fence line. For open flame use is about 2-2.5lbs per hour.
Application Frequency: top kill only so expect to have to treat re-growth monthly.
Details: Application must give enough time to heat weeds but not incinerate them. Desiccation due to cell disruption is the mechanism of control not burning them to the ground.
Specific use pattern: Two applications 3 to 4 weeks apart should be expected to give control. Limit use in some areas to early spring so as to reduce fire potential. Repeat application in the fall. The flame weeder is not safe to use around trees or in established shrub beds due to the risk of desirable plant damage. Use will be on fence lines as a line trimmer would be used. Propane is a fossil fuel and there is a significant CO^2 contribution from the burning of propane.
Cost: Red Dragon style open torch $100 including tank plus propane costs depending on the volume used.
Hazards: Potential for burns and burning of desired material. Applicator skill and good decision making on appropriate use of flame weeder in a particular location is required.
Studies: There are many studies that show reduction in weeds in crop situations and a few discussing non crop weed control, but few have comparison information, costing and long term control in non crop areas.
SPOT-BURNING USING PROPANE TORCHES
Adapted from Jack McGowan-Stinski, Land Steward
The Nature Conservancy, Michigan Chapter
Controlling weeds using propane generated flame and steam treatments in crop
and non croplands Dr. Thaddeus Gourd Extension Agent (Agriculture)
Colorado State University Cooperative Extension in Adams County

6. **Product**: Weed barrier cloth, Dewitt Pro5 weed barrier. 3' by 250' roll. With bark for aesthetics.
Application: In spring remove weeds from site manually or with line trimmer. Lay weed barrier down and cover with 1" layer of bark mulch if barrier clothe is being used.
Application frequency: One time establishment the just monitoring bark level and integrity of mulch material.
Details of use: Product selection becomes a cost issue with the permanent mulch products. The cocoa fiber mats last anything from three to ten years depending on the information source. Initial cost is $15 each. Compared to the cost of current treatment of $0.08 per tree it would take 93 years with two applications a year to break even. The cost comparison on the rubber products is even worse with a single ring costing in the region of $35. The less expensive and more realistic option to include in the trials is weed barrier cloth with a layer of decorative mulch. The costing for this is about $3 per tree and it should give 3 to 5 years of control possibly longer, although bark mulch will have to be replaced at some point. It will have to be seen what the impact of the mowers will be on this treatment.
Costs: Product cost is $90 for a 3' by 250' roll. Bark mulch is $19.80 per yard
For a tree ring, barrier costs $1.06 plus $0.25 of time to cut to size. Bark mulch cost is $1.67 for 1" depth. There may be additional labor costs to hand remove or mow down existing weeds prior to placement of barrier cloth.
Hazards: Unclear of mower impact, flying bark chips, cloth getting caught in mower blade.
Studies: Evaluation of Landscape Fabrics in Suppressing growth of Weed Species. Martin, Ponder, Gilliam. Journal of Environmental Horticulture 9 (1) 1991.

7.**Product:** Control.
No treatment of weeds
Monitor weed growth but do nothing about it. Remove seed heads to reduce additional long term weed problems after trials have ceased.

Cost: None.
Hazards: Safety, damage to concrete surfaces, allergic reaction to weed pollens, allowing noxious weeds to reproduce could result in fines. Public may be unhappy with appearance; unkempt park appearance may lead to increased park deterioration and vandalism. May allow establishment of more difficult to control weeds. Mower damage to trees and fence lines could occur if things are hidden behind weeds. Loss of natural areas due to invasive weeds.

8. **Product**: Hemlock chip mulch
Application: 3 inches bark mulch.
Frequency: 1-3 years of weed control
Details: Bark mulch compost mix for establishing desired plants and preventing weed seed germination. The mulch has the advantages of adding organic matter, holding moisture, cooling the ground in the summer and providing a small amount of nutrition.
Cost: Bark mulch is $20 per yard applied at 2 inch depth costs $0.12 per ft^2
Beast mulch is free, although not composted and may contain weed seeds
Installation time and some follow up maintenance.
Hazards: Could provide rodent habitat. Possibly encourages root pathogens, although reports on this are mixed.
Article: Greater Plant and Soil Health for Less Work, Craig Elevitch and Kim Wilkinson AgroForester

9. **Product**: Compost/Mulch Steve Maki, Forestry chip compost
Application: 4 inch deep layer
Details: PP&R horticulturist Steve Maki has developed a use pattern for forestry chips as shrub bed mulch which he claims gives 3 to 5 years of weed control. The forestry chip is a mix of tree material from leaves to coarse chips deciduous and evergreen, the more diverse the better. The chips are windrowed 3ft high for 3 weeks, this gives time for passive composting to occur, internal pile temperatures reach about 130 degrees. Not enough for true composting but enough to start the break down of the smaller material and provide some nutrition for the planting bed. This is then applied in a 4 inch deep layer over the shrub bed. The theory lies in that the larger chips will end up on the top, as rain washes the finer material down, and this leaves a poor rooting medium for weeds. The deep mulch layer prevents weeds from below germinating.
Cost: Transporting material and placement are the costs involved, the forestry chips are free. If this was adopted there would not be enough chips generated by forestry to use this method extensively. Similar chips are available from other tree companies usually for free also.
Hazards: A few species do not do well with thick mulch over the roots as it can encourage some root diseases. This would mean limiting mulching with those species. May be a fire hazard?

10. **Product**: Roundup Pro 2% solution, Surflan AS 3oz per $1000ft^2$
Application Rate: Roundup Pro at 2% solution, Surflan AS at 3 oz per 1000ft2 with sprayer calibrated at 2 gallons per 1000ft2.
Application Frequency: 2 applications per year spring and fall to coincide with rainfall if possible.
Details: Surflan AS is the current weed control product used in the parks system for the majority of weed control when pre-emergent control is desired. Roundup Pro is often used alone also for spot treatments without the pre-emergent treatment. Roundup Pro is a non-selective post-emergent systemic weed herbicide. It has a short life in soil and has very low mammalian toxicity. Surflan AS is a pre-emergent herbicide that prohibits root and shoot growth of the germinating weed seeds.
Surflan AS must be incorporated into soil with in rain or irrigation within 14 days of application. The combination treatment has been used spring and summer as required, in some instances applications are only being made one time per year with follow up treatments of Roundup Pro alone.

Specific use pattern: Roundup Pro at 2% solution, Surflan AS at 3 oz per 1000ft2 with sprayer calibrated at 2 gallons per 1000ft2. Actual volumes applied per tree ring will be 0.083oz Surflan AS, 0.14oz Roundup Pro, 7.4oz water.
Costs: Tree ring, $0.08 plus labor. Fence line, $0.09 plus labor. $0.45 per 1000ft^2
Labor portion will be determined during actual applications with time included for equipment clean up maintenance and reporting of application per state regulations.
Hazards: Roundup Pro, Caution causes eye irritation. Avoid contact with waterways.
Surflan AS, Caution eye irritant can cause allergic reaction in some people after frequent or prolonged contact.
Studies: This is the current control practice, horticulturist experience and use history shows that this is an effective method of control in many park landscape maintenance situations.

11. Product: Mixed species of ground covers to plant under a tree and provide competition for weeds. Species selected are *Fragaria* sp*, Arctostaphylos* "Massachusetts", *Sedum spathulifolium.*
Application: Plant spacing at 12in need 60plants per tree circle 2 or 3 species.
Application frequency: A one time planting.
Details: As mentioned above a mixed planting of 3 of the 4 cover crops mentioned. Plant spacing will be 12in giving a total of 60 plants within the 3 ft tree circle. Ground covers will all be 4 inch pot size at planting. A fertilizer application should also be made at planting to promote early growth. This method is appropriate for tree rings and shrub beds would not be useful under fence lines. The theory is to form a thick mat of desirable cover that will out-compete weeds as quickly as possible.
Cost: $90 per tree ring plus labor time involved in planting, plant acquisition and transportation.
Studies: Reducing weeds in ornamental groundcovers under shade trees through mixed species installation. M. Quigley Hort Technology Jan-March 2003 13(1)

12. **Product**: Motorized trimmers with flexible string lines or solid steel blades for heavy blackberry infestations.
Application Frequency: Similar to hand weeding as only tops of weeds are removed. Monthly at first then bimonthly.
Details: Trimmers are currently used for edging and some clean up work. Trimmer use raises concerns about noise and air pollution and whether these are an acceptable alternative to current weed control practices.
Cost: Estimates on time suggest 1.4 miles of fence line per hour.
Trimmers are already owned. Maintenance costs plus fuel costs plus labor cost. Need to also take into account training time and safety equipment.
Hazards: Flying objects, Heat, pollution from exhaust, Possible strains and injuries to user if required to weed whack for extended periods of time.

13. **Product**: Use of Human powered tools to remove emerged weeds.
Application Rate: One worker and required time to remove problem weeds.
Application Frequency: Monthly in the spring with follow up monitoring and weeding on an as needed basis.
Details: This is currently part of the PP&R IPM strategy. By including it in the trial program we can quantify the costs and success of this approach to weed control. Volunteer labor is often used for hand weeding and one cost option will look at actual costs of volunteers. Weeds removed from the site also need to be disposed of and possible contamination of another site with weed seeds is a possibility. Costs of disposal and prevention of weed seed dispersal must also be part of the final cost analysis. In some cases if weeding can occur when weeds are small than material can be left on site.
Costs: time to weed plus cleanup time times $10 per hour for Seasonal Maintenance worker
Hazards: Poison oak, blackberry thorns and other plant hazards. Trash dumped in planting beds, glass, needles, etc. Unhappy workers and disillusioned volunteers who do not like to spend extended time weeding. Long term wear and tear on employees.

14. **Product**: Garlon 3A 2-3 gallons per acre or a 2% solution spray to complete coverage.
LI700 surfactant 1 to 2 % solution. This surfactant is commonly used with Garlon
Application rate: 1-2% solution
Application Frequency: For directed sprays spring and fall **applications are needed. A site needs to be treated for regrowth for two years after initial treatment**
Details: Three use patterns exist for Garlon at Powell Butte, as a directed spray on mature stands of blackberry, a directed spray on regrowth from mowed blackberry or a stump treatment for blackberry, English Hawthorn and Holly.
Specific use Pattern: As mentioned depends site and species to be controlled
Cost: $57.60 / gallon
Hazards: DANGER may cause irreversible eye damage. Prolonged or frequent exposure may cause an allergic reaction in some people. Avoid contact with skin and breathing vapor.
LI700: May cause skin and eye burns. Vapors are irritating to the nose and throat
Studies: Current use practice, site use pattern of natural resources ecologist.

