ITM (Intelligent Turf Management) to Prevent Weed Invasion

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Almost all weeds that infest California lawns can be controlled by currently-available herbicides. Whereas chemical weed control should not be totally ruled out, intelligent proper lawn management can prevent a significant portion of weed problems and is the basis or foundation of any reasonable approach to weed management.

Since the introduction of synthetic herbicides a few decades ago, these chemicals have become our first line of defense in the control of weeds in turfgrasses. However, to be most effective, herbicides should be used in consideration with other soil, water and environmental factors affecting the growth of both the turfgrass and the weeds.

Weeds are defined as “plants growing where they are not wanted.” Thus a tall fescue lawn is perfectly acceptable, whereas a few tall fescue plants growing in a bluegrass lawn will be objectionable weeds. Generally, weed growth in a lawn is encouraged by inadequate turf cover– that is, a thin lawn with bare spots. Adverse environmental conditions, excessive traffic, and poor management practices are the primary causes of thin lawns. Long periods of drought, temperature extremes, over-irrigation, inadequate fertility, and poor mowing practices can all lead to the decline of grass health and thinning of a turf stand. Rodents, insects and turf diseases, misuse of herbicides, and heavy foot traffic can also destroy sufficient turf to leave a lawn vulnerable to weed invasion.

The information most valuable for lawn weed control is knowledge of the most appropriate turfgrass species for a given situation, and the prevailing weed species found in the geographical area where the grass will be grown. Armed with such information, a turf manager/homeowner can create a management program, which favor the desired turfgrass over the weeds.

Selecting a lawn grass adapted to one’s locality is a good first step toward insuring a healthy, dense lawn that can resist weed invasion. Lawn grass selection should be based on cultivar evaluations conducted at local universities. It is always advisable to use a blend of adapted cultivars rather than a single cultivar, since monostands (i.e., a turf stand composed of a single cultivar) are more limited in the range of conditions under which they perform well. At least three cultivars of one turf species should be used in a lawn grass blend.

Lawn management practices most affecting lawn performance are irrigation, fertilization, mowing and aeration.

Irrigation. Established lawns benefit from deep but infrequent watering. In most areas of California, 1 to ½ inch irrigation once a week is sufficient. If a lawn is sloped, or soil is too impermeable to accept this much water in one irrigation, consider applying half as much every three days. It is always best to let surface soil dry between irrigations; this practice helps reduce weed seed germination and survival.

Fertilization. Almost all California soils are deficient in nitrogen, the nutrient required in largest quantity by lawn grasses. Nitrogen fertilization is therefore necessary, and should occur during the optimum period for lawn grass growth: spring and fall for cool-season grasses like tall fescue; and monthly during the active growing period (mid-spring to mid-fall) for warm-season grasses like bermudagrass. Cool-season grasses need 4 to 6 pounds of actual nitrogen per 1000 ft^2 per year, while bermudagrass benefits from ½ to 1 pound of nitrogen per 1000 ft^2 per growing month. Both cool- and warm-season grasses benefit from annual application of 1 to 2 pounds per 1000 ft^2 of each of phosphorous and potassium. Irrigating after any fertilization is recommended to move nutrients into the grass root zone for efficient uptake. Nitrogen should not be applied to cool-season grasses during hot summer months, or to warm-season grasses during cold winter months; applying nitrogen at these times will encourage weed growth.

Mowing. Mowing grasses to the correct height helps them compete against weeds. The recommended mowing height for Kentucky bluegrass and perennial ryegrass is between 1½ and 2½ inches. Tall fescue can be mowed to 1½ to 3 inches. Bermudagrass lawns should be mowed between 1 and 2 inches. Most annual weed seeds require considerable light to germinate. The above mowing heights allow each variety to maintain a dense canopy that restricts light penetration to the soil surface and thus inhibits weed germination. It is also important to mow weekly or even more frequently. Lawn scalping due to infrequent mowing is highly conducive to weed invasion.

Aeration. Highly trafficked lawns, especially those planted on clay soils, are prone to compaction. Soil compaction reduces air, water and nutrient penetration into the root zone, creating an unhealthy environment for lawn grass growth. Several weeds (e.g. goosegrass) actually thrive in such conditions. Core aeration once or twice per year will reduce the effects of compaction by increasing air and water movement into the root zone. However, timing of core aeration is critical in terms of weed management. As mentioned above, a dense turf canopy is an effective barrier to weed seed germination. Because core aeration opens the canopy, it should be avoided when annual weeds are germinating. In most of California, late spring and early fall for cool-season grasses, and summer months for warm-season grasses, are the best times for core aeration. Although some weed seeds germinate at all times of the year, these periods coincide with the period of most vigorous lawn grass growth, and thereby offer the greatest likelihood that the grasses can win the competition with weeds.