Trial Results

Tree ring Weed control

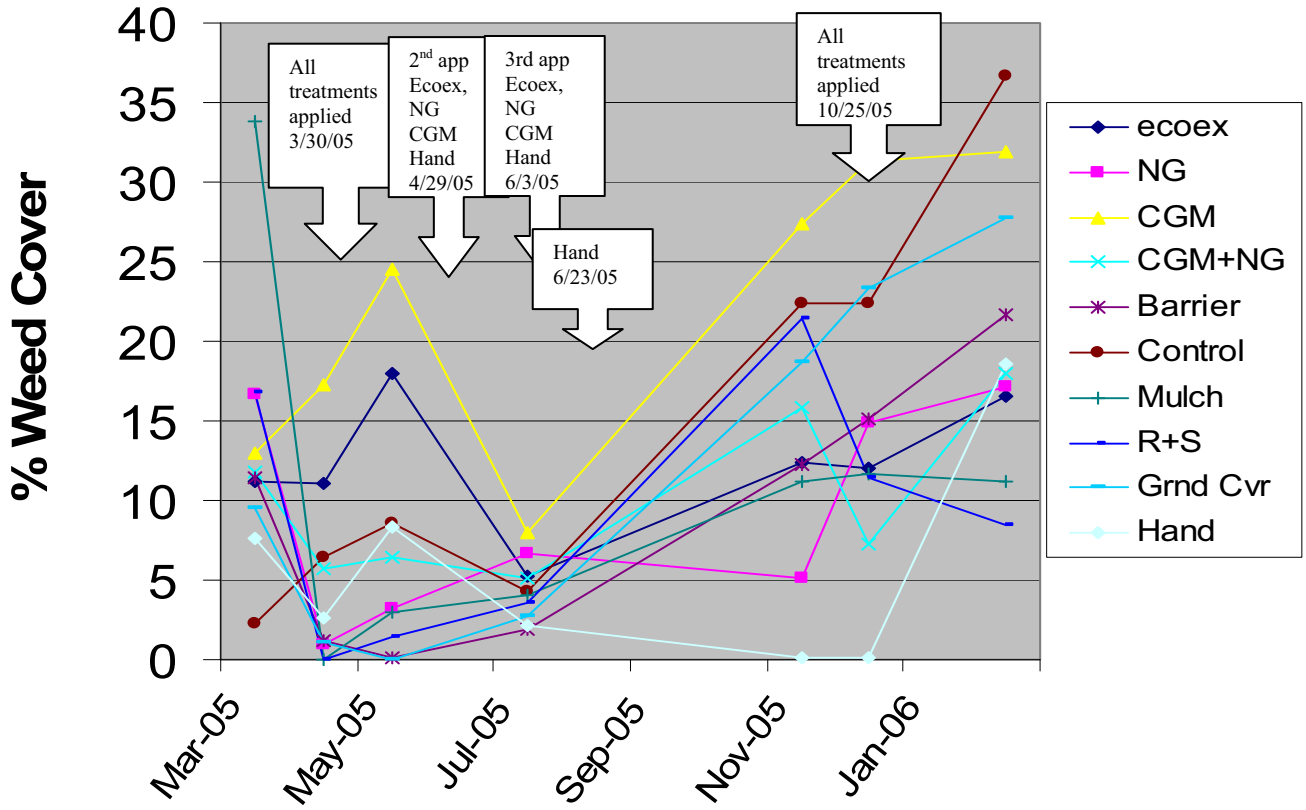
Two parks were used for the tree ring trial, Willamette and Gabriel Park. A total of 70 tree rings were used for the trial with 10 different treatments. The plots were established using a 2 set randomized design so that there were equal plot numbers of each treatment at the two parks. 40 plots were at Willamette park and 30 at Gabriel. In March 2005 the first applications were applied and treatments continued following pre determined guidelines through the first year. Due to changes in Staff there was no data collected in 2006 and the trial was reestablished with a smaller subset of treatment in 2007. Weed data was collected prior to any applications than at 10, 40 and 100 Days after treatment. Weed number and % cover data was collected. In the second year of the trial at Willamette park the plots were sprayed out due to test applications not being made on schedule and all of the plots becoming weedy. In 2007 the trial applications were resumed though only at Gabriel park.
Results were compiled and analyzed for Standard deviation and statistical significance.
Cost information and number of trips and time to apply each treatment were also tracked.
The tree rings cover many species and ages of trees though only three evergreens were in the trial. In general weed burden is significantly less under the evergreen trees and herbicide applications are seldom required.

Cost of trip
During the trial travel distance was 9.7 miles estimated time was 20 minutes. Though for zone maintenance staff the drive to a park would not be as long, an average 4 mile drive was used to calculate costs.
4 miles and 10 minutes will be used for travel cost calculations.
10 minute x 2 for return trip x $31.97 per hour = $10.55 for labor
8 miles x $0.485 (IRS Mileage rate) = $3.88
Cost for a return trip is $14.43

Table 1 Breakdown of cost of various treatments for 1 season of weed control on 10 tree rings

Treatment	No# trips/ applications	Travel Cost	Cost for Materials 10 tree rings	Labor for 1 application to 10 Tree rings	Total Annual cost
Forestry chip Mulch	1	$14.43	$27.50	$8.89	$50.82
Groundcover	1	$14.43	$900	$110	$1024.23
Roundup Pro + Surflan AS	2	$28.86	$0. 80	$6.05	$42.56
NG	4	$57.72	$10.60	$12.70	$150.92
Eco Exempt	4	$57.72	$13.00	$8.81	$144.96
Barrier Cloth	1	$14.43	$30.00	$77	$121.43
Corn gluten Meal	4	$57.72	$5.50	$12.38	$129.24
CGM + NG	4	$57.72	$16.10	$25.08	$173.57
Hand	5	$77.15	0	$10.18	$128.06
Control	0	0	0	0	0

Chart 1.Weed cover % in tree rings March 2005 through January 2006 at Gabriel and Willamette Parks.



Both weed counts and % weed cover were collected through 2005 into early 2006. Initial weed counts prior to treatment did not show any significant difference. The initial evaluations showed significant difference though by mid summer all of the treatments appeared to be the same. In the fall as rainfall increased and the weed burden increased differences between the treatments became significant again. The chart above shows the timing of applications through the season and this becomes more important than the weed control it self. Though most of the treatments showed some weed control (except Corn Gluten meal and the control) the number of trips and time involved in maintaining control became significant with some of the treatments.
The Hand weeding using a hula hoe provided the best weed control though 5 trips were made to hand weed. This was the most frequently applied treatment. Total time to weed was just under 2 minutes per tree ring. The cost of this treatment however was relatively low as no other inputs were required. The cost of tool purchase was not figured in as PP&R already owns many of this kind of hoe and they last for many seasons. From the graph showing control through February 2006 however it should be noted that as soon as hand weeding stops occurring on a regular basis weed number increases. The most successful treatments were mulch, Roundup Pro + Surflan AS and hand weeding, Natures glory Eco exempt HC, and Corn gluten meal with Natures glory all provided the same level of control with about 5% weed cover at best and 18% at worst. Corn gluten meal preformed worse than the control and the Barrier cloth and ground cover though were initially very clean were as weedy as the control by the end of the first year.

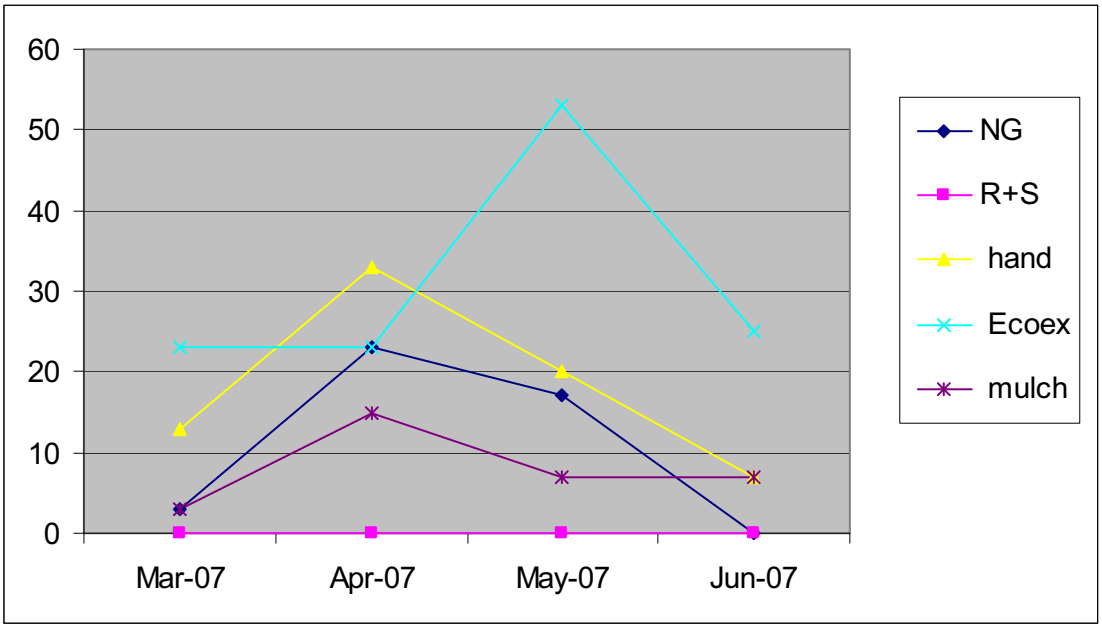
Factors impacting product success were the lack of root kill and insufficient barriers to new weeds germinating. The Roundup Pro and Surflan AS combination performed well at the start and end of the trial though through the late spring and early summer followed the same curve as the control. The preemergent effect was minimal though effective knock down from the Roundup Pro did occur. Fall weed emergence was prevented with a Surflan AS application and thus weed cover through the winter was reduced. Roundup Pro + Surflan AS combination finished the trial with the least weed cover. Mulching with forestry chip mulch gave acceptable

weed control through out the trial being statistically not different from the Roundup Pro + Surflan AS application.

From a cost perspective Roundup Pro + Surflan AS, and mulching, were the cheapest by half as much as the next cheapest treatments. Barrier cloth, hand weeding, corn gluten meal, Eco exempt, and Natures Glory were all similar in cost being within $30 of each other. CGM plus NG was more expensive than NG alone but the control level was the same thus the additional costs were not justified. The planting of groundcovers was prohibitively expensive and establishment of the plants was minimal over the three years of the trial.

The treatments were repeated in Spring 2007

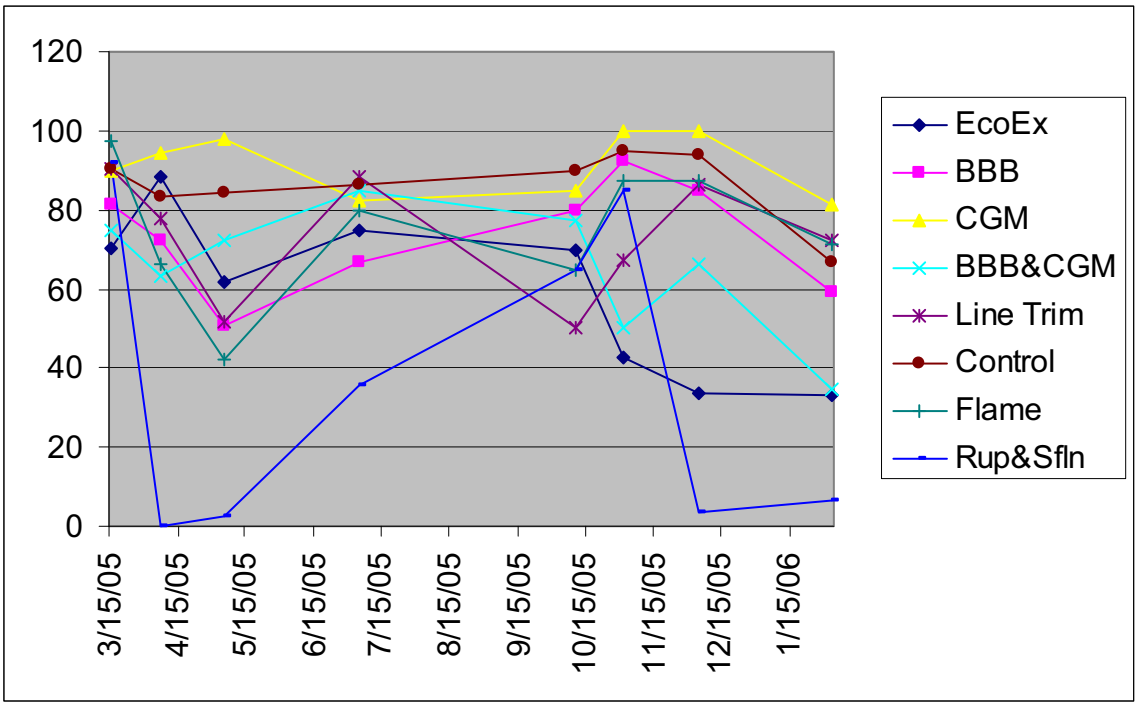
Chart 2: Average % weed cover in tree rings at Gabriel park March 2007 through Jun 2007.