In summary, an intelligent lawn management program tailors irrigation, fertilization, mowing and aeration to minimize weed germination and maximize the competitiveness of lawn grasses. Locally adapted lawn grass species and cultivars, sound cultural practices and a judicious use of herbicides will contribute to a clean environment and produce healthy, vibrant lawns for all to enjoy.

Integrated Plant Management (IPM) in the Landscape

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Weeds seem to be ever present in the landscape. They germinate in the spring, summer, fall and winter, then they continue to grow until they seed and die. These are called annual weeds (summer or winter annuals). The really difficult weeds are perennial and grow throughout the summer then go dormant in the winter. Though they seem like they are gone, they are just resting until next spring when they will start growing again. They also produce seed and drop them to the soil so they can produce more plants for the next few years. These weedy plants look unsightly, but they also compete with the ornamental plants for water, nutrients, and light. These weeds are often good hosts for nematodes, insects, viruses and other pathogens.

Integrated plant management (IPM) as used in this presentation means the combining of methods to manage vegetation where it is not desired. These methods can include, using plants for competition, mechanical (rototiller) cultivation, physical (hand pulling or hoeing), mulching, or preemergence and post emergence herbicides. The landscape can be defined as different planting areas including, turfgrass, bedding areas, flower plantings, shrub and ground cover plantings and tree basin areas. Each of these sites may need different types of methods to manage weeds. Some methods can be used in more than one area, but not all methods can be used in all areas.

It is imperative to know what weeds are present or are expected to be present before a weed management program is started. If organic mulch is placed over the weed bermudagrass, it may slow the growth initially but it will not control the weed, whereas if the mulch is placed over soil where annual bluegrass or barnyardgrass will germinate, it will give control. If herbicides are to be used it is extremely critical to be able to identify the species so the best control can be achieved.

Principles of Good Weed Control. There are three basic principles to keep in mind to control or suppress weeds. First, try to reduce the weeds from germinating, secondly, if weeds germinate keep them from establishing, and thirdly, keep weeds from seeding and replenishing the soil seedbank. Any technique that will achieve these principles can be effective in reducing weeds.

In turfgrass areas, the best method of weed control is to grow a thrifty, vigorous turf. This includes the best turf species and varieties for your planting area, correct mowing height and frequency, correct fertilization (amount, frequency and timing), and correct irrigation for turf growth but not weed growth. In many home lawn areas of Sacramento, a vigorous, cool season turfgrass of turf-type tall fescue or perennial ryegrass may be the best turf. Other grass types may be effective but will take additional management attention to be the most vigorous and thus the best competitor to weeds. Often bermudagrass is a common turf type in the Sacramento area. It can be an effective turfgrass, but it can also become a weed, especially in flowerbeds.

In ornamental beds, often the best method of weed control is to densely cover the soil with plants. This can be done with perennial ground covers, or a combination of ground covers, low shrubs and trees. The objective is to reduce or eliminate light from reaching the soil.

Mulches. Applying mulches to bare soil is a method of reducing or eliminating light, thus reducing weed germination and establishment. Mulches can be organic (plant derived) chips, compost, or "yardwaste" or synthetic spunbonded or woven polyethylene or polyester materials (geotextiles). Organic mulches can control weeds but a mulch must be maintained so light can not reach the soil so weeds can not germinate through the mulch and establish. If the mulch is very fine, only two inches of mulch may be required annually to control germination. If the mulch is coarse, such as wood chips, it may take three to six inches to exclude light and reduce germination. Another name that has been used for the synthetic materials is landscape fabrics. These geotextiles come in various weights, colors, and sizes. They need to be firmly attached to the soil and to make them attractive; chip mulch may be placed over the top the fabric. If weed seeds blow into the mulch, they may germinate and grow on top of the mulch. These can be removed easily by hand if they are pulled when the weeds are young. Bear in mind that synthetic mulches eventually break down and must be removed, which may not be easy if covered with thick mulch.

Preemergence herbicides. In areas where weeds persist in coming up year after year, it may be desirable to use preemergence herbicides in the plantings. Often when ground covers are being established, using a preemergence herbicide reduces the competition from the weeds so much that the plants establish quicker than where weeds are pulled from around the plants. Preemergence herbicides control weeds as they germinate. There are many excellent herbicides available for use either in turfgrass areas or in shrub beds. Some of these herbicides include commercial formations containing oryzalin, benefin and trifluralin or oryzalin, isoxaben, pendimethalin or prodiamine. All of these herbicides are selective to certain plants thus, none will control all of the weeds that may be found in the landscape. Depending upon the herbicide, weeds may germinate and be controlled as they emerge from the soil or they may control the seedling before it emerges from the soil. Many preemergence herbicides can be applied around established plants to control weeds as they germinate without injuring the established plant. These herbicides generally have low water solubility and absorb tightly onto soil and organic particles. Thus, they stay in the surface of the soil whereas the roots of established plants are well below the herbicide and are not affected. Use caution when hand weeding to avoid removing young ornamental plants at the same time. With vigorous ground covers, if weeds can be removed for two to three months, the covers are so well established that additional weeding requirements are reduced.

Post Emergence Herbicides. Once weeds are established, they are more difficult to control. The larger the weed the more energy is required to remove the plant, whether by pulling, digging or killing with a herbicide. Some weeds, like purslane, when pulled but not removed from the landscape, will not be controlled since they can root and re-establish. There are two types of post emergence herbicides that can be used in the landscape. The first type is a contact herbicide that basically kills the green tissue that the herbicide touches. These herbicides either affect the tissues directly or affect physiological processes in the plant. They generally are fast acting (hours) and must have through coverage of the leaf tissue to be effective. Examples of these materials would be magnesium chloride, Reward (diquat), Sharpshooter (pelargonic acid), or Finale (glufosinate). The second type is called a translocated or systemic post emergence herbicide. These herbicides are applied to leaves and then they must move inside the plant to active sites of growth or where processes are being conducted where the herbicide is active in affecting the process. Examples of these materials are Poast (setoxydim), Envoy (clethodim), Roundup (glyphosate), 2,4-D and others. Some of these herbicides can be used to control specific weeds in turfgrass or in certain ornamentals without injury to desirable plants (selective herbicides), such as 2,4-D, MCPP, (Turflon) triclopyr or Ornamec (fluazifop). Other herbicides when applied to the leaves of growing plants are not selective (glyphosate or sulfosate) but when applied around the base of trees can be used to selectively control weeds without injuring the tree. These translocated herbicides are used when perennial plants are to be controlled.

There are many options for weed management in the landscape. No one practice in itself will control all weeds and will be safe to all ornamentals. By using good growing management conditions for the desirable plants and combining different practices for weed management, weeds can be controlled without a lot of extra effort. Timeliness of practices can make the job a lot easier and help produce excellent results.

Managing Weeds Organically

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Introduction

When managing weeds, the first task is to determine: What is a weed? Weeds are plants in the wrong place. It could be turfgrass in a vegetable garden, or oxalis in a lawn. In one part of the landscape a plant may be desirable, while at another location the same plant might be considered a weed.

The next step is to evaluate your landscape's weed problem. Typically, industrial and residential sites are more tolerant then sports turf areas. Sports turf sites require the same turf species throughout the area. For example turf managers do not want part of a golf green to be bent grass while other parts are bermudagrass, or golfers will complain. Homeowners are much more tolerant of weeds. In many instances, if asked if their lawn has a lot of weeds, they typically would say no. However, when a survey of weeds is conducted, a large part of the lawn could be weeds. Because they are green grassy weeds the homeowner thinks it looks fine. The greater the tolerance of homeowners to weeds, the easier the management and fewer pest management practices (in particular, herbicides) will be necessary to maintain an acceptable lawn.

Different people can perceive the same plant in the same landscape situation, differently. One might consider it a weed, another would think it a beautiful flower, while another could think of it as a beneficial plant. White clover is a good example. Back at the beginning of the last millennium, white clover was considered an integral part of a healthy lawn. About mid century pesticide manufacturers began promoting that a turf monoculture was possible with the use of herbicides. Soon the diverse lawn lost its desirability in favor of monoculture turf stands and clover lost its desirability. Now there is a growing trend for more environmentally sound lawns, which include a more diverse selection of plants. This diversity of plant varieties creates a more stable environment that is less likely to have pest problems. For example, some seed companies even offer lawn seed blends that include low growing flowers (e.g., clover). Environmentally aware turf experts know that clover provides lawns several benefits. Clover's best feature is that it produces nitrogen, which is made available to the turfgrass. The result is reduced nitrogen fertilizer requirements and greener lawns. (Just go to a city park that is not maintained with the heavy use of broadleaf herbicides. Look at the lawn and notice areas that appear to be greener than the rest. Walk over to the area and you will often see clover mixed in the turfgrass. The grass is greener due to the production of nitrogen from the clover.) Clover also adds organic matter, loosens the soil improving rooting of the turfgrass, is drought tolerant, increases diversity and pest resistance and reduces fertilizer expenses.