The results from the 2007 were similar to the results from 2005 through 2006. Roundup Pro + Surflan AS was the cleanest weed control treatment though mulch provided similar weed control levels. Again as the season progressed and the site dried up there was a decrease in weed pressure. Natures glory and Hand weeding were not significantly different in there weed control however Eco exempt again provided poor weed control early in the season. Eco exempt need for high temperatures (preferably above 60 degrees Fahrenheit) makes it a difficult product for spring applications in Portland.
Due to the poor performance of barriers, ground cover and corn gluten meal they were not included in this section of the trial. Prior to the spring trial beginning the trees used in the ground cover trial in 2005 were checked to see of cover had established. Only Kinnikinnick had survived and that was only two plants that were still very small. The tree rings are tough location to establish plants. Since completion of this trial there has been work at another city park system looking at low growing turf options for around the base of trees. This should be considered for future trial work.

Gabriel Park Fence lines weed control

Chart 3. Gabriel Park fence line weed number per square foot March 2005 through Jan 2006.



Because of the narrow strip of plants beneath fence lines and the infiltration of turf and weeds from the surrounding areas weed control was difficult. Only Roundup Pro and Surflan AS have any sustained impact on the weed number and even with this mix it was short lived. In order to maintain these sites 2 applications per year with Roundup Pro + Surflan AS or up to 6 applications with other techniques are required. Cost of treatment rapidly becomes an issue with travel and labor costs for additional treatments. The second round of treatments showed the same trends.

Some treatments reduced the vegetative growth but did not reduce weed number. The propane weed burner was effective at reducing the amount of plant material and visually improved the appearance of the fence line. Repeat applications were essential and over the length of the trial there was no reduction in the weed number present. During the summer it is not possible to flame weed due to increased fire hazard but in the fall and spring this is an effective tool. At the same time as the IPM enhancement trial was being run there was a three year trial of pesticide free park maintenance at three Portland parks. Flame weeding was used extensively at two of the parks and was a useful tool. Repeat applications are required on a monthly basis until it becomes too dry to flame weed usually by the end of June. Propane use also generated a large amount of carbon due to the burning of a fossil fuel. Propane releases 12lb of carbon per gallon of fuel. The string line trimmer is a commonly used tool by parks staff for non chemical weed control. In the trial it was an effective tool for reduction of vegetative growth but did not reduce the weed number. There is no fire risk so this tool could be used throughout the year how ever there is a hazard created during operation for parks users and staff. All appropriate safety equipment must be worn to reduce ear damage, eye and leg injury due to flying debris. Parks users need to be 50 feet away during operation. The small engines of the type used on these trimmers have been identified as gross polluters and new federal mandates are requiring manufacturers to produce motors with lower emissions.

Corn gluten meal was a poor option for weed control in this setting due to there being many emerged weeds present prior to the application. The meal acted as a fertilizer increasing the weed cover. In the second round of the treatment corn gluten meal was not used due to its poor performance. Corn gluten meal was trialed in combination with blackberry and brush blocker a vinegar based herbicide. Weed count was lower than the blackberry brush blocker alone though weed count was still high. There may have been some preemergent activity though weed number was still high at 40 weeds per ft^2. Blackberry brush blocker alone at the highest rate was not significantly different than the control. The initial application did reduce weed number though regrowth to the previous level occurred 6 wks later. Additional application seemed to have no effect on weed number. There was a natural decline in weed number in all plots through the winter. Eco exempt the clove oil product trialed was poor in the spring applications though did depress weed number in the fall applications. This may have been due to the day time temperatures being higher in the fall that the early spring applications. This effect was noted in the other trial sites also and temperatures above 60 being required for this product to be truly effective, and below 50 there is no effect at all. In Portland's climate this is quite limiting and reduced efficacy in the spring is a problem as this is the best time to reduce weed number when they are small and easier to kill.

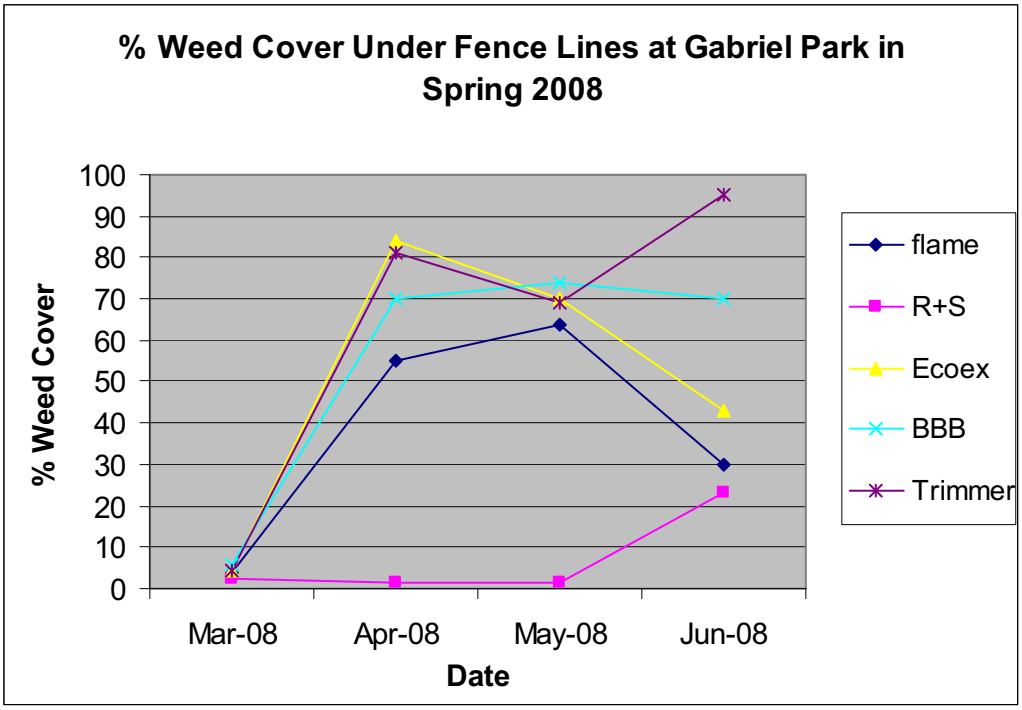
Table 2.Cost of various Fence line treatments spring 2007.

Treatment	No# trips Applications	Travel Cost	Cost for Materials 1000ft of fence line	Labor for 1 application to 1000ft of fence line	Total March through June cost
Roundup Pro + Surflan AS	1	$14.43	$4.50	$22.11	$41
Blackberry and Brush block	3	$43.29	$26.40	$40.70	$245
Eco Exempt	3	$43.29	$48.80	$29.70	$279
Flame	3	$43.29	$30.00	$70.95	$346
Line Trimmer	3	$43.29	$2.35	$74.06	$273

From a cost perspective Roundup Pro + Surflan AS was substantially less expensive than any of the other treatments. In general the cost of travel and labor were the biggest factors limiting the use of many of the materials. Even with out the travel cost the labor for applications alone adds up quickly. Portland parks have many miles of fence lines and the budget for treatments on these sites alone is high.

This trail did not look at the cost effectiveness of permanent design features that remove the need for weed control under fence lines. The addition of heavy rubber pads or concrete strips under the fence can remove the need for weed control. Mowing can occur up to the permanent barrier and no additional vegetation management is required. Though these systems have higher up front cost they allow Park maintenance staff to spend their time on other tasks and still give years of weed free fence line.

Chart 4.



In the spring of 2007 some of the treatments were repeated. As can be seen there was a repeat of the previous results. Roundup Pro + Surflan AS gave the best weed control, control from Eco Exempt improved with increasing day time temperatures while Blackberry and Brush Blocker seem to have no effect on weed cover. Line trimming reduced weed height but actually increased weed cover and propane weed burning controlled weed height though there was an increase in % weed cover from the start of the trial.

Shrub bed Weed control

The shrub bed trials were carried out at the Ladd's addition east rose bed a established neighborhood rose display garden. The weed pressure was high and the site is irrigated though the summer. In 2005 eleven treatments were applied to the site replicated four times. In 2007 the list of treatments was reduced to those that were effective.

From a weed control stand point the forestry chip, bark mulch and Roundup Pro + Surflan AS were all effective. From a cost stand point Roundup Pro + Surflan AS was least expensive though forestry chip costs though high in the first year were comparable over the three years of the trial. Roundup Pro + Surflan AS cost $52.70 per year ongoing with two applications per year the 3 year cost for forestry chip was $288.11 ($96.36 /yr). With some maintenance three years of weed control from one application of forestry chips was achievable. The maintenance included spraying out some creeping type weeds (creeping butter cup) and applying small amounts of mulch to thin areas(this was included in the cost). Bark mulch blown in by a contractor was an effective weed suppressant though establishment of maple seedlings began after 18months. Some hand weeding and an additional mulch application was required at this stage. The fines in the bark mulch make it less effective as a long term weed suppressant as weeds can establish in the bark dust. This mulch is more aesthetically pleasing to many park users and is uniform in color and particle size. The forestry chips are much larger wood fragments and the color much lighter also there can be significant difference in the chips depending on the trees being chipped. Variation in loads is minimized if the chips are stockpiled

and turned for several weeks before being used. With both wood mulch products there have been concerns raised about adverse effects on plant health though this was not observed in the trial.

The non traditional or organic herbicide products were mixed in their efficacy though all were moderately expensive. Corn meal was an ineffective preemergent in this setting. Though there is information that suggests this product would work the majority of weed control work in the northwest with this product indicate it is usually a poor weed control product. In the trial it was used alone and in conjunction with Nature's Glory Weed and Grass Killer an acetic acid based contact herbicide. In both situations there was an increase in the weed cover. Grass weeds especially responded to the nitrogen released as the product breaks down. This product was pulled from the trials as the areas in which it was used become weedy to the point of being a nuisance and complaints were received from park neighbors and the maintenance staff. Corn gluten meal was also expensive 4 applications cost $177 including travel costs per 1000ft2

The two top kill products used were Natures Glory weed and grass killer and Eco exempt HC. Eco exempt is a clove oil based product had a strong odor of cloves and applicators and public commented on the odor. After some time applying the product the odor got to be irritating to some applicators, though had no physical effects. The efficacy of the clove oil product was variable and there seemed to be a heat requirement for the product to work at all. Generally if the temperature was above 50 degrees Fahrenheit the product worked good at killing the top growth of green tissue. Unfortunately because the efficacy was poor early in the spring when weeds were small the control of larger weeds was more difficult and even those where top kill was acceptable they grew back quickly. Eco exempt was an expensive product and had to be applied regularly in order to maintain the site. Cost of materials time and travel was $224 per 1000 square feet for the season assuming 6 applications.

Nature's glory was a more effective top burn product though there were still times when it was not effective, the formulation of this product included a surfactant which made it easy to apply and it seemed to spread across the surface of the weed. Natures Glory was corrosive to rubber parts of the sprayer. On one occasion large amounts of liquid leaked from the sprayer. It was important to thoroughly rinse out the sprayer.

Hand weeding was an effective weed control method in the trial and was cheaper than the alternative herbicidal products. It was more expensive than Roundup Pro plus Surflan AS and forestry chip mulch due to the need to repeat the weeding on a monthly basis. The tool used to hand weed was a hula hoe, this tool allowed weeding to be done with minimal bending and disturbed the soil only on the surface thus not bring weed seeds to the surface. If soil tilth is good weeding with the hula hoe is easy and requires minimal effort. The entire surface of the bed was weeded each time regardless or whether weeds covered the entire surface or not. This approach helped the soil tilth and prevented weeds from getting rooted in before the control occurred. Weeds such as dandelion, thistle and grasses could be problematic if allowed to establish. The first weeding through the beds each spring was difficult, as was weeding if not done every month.