The best method of weed management is prevention. Mulch can prevent weeds in shrub, flower and vegetable beds very successfully. Using landscape fabric under an organic mulch (e.g., bark, compost, cocoa hulls) will be more effective. A shallow cultivation will remove any weeds that do appear, if done regularly before they get large.

Rocks are often used as a mulching material, however, it has some definite drawbacks. Rocks do not decompose and will not add humus to the soil like organic mulch materials. They also absorb a lot of heat in the summer. This raises soil temperatures creating a hot, stressful environment for plants, increasing pest susceptibility. If weeds do come up in rock mulches, mechanical cultivation is difficult.

Soil Testing

A soil analysis is the first and most critical maintenance practice when creating a weed resistant lawn. Only by following the recommendations of a soil analysis can you create a healthy, nutrient balanced, fertile soil with an appropriate pH and an abundance of beneficial soil organism. Without these recommendations you likely will add too much of one nutrient and not enough of another. The result is unhealthy, pest susceptible plants, a poor soil microbial population and a thin lawn, that will be attractive to weed invasion. When the soil is properly balanced it will stimulate the growth of an abundance and diversity of beneficial soil microbes. This results in a more stable ecosystem that is less susceptible to pests. By reducing pest problems, there will be less thinning of the lawn and fewer areas susceptible to weed invasion.

Most of the soil organisms stimulated by an appropriate fertilization program, as recommended by a soil analysis, are very beneficial to turfgrass (and other plants). Mycorrhizal fungi in a fertile soil will multiply and help plants obtain moisture and nutrients. Actinomycetes, know as the soil maker, recycling organic matter into available nutrients for plant and microbial use. They also create natural antibiotics, which help fight off pests.

The fertilization program is only as good as the soil analysis. Make sure you choose the right soil testing company. They should be familiar with the type of plants you plan on growing (e.g., lawn, landscape plants). Most soil labs analyze commercial agricultural soil rather than landscapes. You also want to choose a service that has knowledge and experience making organic recommendations. Again most soil labs give chemical recommendations and do not have the expertise to make qualified organic recommendations. Ask the soil testing services you are considering to send you a sample report. Then compare them and see which provides you the best information. Many soil testing services only provide numbers (e.g., 5ppm Nitrogen) which, for most gardeners and landscapers is meaningless. Typical recommendations might say, add a 16-16-16 fertilizer with iron and end there. For most gardeners and landscapers this does not provide a lot of information. A good soil report will fully analyze their findings. Instead of just giving numeric values for nutrient levels, a more descriptive terminology (e.g., high, low) would be more informative. The recommendations should also explain what these values mean and how to correct any problems and maintain those nutrients that are in proper balance. Living Resources Company performs soil analysis with complete organic recommendations. Their informative reports are typically 6-10 pages long.

The soil testing service should provide you with information on how to take a soil sample to submit to the lab as well as a questionnaire on your horticultural practices over the last two years. If you don't collect the soil properly, the recommendations will be worthless. If you don't tell them that you just applied fertilizer they will not be able to take that into consideration when evaluating the levels of nutrients, and will make the incorrect recommendations. Make sure you sample and care for the soil properly when collecting and sending it, and completely fill out the testing services questionnaire.

Weed Management in Turfgrass and Landscapes

Preparing To Plant. When installing a new lawn, existing weeds and weed seeds must be destroyed. This can be done organically. Start by removing (sod cutter, mow, etc.) the existing vegetation and leveling the soil. One method of weed management is with solarization. To be effective it must be done between June and August in full sun. Wet the soil to a depth of 12 to 18 inches. Cover the area with clear plastic and seal. Let the sun cook the soil for a minimum of 6 weeks (longer will be more effective). The heat created will destroy many weed seeds, insect eggs and disease spores.

Other times of the year use black plastic. It must stay on the soil longer, but will effectively kill existing vegetation, by exclusion of light preventing the manufacturing of food, starving the plants to death. After the plastic is removed, weed seeds may still be present. Cultivate the soil (work in recommended soil fertilizers and amendments) and water. Allow weed seeds to germinate. Cultivate the soil before weeds are two inches high, killing them. Irrigate and allow more seeds to germinate and then cultivate. Repeat the process until almost no weeds germinate. Two to three cycles are usually sufficient. With each new cultivation, make sure to work the soil to shallower and shallower depths, avoiding bringing up weed seeds from the soil's depths.

It is critical to choose the best possible turf varieties. They should be adapted to your growing conditions (sun exposure, climate, soil, etc.). New and improved varieties are frequently made available. More and more varieties are infected with beneficial organisms known as endophytes which provide resistance to drought, stress and pests.