From a labor management point of view treatments which require monthly visits have a large opportunity cost as that time could be spent on another park or another activity. A once per year weed control that is effective alternatively frees up time for other tasks. Scheduling the multiple visits to the parks needing to be treated also is problematic. If the weather is bad then more labor would be required in order to get back on the schedule or weeds will quickly be out of control. As weed control is not the solitary task of parks employees but a part of the overall management the time spent on this activity is always in question.

If weed control is not timely then a huge labor cost is required to bring sites back into line with parks maintenance standards. During the trials the corn gluten meal plots and the control plots went for two months with not weed control. These sites were then hand weeded due to complaints from park users. The plots had thick turf grass and tall annual weeds. It took 3 hours per 100 sp ft to remove the weeds and over 100lbs of weeds and soils were removed. For any weed treatment the consistency and timing of the treatments must be managed. With the non traditional weed control products this management and commitment to the weed control system has very little room for error or delay.

In the spring of 2007 the treatments were repeated. 4 applications of Eco Exempt HC, Natures glory and hand weeding were applied. Weed control was poor in all but the hand weeded plots. Beast grinding mulch was the third worst weed control strategy and introduced weeds which were not present in the other plots. As mentioned earlier the beast grindings were generated by parks from the organic material generated through the general park activities. This material is branches leaves and weeds. The grinder produces a mixed product with fines as well as larger wood chunks. The ground material is piled and used by park staff to amend shrub beds within the system. At all but one site this material is unturned and the material heats up under anaerobic conditions. Weed seeds and pathogens are not killed under these conditions and there is potential for this product to contaminate shrub beds. Ideally beast grinding piles should be turned every 10 days until the pile has stopped heating alternatively the piles could be arranged so that they passively aerate. The result would be higher quality compost with less weed seeds
Overall the forestry chip mulch was the best alternative to Roundup Pro Surflan AS though herbicide use as a spot treatment is helpful in maintaining the mulch integrity. Forestry chips are a waste product produced in Parks and can be delivered easily to park sites as required. There is a labor cost in spreading the mulch and some park users and staff do not like the light color of the chips. Steve Maki a PP&R horticulturist has been developing protocols for using and composting the forestry chip mulch over many years. He feels this is an effective weed management technique which is sustainable and responsible.

Chart 5: Weed number per 1000ft^2 in Rose beds at Ladds Addition East Rose Garden with different weed control practices.

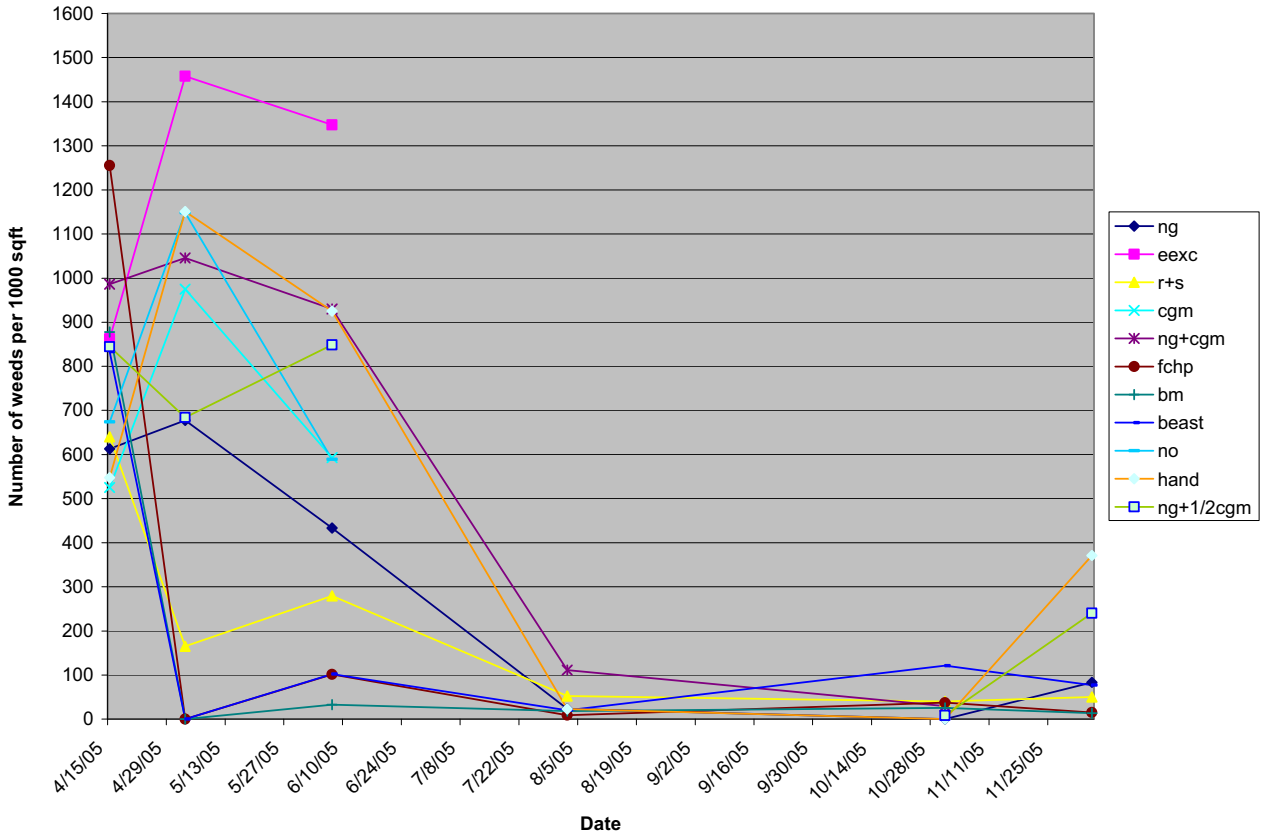


Table 3. Costs of various shrub bed treatments April 2005through Dec 2005 at Ladd's Addition rose garden.

Treatment	Number of applications	Travel Cost	Materials cost for 1000 ft^2 shrub bed	Labor cost for 1000ft^2 shrub bed	Cost For Spring Weed control For 1000 ft^2
Natures Glory (ng)	4	$57.72	$15.33	$15.45	$180.84
Eco Exempt (Eexc)	4	$57.72	$30.62	$11.01	$224.24
Roundup Pro Surflan AS (r+s)	2	$28.86	$4.50	$7.42	$52.70
Beast Grindings (beast)	1	$14.43	0	$100	$114.43
Bark Mulch (bm)	1	$14.43	$349	$8	$371.43
Corn Gluten Meal	4	$57.72	$19.20	$10.60	$176.92
Forestry Chip Mulch (fchp)	1	$14.43	0	$269.22	$283.65
Hand Weeding	4	$57.72	0	$17.24	$126.68

Chart 6.

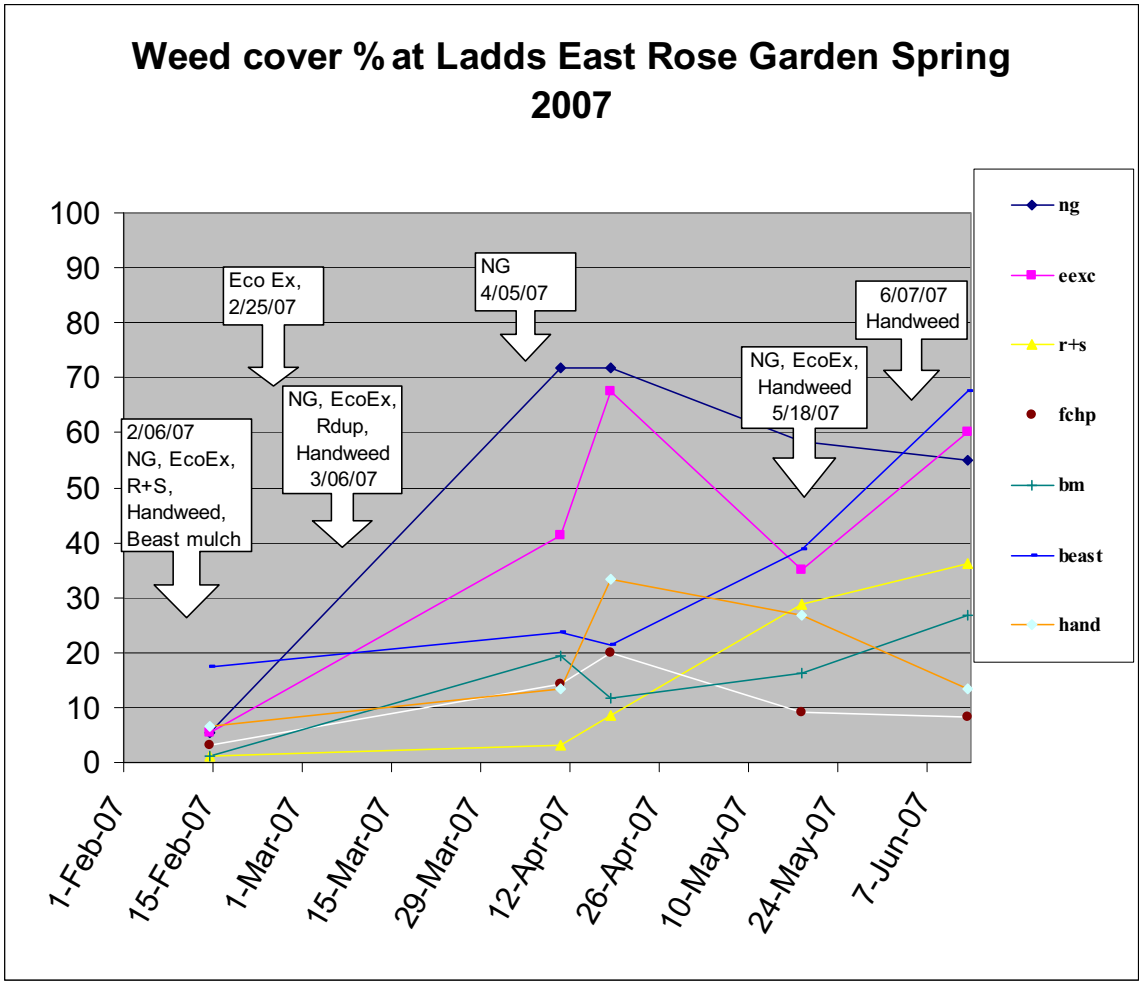
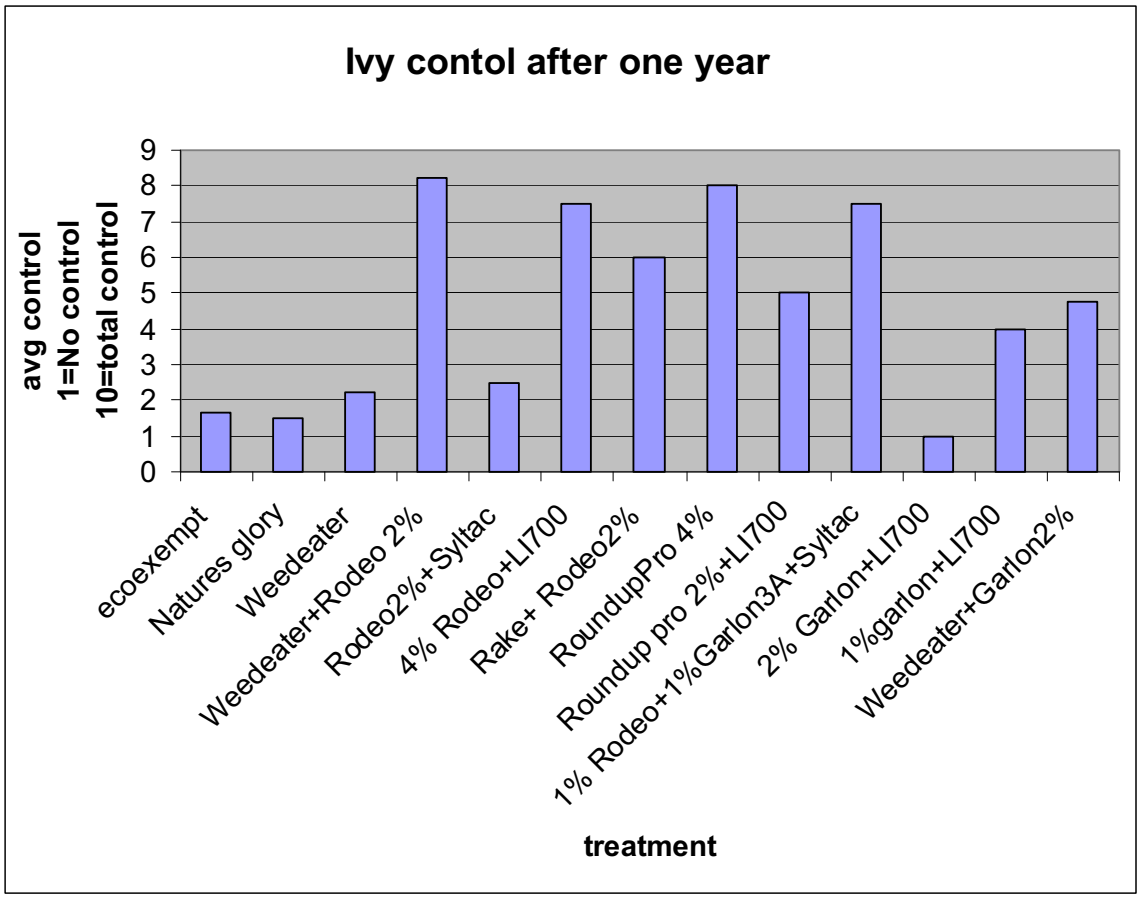