Be sure to use quality seed, sod or hydroseed. It should be weed free, and contain a blend of new and improved varieties. Blends are best, creating more diversity and stability. Don't skimp on your budget here or you will pay for it down the road with higher maintenance and pest management costs.

Irrigation. Proper cultural care is critical. Remember, happy, healthy plants grow better and will out compete weeds. Irrigation in our area is the major maintenance problem that results in thinning lawns and weed invasion. Overwatering kills turfgrass, which is replaced by weeds. Underwatering, although not as common, results in stressed plants that are more susceptible to pest attack. This results in thinning lawns and weed invasion. Regularly check the coverage of your irrigation system. Randomly place cans across the lawn and following a regular irrigation cycle, measure the water in the cans. They should all contain approximately the same amount of water (less than 10% variation). If water is not being distributed evenly, adjust your irrigation system. It is also important when applying irrigation that you water deeply and infrequently. Water should penetrate 6 to 8 inches every time you irrigate. Dig in the soil to make sure the water is going deep enough. Light daily watering results in shallow root systems which make grasses susceptible to drought, deficient in nutrients, and more susceptible to pests, resulting in thinning and weed invasion.

Soil Aeration. Compaction is an enemy of healthy turf. Compacted soils stress lawns which encourages weeds that prefer a compacted soil to encroach. Aerating the turf twice annually, when it is actively growing (spring & fall for cool season grasses) is critical. It will improve water infiltration and percolation, root growth, microbial activity, and nutrient availability. When done just prior to fertilization, it allows the nutrients to move into the root zone of the soil. Aeration should be done with hollow tines that leave soil cores on the surface. Solid tine devices actually compact the soil.

An important warning about aeration. Many aerators have dozens of tines. If each is filled with a plug of soil, those plugs likely contain disease spores, insect eggs and lots of weed seeds. Before an aerator it brought to your landscape it must be completely cleaned. All soil from the previous site must be removed. There are two basic types of aeration machines. Drum types have dozens of tines and must be weighted down with water to get the tines to penetrate the soil. This somewhat compacts the soil while aerating it, and it takes time to clean them between job sites. The other type has three or four tines that work on a crank shaft, which forces the tines into the soil. These are much lighter machines and are easier to clean when moving between jobs. In between aerations avoid compacting the soil. Pathways should be designed so they will be used, keeping the majority of traffic off the lawn. Shrubbery properly placed can help direct traffic to the pathways. When the turf is wet, avoid as much traffic on the lawn as possible. In particular, keep heavy equipment off the lawn when it is wet. Soil is highly susceptible to compaction when wet.

After the lawn is aerated, it is a good time to overseed. It is helpful to dethatch and lightly cultivate the soil, creating a good seed bed. Overseed with new and improved varieties of turfgrass that will work well with the existing blend.

Mowing. The simple task of mowing has a great deal of influence on weeds. Mowing high (2.5 to 3 inches) encourages a deep root system resulting in a healthier plant that is more capable of out competing weeds. It also encourages a thicker turf stand, which shades the soil surface, decreasing weed seed germination. As with aerators, it is critical to thoroughly clean lawn mowers before leaving a site. Otherwise, weed seeds, insect eggs and disease spores will be spread from one lawn to the next. MOWR-Kleen (P.O. Box 867, Yarmouth, ME 04096: 207/846-4598) manufactures a devise that clips on to the mower deck. A hose is attached, the water turned on and the underside is washed. Keeping the blades sharp is also important. Ideally, they should be sharpened after every eight hours of service. This will keep them cutting the grass instead of tearing it. A clean cut is less susceptible to insect and disease attack and more tolerant of stress.

Lawn edgers create real weed problems. They are not cleaned between jobs, bringing weed seeds (and disease spores) from site to site. They dig into the soil creating an ideal environment for sprouting the weed seeds they plant. Make sure to clean these tools before moving from one site to the next. Ideally, landscapes should be designed with curved lines that will allow mowers to cut right to the end so edgers are not required. Specially designed curbing (e.g., creative curbing) is designed for just this purpose.

Organic Preemergence Herbicidies. Organic landscaping is making remarkable technological advancements. If you are conditioned to apply a pre-emergent herbicide, there is now an organic product that can do the job. Corn gluten meal has been shown to be fairly effective at preventing weeds. Prevention improves with every subsequent application. It is being marketed as corn gluten meal, as well as pelletilized products (e.g., Supressa, Bioweed, Weed Prevention Plus). Sources include: BioScape Inc. (Bioweed), 4381 Bodega Ave., Petaluma, CA 94952, 877/246-7227; Hardesty Organic Supply (Suppressa™), 252 Hedge Rd., Menlo Park, CA 94025; K & D Enterprises (Suppressa™), 4107 Morgan Rd., Ceres, CA 95307, 209/538-8492; Peaceful Valley Farm Supply (Corn Gluten Meal), PO Box 2209, Grass Valley, CA 95945, 530/272-4769; Down To Earth Distributors, PO Box 1419, Eugene, OR 97401, 541/485-5932. Corn gluten meal is a patented product, which makes it somewhat expensive. Research is underway and looks encouraging for wheat gluten meal, a non-patented product that would be considerably less expensive.