Table 4. Costs of various treatments at Ladd's Addition rose garden, spring 2007.

Treatment	Number of applications	Travel Cost	Materials cost for 1000 ft^2 shrub bed	Labor cost for 1000ft^2 shrub bed	Cost For Spring Weed control For 1000 ft^2
Natures Glory (NG)	4	$57.72	$15.33	$15.45	$180.84
Eco Exempt (EcoEx)	4	$57.72	$30.62	$11.01	$224.24
Roundup Pro Surflan AS	2	$28.86	$4.50	$7.42	$52.70
Beast Grindings	1	$14.43	0	$100	$114.43
Bark Mulch	0	$14.43	$69.00	$95.91	$179.34
Forestry Chip Mulch	0		0	$4.26	$4.46
Hand Weeding	4	$57.72	0	$17.24	74.96

Ivy Control

Chart 7. Ivy control at Hoyt Arboretum one year after the first application



The ivy control portion of the trials tested efficacy of some alternative products along with reduced rates of existing herbicide products used. Initial treatments were made in April 2006 and the plots were evaluated in January 2007. After one application 80 to 90 % weed control was achieved with 2 products and over 70% control was achieved with two others. One of the treatments though having an average control of 60% across all four plots had 1 plot where treatment was very poor. The average across three plots was better than 70%. There were some surprises and unexpected successful treatments. Overall it was shown that low rates of systemic herbicides can give good control of dense ivy with just one application. A follow up application should be performed one year after the first to clean up remaining plants.
The best controls were Rodeo at 2% solution with pre cut using a line trimmer, Roundup Pro pro at 4% solution, Rodeo at 4% solution with LI700 at the highest label rate (.6oz per Gallon) and a low rate combination of Rodeo (1%) Garlon (1%) and low rate of syltac surfactant (0.2oz per gallon). Roundup Pro at 2% solution was not effective even with the addition of LI700 surfactant also Garlon alone is not effective on ivy at the 1% or 2% rates. Using a line trimmer to damage the ivy prior to herbicide application improved the efficacy of glyphosate though did not increase Garlon efficacy. It appears from this trial that Garlon can cross into the ivy plant but does not have the right mode of action to kill ivy. Rodeo and Roundup's active ingredient glyphosate appears to be the opposite. It is difficult for glyphosate to enter the plant but when in it has the right mode of action to kill the plant. The addition of Garlon to 1% Rodeo solution demonstrates this. 2% rodeo plus Syl-Tac surfactant was not a good ivy product however 1% rodeo plus 1% Garlon and Syltac was. It is possible that Garlon and Rodeo with no additional surfactant may be enough to kill ivy though this has not yet been trialed.

The need for some form of assistance to get glyphosate into the ivy is reinforced with the line trimmer and leaf raking of ivy that occurred in two of the treatments prior to the application of Rodeo with no additional surfactant. Both of these treatments were superior to 2% Roundup Pro plus LI700 and 2% rodeo plus Syltac surfactant. The plants were line trimmed to the point of leaf removal and stem damage the herbicide was applied approximately 10 minutes later. The leaf rake plots were raked vigorously prior to the application. The raking did not remove leaves though was vigorous enough to scratch the leaf surface and turn some leaves upside down. One of the leaf rake plots did not receive a thorough raking and control in that plot was poor at only 20% though the other three were over 70 %. It is important that if hand raking plots a thorough and complete job must be done prior to the herbicide application. The line trimmer and rodeo plots had control rates averaging 80% to 90% equal to 4% Roundup Pro but with 2/3 of the active ingredient glyphosate.

Achieving good control with such low rates and with products that are deemed safe for use in riparian areas (Rodeo and Triclopyr 3A) is a bonus for anyone looking to control ivy in natural areas. Ivy is often found near streams in our natural areas and there are limited options for controls on these sites. Hand removal of ivy is labor intensive and has negative site impacts in riparian zones. The trampling and soil disturbance leads to erosion and potentially opens up habitat for other invasive weeds. Though there is resistance to herbicide use in many cases this is the method though which the least impact to a site occurs. One application which can reduce ivy loads by 80% using a product that has been shown to have little or no impact on aquatic organisms.

Both the raking and line trimmer methods are more expensive to apply as there is additional labor cost and the expense of running the line trimmer. Line trimmers are also a source of pollution though new low emission small motors are becoming available the older units currently in use are problem polluters considering their small size. Additional costs per 1000 ft^2 are just over $5 for line trimming and $10 for raking though in some sensitive areas these additional costs can be justified in order to use the least toxic approach.

The combination of Garlon and Rodeo with a low rate of surfactant or potentially no surfactant (method to be tested) gives about 80% control, this method represents the lowest rate of product use. Glyphosate in the mixture is applied at less than 1oz by weight per 1000 ft^2 and triclopyr at less than 0.5oz. For comparison the rate of Roundup Pro required for control was 4% which is 2.6oz by weight of glyphosate per 1000ft^2. Using this mixture would cut the amount of product used on a site considerably though there is an additional product in the mix and Garlon requires additional handling care by applicators. Garlon 3A has an eye hazard warning on the label and safety goggles or a face shield are required when mixing as well as access to an emergency eye wash station. This limits mixing in the field unless a portable eye wash station is available though at all parks facilities where mixing occurs eye wash stations are present.

From a cost perspective the applications that are herbicides with no physical damage being done to the ivy are cheaper due to the reduced labor involved. Rodeo, Garlon and Syltac cost $1.10 per gallon, 4% Roundup Pro costs $1.23 and 4% Rodeo plus LI700 cost $1.73. 2% Rodeo costs $0.85 per gallon but additional labor is $5 to $10 per 1000$ft^2$. Labor costs for application are not includes as one application of each product occurred and all products were applied in the same manner.

Top burn products trialed caused some leaf discoloration but none completely removed leaves. All of the products were regrown by one year later as additional follow up treatments were not made with these products. It is unlikely that additional treatments would have killed ivy as they would need to be frequent and spaced to remove all leaf material as regrowth occurred. This approach is expensive and does not fit with management practice in our natural areas. Line trimming also only provided short term results and the ivy would need to be trimmed back frequently. Hand removal has been successful and there is extensive documentation on the hours involved in hand pulling ivy. Usually volunteer crews have been engaged in this work. Hand removal is extremely useful in removing ivy from trees though is less successful when dealing with ground ivy. The large vines that are found climbing trees are cut and a circle of ivy is removed from the base of the tree. This essentially sets the area up for a ground treatment with an appropriate herbicide.

Table 5. Cost of various treatments for Ivy control

Costs shown are materials only as the labor involved was equivalent except as noted for the line trimming and raking methods.

Prices based on 2006 purchase prices to PP&R

Product	Ounces of AI per gallon	Surfactant	Mix cost per Gallon
Rodeo 2%	1.76oz	No	$0.85
Roundup Pro 4%	2.6oz	Factory mix	$1.17
Garlon 2% + LI700	1oz	Li700 .6oz	$1.23
Rodeo 1% + Garlon 1% + Syltac	0.88oz + 0.5oz	Syltac .5oz	$1.10
Rodeo 4% + LI700	3.52oz	Li700 .6oz	$1.73
Blackberry Brush blocker	1:1 mix ratio	No	$9.40
Ecoexempt HC	1:5 mix ratio	No	$19.20

Concerns when selecting weed control methods.

Worker and citizen exposure to potential hazards is always a concern when determining appropriate weed control practices. While it may be assumed that only pesticides or herbicides bring risks to workers and citizens, all methods of weed control can result in hazards or risks. It is also important to understand that pesticide use within PP&R's IPM program is carefully researched and controlled to minimize potential risks. Choice of pesticide materials is screened and prescribed so that their use does not place park patrons at any undue risk. Some pesticides are capable of creating hazards, however the current PP&R IPM practices are very specific in the low toxicity products used, the public notification and signage required, and the placement of pesticides so that exposure to park users is minimized.

Through the trial we identified many products and method s that have some merit as weed control products based on efficacy and cost, however there are additional concerns which should be considered when reviewing and selecting treatment method. Worker hazard, environmental impact, CO2 emissions and over all sustainability of certain methodology

Worker Hazard: Minimizing worker exposure to job hazards is a priority at PP&R and with the majority of employers. Employees should have a safe work place and their job though being physically demanding should not contribute to on the job injury. There are two major areas of concern when dealing with employee safety in regards to weed control issues.

Worker Exposure: The exposure of workers to certain chemicals can cause acute and chronic illness. Of the products used at PP&R the selection process in place removes those which can cause severe illness. Eye exposure hazards are of concern and several products can cause irreversible eye damage. Personal protective equipment (PPE) is used to reduce the chance of exposure and the labels of all herbicides used stipulate a minimum level of protection required to protect the employee.
The following list summarizes the PPE requirement and potential hazards posed by the Herbicides used in the trial. This is from the herbicide label.

Roundup Pro: PPE Required, Long sleeve shirt, long pants, socks. Avoid contact with eyes or clothing. May cause temporary eye irritation.
Lowest level of hazard identification "Caution" rating
National fire protection association (NFPA) rating for health -1

Surflan AS: PPE Required Long-sleeved shirt and long pants Chemical-resistant gloves Shoes plus socks Mixers and loaders must wear a chemical-resistant apron in addition to other PPE
NFPA rating for health -2

Garlon 3A: PPE Required Long sleeve shirt, long pants, shoes socks, Protective eyewear, chemical resistant gloves.
Hazard warning "Danger" due to eye damage concerns
NFPA rating for health-3

Eco Exempt HC: PPE Required Protective eyewear Chemical resistant gloves made of neoprene, nitrile or natural rubber. Potential Health Effects: Prolonged exposure to this product may cause skin irritation, eye/nasal irritation, dizziness, headache or nausea. Lowest level of hazard identification "Caution" rating
NFPA rating for health-1

Natures Glory Wed and Grass Killer: PPE Required Goggles or face shield required when handling or applying.
Lowest level of hazard identification "Caution" rating
NFPA rating for Health-2

Blackberry and Brush Blocker: PPE Required Wear protective eyewear and gloves when handling, mixing and applying this product
Acute health hazards
Direct liquid contact with eyes can cause burning or severe irritation.
Direct liquid contact with skin can cause irritation.
Ingestion can irritate mouth, throat and other tissues of the respiratory and digestive tract.
Inhalation can irritate mouth, throat and other tissues of the respiratory tract.
Chronic health hazards: None known.
Lowest level of hazard identification "Caution" rating
NFPA rating for Health-1

The surprise when researching the organic herbicides was that the acute worker exposure hazards were similar to the more traditional products. Eye injury was the biggest concern along with skin irritation issues. The organic products may actual present more concerns due to the amount of application required during the season. Each time the product is handled there is a chance of injury. With Roundup Pro and Surflan AS there two applications made per years though with the top burn acid based products up to 6 applications per year were required to maintain the trial sites. This is three times as much exposure to the skin and eye hazards.