Weeding Tools. If weeds invade the turf, there are alternatives to postemergence herbicides. Hand weeding is the most effective. A dandelion weeder will get most of the roots, preventing hardy weeds from coming back. A variety of garden hoes can also be utilized. More effective and easier then hoes, long handled weeders do not require getting down on your hands and knees and do a comparable job. The well advertised Weed Popper (Bon Ami Co., Garden Weasel Div., 1025 W. 8th St., Kansas City, MO 64101-1200) along with the RotoWeeder (Texas Recreation Corp., Box 539, Wichita Falls, TX 76305) do a fair job. The best model is the Back-Saver Weeder (however, I believe it is no longer being manufactured by Rugg Manufacturing Co., 105 Newton St., Greenfield, MA 01301).

Flamers. A real alternative to post emergent weed killers is flame weeding. It is particularly effective as an edging tool, and in cracks in driveways and sidewalks. Flamers can also effectively control broadleaf weeds in lawns. Grass is adapted to fire. It is capable of surviving prairie fires. Turf's growing points are protected from fire. A light singeing of the weeds (about a three second duration) will superheat the water in the plant cells, causing cell walls to burst. Top growth of the weeds will be destroyed, while the growing points of the turf will survive. Flaming works best on young weeds. Turf may look slightly burnt, but evidence of burning will be removed with the lawns next mowing. The major caution with flame weeding is that it should only be used on green vegetation. Flaming dry vegetation can result in fire danger and it must be avoided. There are three manufacturers of flame weeders. The Red Dragon hand-held flamers (Flame Engineering, Inc., West Hwy. 4, P.O. Box 577, LaCross, KS 67548: 800/255-2469) are primarily used by the forestry service for setting backfires. They produce a rather sizable flame, which is only practical for use on driveways, walkways and other similar areas. The Singafier (from Turf-Tec International, 4740 NE 12th Ave., Oakland Park, FL 33334, 800/258-7477, 305/938-7477) is a professional model flamer designed for the landscape industry. A new product, the Primus Garden Flamer (from Primus-Sievert Inc., P.O. Box 186, Cherry Valley, IL 61016, 815/332-5504), was designed for backyard gardeners and is reasonably priced.

All flamers run on propane. Flamers are a viable alternative to postemergence herbicides. They are effective against a wide variety of weeds in many situations. Although there is some initial expense for equipment, operating costs are minimal (the cost of propane). Flamers save applicators money compared to expensive herbicides, and they are much more environmentally sound.

Organic Postemergence Herbicides. If you feel you must use a postemergence herbicide, there are organically acceptable herbicide products. Safers manufactures Superfast which is a potassium salt of fatty acid product. Fast Acting Weed Killer manufactured by Necessary Organics, is made from ammoniated soap. Nature's Glory Weed & Grass Killer is made from vinegar and lemon juice, by Ecoval US Incorporated.

Education. Education is an important component in organic weed control. New products, tools and techniques are always being developed. It would be beneficial to subscribe to a variety of publications relating to landscape care. Only one publication, "BUGS Flyer - The Voice Of Ecological Horticulture" (BUGS, PO Box 76, Citrus Heights CA. 95611: 916/726-5377: bugslrc@cwia.com) specifically deals with organic landscape maintenance. Various trade and garden magazines have occasional articles that discuss organic weed control. The garden section of local newspapers, and local garden radio talk shows may also discuss this topic. This will keep you informed on new techniques allowing you to reduce your reliance on toxic herbicides.

Summary

Most weeds can be discouraged using organic techniques. The first step in eliminating weeds organically is to test the soil and follow its recommendations so a fertile soil can be created. This will result in a biologically diverse and stable growing environment that will help create healthy plants and make it more difficult for weeds to become established. Weeds can be prevented with proper plant selection.

Cultural techniques (fertilization, irrigation, mowing/pruning, aeration, cleanliness, and the use of new organic preemergence weed control products) will encourage a dense turf that will resist weed invasion. If weeds still sprout, mechanical tools, heat, and new post emergent organic weed killers can keep most weeds under control. To improve your organic weed control practices keep informed on new products and techniques as they become available and consider adding them to your management practices.

Thistle and Brush Management for Rural and Foothill Landowners

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The purpose of this presentation is to discuss management of three major weed species affecting landowners in California's urban/wildland interface area. These species are representative of other problem weeds in this area. The weeds are yellow starthistle, poison oak, and blackberries. I hope to provide possible control strategies for these problem weeds. I will focus, though, mainly on herbicide options. Finally, I hope to stimulate discussion and questions from the audience.

Before I get into a discussion of herbicides, I want to bring up the concept of Integrated Vegetation Management. Integrated Vegetation Management, or IVM, is the weed component of IPM to or Integrated Pest Management. IVM is a philosophy of using all tools to optimize resource values. These tools include physical, cultural, biological, and chemical vegetation management methods.

Physical vegetation management is just what it sounds like. It can be manually pulling weeds, mechanically chopping them with machinery, or burning the vegetation with prescribed fire. Cultural vegetation management includes such things as seeding desirable crops or forage plants, and fertilizing these crops. Biological vegetation management includes such traditional strategies as grazing weeds and other vegetation with domestic livestock or wildlife. It also includes biocontrol, or biological weed control, with insects that target specific pest weeds. Just as the name infers, chemical vegetation management is the judicious use of chemical herbicides to control unwanted weeds.

Herbicides have many advantages over other vegetation management methods. They are almost always more cost-effective than other methods. They are less intrusive than other methods, in that they do not disturb the soil structure or cause dust the way mechanical vegetation does. They also do not cause the smoke problem of prescribed fire. Herbicides applied at the proper time and stage of weed growth minimize regrowth of perennial or biennial weeds. They can also help deplete the seed bank of invasive weeds. Herbicides may be combined with fire or mechanical vegetation management methods to provide a more complete solution to landowner management objectives.

Yellow Starthistle Management

Yellow starthistle is an annual composite weed that seems to grow year-round. It is an exotic invasive weed species. It has no natural enemies in the Western Hemisphere. Most people who are concerned about this weed know what it looks like, and I should refer you to the many excellent technical publications from the University of California for more technical information. Starthistle generally germinates in the late fall or early winter, and continues germinating to into the early summer. It goes through several stages of growth. The first recognizable stage, and the most important for herbicide control, is the rosette stage, when there are several small leaves laying flat on the ground. This generally occurs in January, February, March, and early April (the unusual rain patterns of 1998 and 1999 allowed starthistle germination well into June). After gathering starch and energy in deep roots during the rosette stage, yellow starthistle enters the bolt stage where it begins its vertical growth of a grayish-green stalk. The plant then goes into the spiny bud stage, where the thistle stickers appear without any flowers. Finally, the yellow starthistle flower head appears, giving the weed its name and its distinctive appearance.

Yellow starthistle can cause several problems. It will:

- Cut range productivity
- Cause possible allelopathy to other plants
- Cause "Chewing disease" in horses
- Cause painful sticker injuries to both people and animals
- Be a possible fire hazard

Yellow Starthistle Treatments

Yellow Starthistle is easily prevented by many soil-active preemergent herbicides. However, these products are not good choices for most foothill or wildland sites because the landowner or manager usually wants to grow grass and certain broadleaf plants for livestock forage. Postemergent systemic herbicides are usually the best choice for starthistle control. There are several herbicides available. They include glyphosate, triclopyr, 2,4-D, dicamba, and clopyralid. Glyphosate, usually known as Roundup, is a non-selective herbicide that will control grass as well as starthistle. Triclopyr, known as Garlon or Remedy, is a selective broadleaf herbicide that does a good job on starthistle, but is usually a better choice for woody brush plants. 2,4-D, known as Weedar or Weedone, and Dicamba, known as Banvel or Vanquish, are selective broadleaf herbicides that do a good job on starthistle. Both 2,4-D and Dicamba, however, are usually restricted materials that require a permit from the county agricultural commissioner before they can be used. Clopyralid, or Transline, is the newest starthistle herbicide on the market. It has proven to be the best choice for yellow starthistle control.

Transline herbicide contains three pounds of clopyralid active ingredient per gallon of formulation. It is a non-volatile water-soluble amine formulation. Transline is selective for broadleaf weeds only. It has a narrow spectrum of weed control, mainly composite species. This narrow spectrum of control is a benefit when rangeland managers want to maintain desirable broadleaf species, such as filaree. Transline is a foliage-applied translocated herbicide. It has no grazing restrictions. Clopyralid, the active ingredient in Transline, has both post and preemergent activity on sensitive weeds. When applied at labeled use rates, Transline will provide seasonal weed control. The product residual lasts from 30 to 90 days.