Chronic exposure concerns: With any of these products the long term exposure hazards are minimized through following the instructions on the label for mixing and applying including wearing the appropriate protective equipment. The products certified as organic are all based on either acetic or citric acid though Eco exempt lists clove oil as an active ingredient. The MSDS (Material Safety Data Sheet) for these products do not indicate any long term or chronic exposure hazards. None of the active ingredients are known carcinogens. The group of existing herbicides Roundup Pro, Garlon 3A and Surflan AS are all also considered safe products. Long term exposure hazards for Roundup Pro are practically non existent with ingestion amounts being about 1 pound per 200 lb of body weight with no observable adverse effects. For triclopyr the toxicity is also very low. Surflan AS a commonly used preemergent herbicide also shows little ability to enter the body and has low long term exposure risks being neither a carcinogen of mutagen according to the product MSDS. Exposure of the public to any of these products is extremely unlikely in our current use patterns. Correct PPE minimizes the exposure of applicators and also careful handling practices. The highest exposure time is during the mixing of the tank when the concentrated product is being used. The less often mixing occurs, the less exposure there is to the applicator.

Worker Fatigue/ Repetitive use/ Strain injuries.

These type of injuries can also be considered in the realm of acute and chronic injury. Acute injury being immediate and severe accidental injuries while chronic being from long term repetitive strain type injuries.
Back pack spraying is physical work, the mixed tanks of product weigh 30 pounds when full and a lot of distance may be traveled while emptying the container. Minimizing the amount of time employees spend spray reduces there expose to herbicides but also reduces the chance of injury from carrying the sprayer. Some applicators choose to use systems with a hose reel and the tank mounted in a gator or pickup. This reduces the weight of material that needs to be carried. The fewer applications to be made per year the less opportunity there is for injury.
Hand weeding, spreading mulch and using a line trimmer can also cause injury. As with all physical work the job must be done with safety in mind, all protective equipment should be worn and the employee must be physically capable of the task.
Avoiding days of constantly doing the same task can reduce the chance of fatigue and repetitive strain injuries. It is important that the PPR IPM program allow for a variety of weed management options so that time can be spent on different tasks than just hand weeding for example.

Carbon Footprint

The calculation of carbon footprint is based on the assumption that the energy used to generate the different herbicides is equal. This assumption is based on energy used for conventional herbicide production as production of acetic acid, citric acid and clove oil were not available but considering there is processing, formulation and transportation involved they may be very similar. In a study from New Zealand (Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry, Caroline Saunders, Andrew Barber, Greg Taylor) herbicide carbon footprint was calculated using energy required per mega joule (MJ) of energy used in the production formulation and transportation of the product. Glyphosate the active ingredient in Roundup Pro was identified as a high energy use product, while other herbicides were grouped together at a lower rate. This rate was generated using averages across a range of manufacturing systems and may not be 100% accurate however provides the closest available figure for any discussion on carbon footprint of herbicide use.

The differences in carbon footprint come down to the amount of active ingredient used per 1000ft2 and the number of trips involved. For the string line trimmer, propane flame weeder and hand weeded plots there are differences which were calculated and added to the footprint for vehicle traffic to and from the park site.
Base information

Truck Typical Park's vehicle F150 FWD V8 pickup (14mpg) produces 1.92lb CO_2 per Mile (source Terrapass.com).
Miles for trip to park, average round trip from reporting site to park is 4 miles. 4 miles X 1.92lb CO_2 / mile = 7.68lb CO_2

CO_2 released consumed in the manufacturing of herbicides is 0.06 Kg CO_2/MJ (energy unit), Glyphosate production, packaging, and transportation use 550MJ of energy/Kg of ai (active ingredient). For other Herbicides production, packaging, and transportation uses 310MJ/Kg of ai.

Carbon released by product for 1000ft^2 of sprayed area.

Roundup Pro: Used at the 2% rate 0.06Kg CO_2 / MJ X 550MJ / KG ai X 1.82Kg ai per gallon /128oz per gallon X 2.2lb per Kg = 1.03lb CO_2 /oz
Use 2.6 oz per gallon 2.6 X 1.03lb CO_2 /oz = 2.06 lb CO_2 per mixed gallon.
Application rate is 1 gallon per 1000ft^2 so CO_2 released per 1000ft2 is 2.06lb per application
2 applications per year plus vehicle travel of 7.68lb per application
2 X 2.06 + 2 X 7.68 = <u>19.48 lb per 1000ft^2</u> (in reality more than 1000ft2 would be sprayed per trip to the park so this over estimates the contribution of CO_2 release from the vehicle travel.)

Surflan AS. 0.06Kg CO2 /MJ X 310MJ/Kg ai X 1.82Kg ai per gallon /128oz per gallon X 2.2lb per Kg = 0.58lb CO_2 /oz
Use 3 oz per gallon. 3oz X 0.58lb CO_2 /oz = 1.64oz per mixed gallon
Application rate is 1 gallon per 1000ft^2 with 2 applications per year.
2 X 1.64 lb CO_2 + 2 X 7.68lb CO_2 per trip = <u>18.64lb CO_2 per 1000ft2 per year</u> (in reality more than 1000ft2 would be sprayed per trip to the park so this over estimates the contribution of CO_2 release from the vehicle travel.)

Garlon 3A. 44% ai used at 2% solution
1 gallon of concentrate contains 1.67 Kg of ai
0.06KG CO_2 /MJ X 310MJ/KG ai X 1.67Kg ai per gallon /128oz per gallon X 2.2lb per Kg / 128oz per gallon formulation X 2.6oz per mixed gallon = 1.39lb CO_2 per mixed gallon
Use rate of 1 gallon per 1000ft2 one application per year

1.39lb + 7.68lb = 9.07lb CO_2 released per 1000ft (in reality more than 1000ft^2 would be sprayed per trip to the park so this greatly over estimates the contribution of CO_2 release from the vehicle travel.)

Blackberry Brush Blocker 20% citric acid 8% acetic acid. Mixed at a 1:1 ratio
1.06 kg ai per gallon. 0.06KG CO_2 /MJ X 310MJ/KG ai X 1.06KG ai per gallon /128oz per gallon X 2.2lb per KG / 128oz X 64oz = 21.69 lb per mixed gallon.
6 applications per year. 6 X 21.69lb CO_2 + 6 X 7.68 lb CO_2 =176.22 CO_2 /1000ft^2 (in reality more than 1000ft2 would be sprayed per trip to the park so this greatly over estimates the contribution of CO_2 release from the vehicle travel.)

Natures Glory. 25% acetic acid = .95 Kg ai/gal. mix at 1:2.25 ratio
0.06Kg CO2 /MJ X 310MJ/Kg ai X 0.95Kg ai per gallon /128oz per gallon X 2.2lb per Kg / 128oz X 38.87oz = 11.84 lb per mixed gallon.
6 applications per year. 6 X 11.84 lb CO_2 + 6 X 7.68 lb CO_2 = 117.12 CO_2 /1000ft^2 (in reality more than 1000ft^2 would be sprayed per trip to the park so this over estimates the contribution of CO_2 release from the vehicle travel.)

Eco exempt HC. 21% clove oil = 0.80 Kg ai/gallon. Mixed at 1:5 ratio
0.06Kg CO2 /MJ X 310MJ/Kg ai X 0.80Kg ai per gallon /128oz per gallon X 2.2lb per Kg / 128oz X 32.74oz = 5.37 lb per mixed gallon.
6 applications per year. 6 X 5.37 lb CO_2 + 6 X 7.68 lb CO_2 = 78.3lb CO_2 /1000ft^2 (in reality more than 1000ft2 would be sprayed per trip to the park so this over estimates the contribution of CO_2 release from the vehicle travel.)

String line trimmer fuel consumption 600mls per hour fuel consumption. For 1000ft^2 used 250mls of fuel. CO_2 release from fuel consumption is 8.7 Kg per 1 gallon of gasoline.
250ml / 3785mls per gal X 8.7Kg/2.2lb per Kg = 0.26 lb CO_2. 6 applications per year. 6 X .26 + 6 X 7.68lb CO_2 = 47.64lb CO_2 per 1000ft^2 per year (in reality more than 1000ft2 would be treated per trip to the park so this over estimates the contribution of CO_2 release from the vehicle travel.)
Even though their carbon footprint is low small engines have been under scrutiny recently due to the high amount of air pollution they give out. Even though they are low fuel users their design Has not been changed in a long time and they burn fuel inefficiently resulting in other pollutants than just CO_2

Propane and CO_2 production. CO_2 production from propane combustion is figured at a ratio of 12.4lb CO_2 /gallon of propane. (http://www.conservationfund.org) This does not include energy of production or transportation of the propane so is not the total CO_2 amount. Because of difficulty finding accurate figures to use, the rate of 12.4 gallons will be used. Using data from the Flame Engineering web site (http://www.flameengineering.com) on fuel consumption rate a 5 gallon tank will give just under 9 hours burning time. Time to weed burn 1000ft^2 is 50 minutes
50 minutes per 1000ft^2 /9hrs X 60minutes/hour X 5 gallons of propane per 9 hrs = 0.46 gallons of propane per 1000ft^2
CO_2 is released due to propane combustion at 12.4lbs per gallon of propane
0.46 gallons X 12.4lb per gallon = 5.74lb per 1000ft^2
6 applications per year required for weed control.
6 X 7.68lb CO_2 from vehicle travel + 6 X 5.74lb CO_2 from propane = 80.52 Lb CO_2 per 1000ft^2 (in reality more than 1000ft^2 would be treated per trip to the park so this over estimates the contribution of CO_2 release from the vehicle travel.)

Appendix 1B: Product pre-selection list

Initial product list from which final list was selected.

Alternative Herbicides for Weed Control

Acetic Acid

Explanation – Acetic acid is the substance that imparts a sour taste to vinegar.
Pure acetic acid is a colorless liquid that is flammable and highly corrosive. Most acetic acid produced for industrial purposes, such as the acetic acid used for weed control, is derived via a chemical reaction by the combining of methanol and carbon monoxide with a catalyst.

Mode of Action – Acetic acid is a non-selective contact herbicide or "top killer"; it only acts on the areas of a plant that it comes in contact with, such as the stem and foliage. Plant roots are not directly affected; so multiple applications are usually required in order to control weeds using acetic acid. Young, actively growing herbaceous weeds are the most susceptible to acetic acid treatments. Acetic acid works by causing plant desiccation, which means that it causes plants to "dry out". It does this by breaking down plant cell walls, plant fluids then "leak"out and this is what causes the "drying out". Shortly after an application of acetic acid weeds become discolored and turn brown. After a few hours the weeds will be black and due to the leakage of fluids, water logged.

Precautions - Acetic acid is not equivalent to the "regular" vinegar that people put on their salads, pickle with or perhaps use as a household cleaner. Food grade Vinegar can contain up to 5% acetic acid but it is highly diluted in water. For acetic acid to be effective as a herbicide concentrates of 10% to 20% and higher, which can be highly dangerous (see link, http://pested.osu.edu/peptalk/Turf%Au2002.htm#vinegar), must be used. Some of the dangers involved with the use of higher concentrations of acetic acid are allergic sensitization, possible irritation or burning of the skin, eyes, respiratory tract and severe damage to the digestive tract if swallowed.
Damage can be irreversible in some cases. Repeated or prolonged exposure to high concentrations of acetic acid has also been found to have various adverse health effects. For more information on the associated health risks of acetic acid use see the following link, http://wsprs.wsu.edu/VinegarFactSheet.pdf

Applications – Spot spraying for weed control in shrub beds, flowerbeds and turf, tree rings, fencelines, cracks/gaps with weeds in hardscapes.

Links:
http://www.hazard.com/msds/f2/bkk/bkktd.html
http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_044001.htm
http://aenews.wsu.edu/Oct02AENews/Oct02AENews.htm#Vinegar
http://ars.usda.gov/is/pr/2002/020515.html
http://www.hort.wisc.edu/mastergardner/Features/weeds/vinegar/vinegar.htm

Products
The products are as follows, for each additional in formation is available only a summary of name, label, MSDS, source, and price information is given.

AllDown Green chemistry Herbicide, Summerset Products Inc. Citric acid 5%, Garlic 0.2%, acetic acid, yucca extracts and water 94.8%. OMRI listed. Use full strength for spot spraying. pH 2.35, possible eye irritant 32oz is $14 is available in 2.5 gal $37.95

Burnout and Burnout II, St Gabriel Laboratories, Clove oil 4%, Sodium Lauryl Sulfate 3%, Vinegar, leicithin, water, citric acid, mineral oil 93%. Eye protection. Mix 3parts H2O to 1 part BO2 or 2:1 for larger weeds. 2.5 gal cost $89.95.

Blackberry and Brush Block, Greenergy Inc, Citric acid 20%, inert ingredients vinegar 8%, water 72%.
pH 2, eye protection, mix 1:3 water or 1:1 if larger weeds.coverage is 2 quarts per 100ft2 at high rate.
Cost

Natures Glory Weed and Grass Killer, Cost: 1 gallon $25.00. 1:3 mix ratio.

Articles
Dela Cruz, Rita T. 2002. Vinegar: the effective weed killer. In Bureau of Agricultural Research Today 4:2. United States Department of Agriculture, Washington, DC

Corn Gluten Meal
Explanation - Corn gluten meal is a by-product of wet-milling corn processing. Various studies have found corn gluten meal to have pre-emergence herbicidal effects as well a being a source of nitrogen fertilizer.
Mode of Action - Proteins naturally present in corn gluten inhibit normal plant growth. Young, actively growing herbaceous weeds and grasses are the most susceptible to corn gluten meal treatments.
Applications – Weed and feed for established turf, pre-emergent weed control in established shrub and flower beds, pre-emergent weed control in tree rings

Links:
http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_100137.htm
http://www.gluten.iastate.edu/
http://www.uwex.edu/ces/wihort/turf/CornGluten.htm

Products
Several products on the market with herbicide labels,
Wilbur Ellis A-maiz-N
Blue Seal Feeds - Safe 'N Simple
Butterfield Gardens - WeedFREE
Cereal Byproducts, Inc. - Earth Friendly
Down to Earth Distributors - Supressa
Environmental Factor Inc. - Turf Maize
Gardens Alive! - WOW!
Hardesty Organic Supply - Supressa
Lawn Ranger - Safeway
Safe Earth Lawn & Gardens - Corn Gluten Meal Weed Control
Soil Technologies Corp. - DynaWeed

Mustard Seed Meal
Similar to Corn Gluten meal only derived from Mustard. Higher amounts of chemicals that reduce germination. Product is currently unavailable to purchase. Is being researched at Idaho State University in Moscow Idaho.

Articles

Bingam, Barbara R., Christians, Nick E. 1995. Greenhouse screening of corn gluten meal as a natural control product for broadleaf and grass weeds.
HortScience 30(6):1256-1259

Carey, K., Gunn, E. 2001. Crabgrass and broadleaf weed control in turf using corn gluten meal based fertilizer. Guelph Turfgrass Institute 2001 Annual Research Report

Christians, Nick. 1993. The use of corn gluten meal as a natural preemergence weed control in turf. International Turfgrass Society Research Journal 7: 284-290

Essential Oils

Explanation – Essential oils are extracted plant essences that typically retain the characteristic odor of the plant or plant part (i.e. roots, seeds, stems, foliage, etc.) used in the extraction. Essential oils are widely used for flavorings, fragrances and cleaning solutions. Current research has shown some essential oils to have non-selective herbicidal effects as well.
Mode of Action – Most essential oils, particularly ones that contain high levels of the phenol, eugenol, are toxic to plants. Essential oils act by breaking down plant cell walls, which then causes plant fluids to "leak" out. However, essential oils are only effective as contact herbicides or "top killers"; they will only act on the areas of a plant that they can be applied to, such as the stem and foliage. Plant roots are not directly affected; so multiple applications will usually be required to control weeds with essential oils.
Precautions – Skin and eye irritation, may also cause allergic reactions in certain individuals
Applications - Spot spraying for weed control in shrub beds, flowerbeds, turf and tree rings
Products
The products are as follows, for each additional in formation is available only a summary of name, label, MSDS, source, and price information is given
Interceptor, Certified Organics. 680g/litre pine oil, pH 10.2, no occupational exposure limits label suggested goggles and respiratory protection 15-20% solution application rate 40 gallons/ acre.Cost? No Label for use in USA currently is labeled for NZ, Aus, Asia.
Biosafe, Agpro NZ. Fatty acids of Coconut oil 700grams per litre. Mix 70ml per liter, $220NZ for 20 liters. Used by Auckland City extensively for there weed control needs. No USA label at this time
Matran 2, Bioganic a division of Ecosmart Technologies. Clove oil 45.6% water, lecithin 54.4%, PPE protective eyeware, mix 1gal with 5 gallons H2O. OMRI listed, Caution hazard rating. $165 for 2.5 gallons
Ecoexempt HC Bioganic a division of Ecosmart Technologies. Clove oil. This is the landscape label of Matran**.** PPE protective eyeware
Articles

Dudai, N., A. Poljakoff-Mayber, A.M. Mayer, E. Putievsky, H.R. Lerner. 1999. Essential oils as allelochemicals and their potential use as bioherbicides. Journal of Chemical Ecology 25:1079-1089

Gauvrit, C., F. Cabanne. 1993. Oils for weed control: uses and mode of action. Pesticide Science 37: 147-153

T.K. James, A. Rahman, M. Trolove, H. Frith. 2002. Efficacy of a certified organic herbicide based on pine essence. New Zealand Plant Protection 55: 207-212

Tworkoski, Thomas. 2002. Herbicide effects of essential oils. Weed Science 50: 425-431

Mulches
Explanation – Mulch is basically a "cover" that is placed on top of the soil.
Mulches can achieve effective weed control because they act as a barrier; weeds seeds deposited in mulched areas will fail to reach bare soil and weed seeds already present in mulched soil often fail to germinate due to the exclusion of sunlight. When organic mulch materials are used nutrients and organic matter are added to the soil as the organic mulch breaks down. Other benefits of mulch are enhanced water penetration and soil moisture retention. The use of mulch also minimizes soil compaction and erosion. Uniform soil temperature is maintained by mulch as well because it insulates the soil, keeping the soil warmer during cold weather and cooler during warm weather. Though it covers the soil, mulch will not pose any barriers to plant fertilization, just apply fertilizer on top of the mulch.

Mode of Action – Mulch prevents weed seeds from germinating because mulch acts as a barrier to bare soil and it excludes sunlight for any existing weed seeds in soil it is applied to. If a weed seed does germinate under a layer of mulch it is likely that the newly germinated weed it will not be able to push through the mulch if the mulch is at a proper depth (see Recommendations for suggested mulch depths). Unless it is a particularly tenacious weed species, weed seeds that get deposited on top of mulch often find these areas inhospitable. Most mulch does not provide the full complement of nutrients found in soil and the upper layer of mulch is drier and more exposed to the elements.

Recommendations – Mulch is best applied to weed free soil when the soil has had a chance to warm, like in late spring. The degree of weed control achieved by mulch will vary with the size of the material used and the types of weed species present. Mulches made up of small, finer materials will form a more complete barrier to the soil than larger, coarser materials because there will be less gaps between the finer material than the coarser. However, mulch made up of smaller particles will break down faster than mulch made up of larger particles and will have to be replenished more often.

In order to get the most effective weed control and benefits from rock or organic mulch, a minimum application depth of 2 inches is recommended, anything less will not provide adequate weed control. The maximum recommended depth is 4 inches, if mulch is applied higher than 4 inches gas and water exchange will be negatively impacted. However, to keep up recommended mulch depths, organic mulches must be periodically replenished because they will break down over time.
Precautions – Do not apply mulch right up to the stem of plants and trees, this will encourage disease and rot.

Applications – Shrub and flower beds, tree rings

Types of Mulches

Non-biodegradable / Inorganic Mulch
Rocks / Gravel –Rock based mulches are fire resistant and will not break down like organic mulches. Because rock mulches do not break down, the need to periodically replenish the mulch in order to keep up a consistent depth is eliminated. Though rock based mulches offer more permanence, this can pose problems to the removal of the mulch and the planting of large woody plants such as shrubs and trees. Unlike traditional mulches, rock based mulches absorb heat during the day and release it at night, which increases water loss. If the rock-based mulch is light in color it will also reflect sunlight. Therefore areas where rock mulch has been applied will tend to be warmer and drier, so the types of plants where rock mulch is going to be used must chosen with this in mind. Another consideration when using rock based mulch is the use of a border in order to keep rocks from migrating out of the areas the mulch was applied to.

Precautions: Do not use rock rich in calcium carbonate such as limestone or marble, as it alters soil pH.

Plastic – The use of plastic sheeting as a permanent inorganic barrier mulch is not recommended, due to the fact that it will act as a barrier to water and gas exchange as well. Plastic can be useful when solarizing soil. Soil solarization defined is laying sheets of clear plastic over newly tilled, moist soil during the warmest and sunniest months of the year. The clear plastic traps heat, which causes the temperature of the soil under the plastic to rise dramatically, killing unwanted herbaceous plants, weeds and any seeds residing in the soil. If the soil you want to solarize is dry or has dried out since tilling be sure to water it until moist before laying clear plastic down, some weed seeds can tolerate extremely dry heat, but will not tolerate moist heat.

Geo-textiles (Woven / Spun Barriers) – Unlike plastic sheeting, air and water are able to diffuse through these types of barriers. Geo-textiles can provide effective weed control because they pose a barrier to bare soil and most weeds are unable to take root on the surface of geo-textiles they are best utilized in permanent plantings. Once installed it is difficult to rearrange plantings and/or add larger plantings such as shrubs and trees. Geo-textiles are also vulnerable to the UV radiation in sunlight and if not covered by something else geo- textiles will eventually be broken down by photo-degradation. Uncovered geo-textiles are also unattractive, to enhance attractiveness and prolong life-span geo-textiles should be covered; bark nuggets are often used for this.
Articles
C.A. Ponder, C.H. Gillian. 1991. Evaluation of landscape fabrics in suppressing growth of weed species. Journal of Environmental Horticulture 9:(1) 38-40

Derr, J.F., B.L. Appleton. 1989. Weed control with landscape fabrics. Journal of Environmental Horticulture 7: 129-133

Biodegradable Mulch

Paper / Cardboard
Newspaper - readily available, provides a barrier that water can pass through but can be tough for weeds to establish on or break through, adds organic matter to soil once broken down buts needs to be covered to enhance attractiveness and keep in place
Cardboard – same as newspaper (info above) but thicker, will last longer and can provide a thicker barrier than paper
D.A. Munn. 1992. Comparisons of shredded newspaper and wheatstraw as crop mulches. HortTechnology 2:(3) 361

Wood Based Mulch
Bark nuggets/ bark chips / shredded bark /bark mulch
Pine is the longest lasting of coniferous, softwood bark
Coniferous, softwood bark is more decay resistant than hard wood bark and does not require additives to adjust pH. Bark mulch will break down faster than bark nuggets chips or shredded bark, bark nuggets are the longest lasting followed by chips then shredded bark
Precautions: The microorganisms that break down wood mulch will draw nitrogen away from plants, therefore wood based mulches must be supplemented with nitrogen rich amendments or fertilizers.

Some other organic materials that can also be used as mulch
Composted Organic Material - can make it by composting a variety of plant materials from kitchen, vegetable garden and yard

Grass clippings – readily available to those that have lawns to mow, some clippings may have pesticide and /or inorganic fertilizer residues so use with caution if wanting to use in organic gardens

Hay / Straw – hay is higher in nitrogen than other mulches so nitrogen supplementation is usually not required with hay, use hay with caution because it can contain weed seeds, straw is less likely to contain weed seeds and it lasts longer than hay, but the organisms that break down straw will draw nitrogen away from plants, nitrogen supplementation is usually required when straw mulch is used

Leaves – readily available in the fall but difficult to keep in place, makes a better mulch if composted into leafmold, certain types of tree leaves may also effect soil properties when fresh

Pine needles – not readily available but makes an attractive mulch that is allopathic, which means that it will inhibit the establishment of weeds in areas it is applied to

Links:
http://eesc.orst.edu/agcomwebfile/garden/soil/solarizing.html
http://eesc.orst.edu/agcomwebfile/garden/soil/soilsolarization.html
http://digital.library.okstate.edu/OAS/oas_htm_files/v63/p25_27nf.html
http://www.ag.uiuc.edu/~vista/html_pubs/mulch/MULCH.html
http://www.eap.mcgill.ca/PCMPC_6.htm
http://hgic.clemson.edu/factsheets/hgic1253.htm
http://www.ces.ncsu.edu/hil/hil-8101.html
http://www.hdra.org.uk/schools_organic_network/leaflets/UsingMulches.pdf
http://www.main.org/aog/mulc.htm
http://ceventura.ucdavis.edu/ben/citrus/weeds/alt_weed_control.htm

W.A. Skroch, M.A. Powell, T.E. Bilderback, P.H. Henry. 1992. Mulches: durability, aesthetic value, weed control and temperature. Journal of Environmental Horticulture 10:(1) 43-45

Physical Weed Control

Herbivores for Weed Control

Explanation – Though there are several species of domesticated herbivores that could be useful weed controllers, goats are the most gastric hardy of them all. In comparison to other domesticated herbivores goats are able to eat the greatest variety of plants. Goats can eat plants toxic to other animals because they can neutralize phytochemicals during digestion. Plants normally too tough for other herbivores such as woody species are also readily eaten by goats and being that goats can stand on their hind legs they are able to graze in areas vertically challenging to other domesticated herbivores. Being vegetarians they will not purposefully pursue or harm resident wildlife. However, goats do not eradicate weeds because they can only eat the parts of plants that they can get to, such as stems and foliage, the roots are left intact. To achieve long-term weed control using goats, multiple grazing and/or other weed control treatments will be required.

Precautions – Goats only provide non-selective weed control, they must be temporarily penned in the areas where weed control is to take place and kept out of areas where desired plants species or single specimens reside Because of their voracious appetites and curiosity they also require human supervision.

Applications – Sensitive areas where herbicide use is undesirable, restricted or banned, wide spread weed infestations over large geographical areas, preliminary weed control i.e. to bring weeds down to a lower height before the use of another treatment method

Links:
http://www.metro-region.org/article.cfm?articleid=1379
http://www.ci.wilsonville.or.us/citynews/news/Goats.htm
http://denvergov.org/Natural_Areas/template23647.asp

Popay,I., Field, R. 1996. Grazing animals as weed control agents. Weed Technology 10: 217-231

Manual and Mechanical Weed Control

Explanation – Manual weed control is control by hand or by the use of non-mechanical hand held tools and mechanical weed control is control via the use of engine operated machines.
Mode of Action – Physical weed control by manual and mechanical means damages weeds by cutting tops off or removing them from the soil by pulling.
Removal of the tops or vegetative portion of weeds will deplete the roots of energy and nutrients, weakening the weeds, but it usually does not kill them off.
Most weeds are able to regenerate from the root mass that is left in the ground after the stem and foliage has been cut off. Pulling weeds up out of the ground may provide more long term weed control than cutting because the entire plant is being removed, however root fragments are often created by treatments that employ pulling and the weeds regenerate from the root fragments. To achieve long term weed control using manual or mechanical methods sites must be re-treated regularly during the growing season.

Manual weed control can be very specific, lessening or eliminating the impact(s) to native or more desirable species. Using manual weed control methods can keep environmental impacts to a minimum.
Applications: Areas where mechanical removal is unpractical and/or herbicide use is undesirable. Weed control in small areas removal of "intermittent" weeds

Mechanical weed control is less selective than manual weed control. It can be difficult to avoid individuals or small plots of desirable plant (or animal) species while operating machinery. Therefore the environmental impact to desirable species and/or areas can be greater with mechanical weed control in comparison to other control methods.
Applications: General weed control over large areas, removal of "flowering" tops of weeds before seeds set, areas where manual removal is unpractical and/or large scale herbicide use is undesirable, cut weeds down to a particular height before the use of another treatment.Examples, Line trimmers, mowers, hand pulling, hand tools such as hoes and mattocks. Digging with tractors or by hand.

Following is a fact sheet from EPA, http://www.epa.gov/air/community/details/yardequip.html

U.S. ENVIRONMENTAL PROTECTION AGENCY EPA 420-F-94-002
OFFICE OF MOBILE SOURCES. FACT SHEET OMS-19 May, 1996

Your Yard and Clean Air, Small Engines are Big Polluters

Most people do not associate air pollution with mowing the lawn. Yet emissions from lawn mowers, snow blowers, chain saws, leaf vacuums, and similar outdoor power equipment are a significant source of pollution. Today's small engines emit high levels of carbon monoxide, a colorless, odorless, poisonous gas. They also emit hydrocarbons and nitrogen oxides, pollutants that contribute to the formation of ozone. While ozone occurs naturally in the upper atmosphere and shields the earth from harmful radiation, ozone at ground level is a noxious pollutant. Ground-level ozone impairs lung function, inhibits plant growth, and is a key ingredient of smog.
Emission control for small gasoline engines has not been a crucial design consideration until now. Consequently, small engines are big polluters. And power equipment users inadvertently contribute to the problem by carelessly handling fuel and by improperly maintaining their equipment.

The U.S. Environmental Protection Agency (EPA) and the power equipment industry are working to investigate and bring to market cleaner technology for small engines.

Pollution Prevention in Your Own Backyard

EPA anticipates that regulations now being developed will bring cleaner lawn and garden equipment to market within a few years. Meanwhile, consumers can make a difference by adopting practices that will help protect the environment now and in the future:

Avoid spilling gasoline.

Preventing spills and overfills is an easy and effective way for power equipment owners to prevent pollution. Even small gasoline spills evaporate and pollute the air.

Use a gasoline container you can handle easily and hold securely. Pour slowly and smoothly. Use a funnel, or a spout with an automatic stop device to prevent overfilling the gas tank. Keep the cap or spout and the vent hole on gasoline containers closed tightly. Transport and store gasoline and power equipment out of direct sunlight in a cool, dry place. Use caution when pumping gasoline into a container at the gas station.

Your Yard and Clean Air

Maintain your equipment.

Follow the manufacturer's guidelines for maintenance. Change oil and clean or replace air filters regularly. Use the proper fuel/oil mixture in two-stroke equipment. Get periodic tune-ups, maintain sharp mower blades, and keep the underside of the deck clean. Take time to winterize equipment each fall.

Consider cleaner options.

Ask your dealer about the new, cleaner gasoline equipment entering the marketplace. Propane and solar options are also available for some types of equipment.

Electric equipment is cleaner than equipment powered by gasoline engines. Electrically-powered lawn and garden tools produce essentially no pollution from exhaust emissions or through fuel evaporation. However, generating the power to run electric equipment does produce pollution.

Use manual tools.

Tools that don't require electric or gasoline engines are especially handy for small yards or small jobs. Hand tools are available to meet a wide variety of lawn and garden needs, like lightweight, quiet, easy-to-use reel push mowers that generate no emissions.

Reduce mowing time.

Use low-maintenance turf grasses or grass/flower seed mixtures that grow slowly and require less mowing. Check with your local agricultural extension service or lawn and garden center about what is appropriate for your region.

Decrease lawn area. Plant additional trees and shrubs to reduce the energy costs of heating and cooling your house and to provide landscaping for wildlife. Native wildflowers and plants require little to no maintenance after planting.

Recycle old equipment.

Instead of selling or giving away your old lawn and garden power tools, take them to a recycling center where they can be converted into raw material for use in cleaner equipment and other products.

By combining these strategies, you can reduce your personal contribution to pollution. In addition, your yard equipment will last longer and you will save money.

For More Information:

The Office of Mobile Sources is the national center for research and policy on air pollution from highway and off-highway motor vehicles and equipment. You can write to us at the EPA National Vehicle and Fuel Emissions Laboratory, 2565 Plymouth Road, Ann Arbor, MI 48105. Our phone number is (313) 668-4333.

Thermal Weed Control

Explanation – Thermal weed control methods employ different forms of heat for weed control. Flaming weed control units use an open flame to control weeds by burning them. Units that emit hot water or steam use the heat from superheated water to damage plant tissues, which severely weakens or kills the plant. Hot foam is heated water mixed with a surfactant. Foam created by the mixture of water with a surfactant insures that the mixture "clings" to weeds, the idea being that the heat from the water will be more effectively transferred to the treated weeds. Heat radiating units have metal or ceramic "tiles" that are super heated; passing the units over weeds causes them to burn without having to use an open flame.

Precautions – Can cause severe burns. Must use with caution during warm, dry weather due to the fire hazard these units can pose. Some plants cannot be controlled with flaming and radiate heat units. Plants such as poison oak emit "toxic" smoke that can cause the same symptoms as when the plant is touched, however if the smoke from the burning of this plant is inhaled it can be life threatening i.e. same symptoms as when touched but in mouth, throat and internal airways.

Mode of Action – Treating weeds thermally destroys plant cells and causes plant proteins to coagulate, which disables normal plant functions, killing or severely weakening weeds.

Applications – Hardscapes, fencelines, cracks/gaps

Links: http://tncweeds.ucdavis.edu/tools.html

Examples of equipment available
Waipuna Hot foam applicator. Approx cost $20-30000
Steam applicators. Several options from $5000 to $20000
Radiant heat units from $1000 to $5000
Open flame from $50 to $500
Each unit represents a different approach to applying heat to the plant and all have various fuel usage and portability issues.

Articles

D. Hansson, J. Ascard. 2002. Influence of developmental stage and time of assessment on hot water weed control. Weed Research 42: 307-316

D. Hansson, J.E. Mattsson. 2003. Effect of air temperature, rain and drought on hot water weed control. Weed Research 43: 245-251

J.Ascard. 1998. Comparison of flaming and infrared radiation techniques for thermal weed control. Weed Research 38: 69-76

Prast, J.P., Collins, M. 2002. Putting the heat on weeds. The Orchardist 75: 54-59

Rifai, M.N., Miller, J., Gadus, J., Otepka, P., Kosik, I. 2003. Comparison of infrared, flame and steam units for their use in plant protection. Research in Agricultural Engineering 49: 65-73

Vitelli, J.S., Madigan, B.A. 2004. Evaluation of a hand-held burner for the control of woody weeds by flaming. Australian Journal of Experimental Agriculture 44: 75-81