In addition to yellow starthistle, Transline controls many other thistles, knapweeds, cocklebur, dandelion, and sunflower. It will also control unwanted legumes such as clover and alfalfa when they grow in inappropriate areas, such as road shoulders.

The Transline applications may be made with both low-volume or high-volume spray equipment. Ground spray volumes are usually between 10 and 30 gallons per acre of spray volume. Aerial spray volumes range between 5 and 10 gallons per acre. High-volume ground applications may range from 30 to 100 gallons per acre.

Transline, as well as other starthistle herbicides, should be applied in the time period from the rosette stage to the spiny bud stage. This usually occurs between December through June. Other weeds should be treated during their active growth. The labeled rate range for Transline is 1/4 to 2/3 pints per acre. During the rosette stage Transline controls starthistle extremely effectively at 1/4 pint, or 4 liquid ounces, per acre. Higher rates are needed on bigger plants (late spring or early summer). For improved control add a nonionic surfactant, such as R-11, at one to two pints per hundred gallons of water. A new alternative surfactant would be 4 to 6 ounces per 100 gallons of Sylgard 309 silicone surfactant. Complete spray coverage is essential for good weed control. Spray skips will allow missed weeds to produce more seed the following year. Transline works relatively slowly. It may take four to six weeks after treatment to see complete weed control. A successful Transline application will minimize the thistle regrowth in following years, deplete the weed seed bank, and increase usable for age for both livestock and wildlife.

Poison Oak

Poison oak is a deciduous a brush species that grows across a wide range of California's wildlands. It grows in oak grasslands, near rural homes, and in urban interface areas. It has been found from sea level up to 5,000 feet elevation. Poison oak has a distinctive three-leaf structure that makes it simple to identify. The most common problem with poison oak is a an allergic reaction caused by contact with oils on the leaves and stems that are irritating to the skin. Allergic oils suspended in the smoke of burning poison oak can be a respiratory irritant. It can cause infections in dogs and cats that pass through heavy poison oak clumps. Finally, poison oak can be a fire hazard, like many other brush species.

Blackberries

There are two major blackberry species in California. The most widespread species is the native California Blackberry. Himalayan Blackberry is a non-native species that is fairly widespread in coastal areas. Blackberries can cause several problems. They can encroach on farmland or rangeland. This encroachment can cut rangeland productivity. Blackberries lines can grow quite large and become traffic visibility hazards. Blackberries tend to grow in riparian areas and may reduce stream flow or access to important waterways. Their vines have very sharp stickers that may cause injury to people or animals that come to close to these plants. And finally blackberries may be a fire hazard.

Brush Management

There are three key elements to a successful herbicide application on poison oak, blackberry, or any other brush species. They are:

1. **Application.** e.g., Total "Spray-to-Wet" Coverage.

2. **Rate.** Proper concentration or rate/acre for target.
3. **Timing.** Apply at proper growth stage of target.

Glyphosate and triclopyr are two herbicides that have been shown to be effective for controlling poison oak. Both glyphosate and triclopyr are systemic herbicides, which means the chemical moves throughout the plant. Other herbicides may burn down the top growth, but sprouts are likely to appear.

Glyphosate applications on poison oak and berries are highly sensitive to proper timing. This is an important reason for understanding the biology of each target species. Glyphosate, commonly known as Roundup® Pro, Rodeo®, or ROUNDUP®, should be applied late in the growth cycle, when the poison oak leaves begin to turn red or the berries start to turn color. Glyphosate moves down in the plant, or at certain times, to the growing points of the target plant. The red leaf color signals that the poison oak plant is moving starches down to its storage areas for the dormant season. The change in fruit color signals the same thing for blackberries. A proper application at this time will carry the herbicide down to the roots and results in a more complete kill of the plant. A common glyphosate concentration is two percent Roundup (2.6 ounces Roundup Pro per gallon of water), applied with spray-to-wet coverage in the late summer or early fall. A nonionic surfactant, such as R-11®, may be added, for spreading and penetration of the spray. Glyphosate is a non-selective herbicide and will kill grass, as well as broadleaf plants.

Triclopyr is a selective broadleaf systemic herbicide. It has a wider treatment "window" than glyphosate and is often considered to give more consistent control of poison oak and berries, since it translocates both up and down in the plant. Triclopyr is a selective systemic herbicide that has been marketed under the name Garlon® 3A and Garlon® 4 for control of difficult brush and broadleaf weeds in forest and rights-of-way. Dow AgroSciences also markets Remedy, a triclopyr ester formulation(same as Garlon 4) packaged in one-gallon jugs for use by small landowners on range, pasture, and non-crop sites. Remedy may be sprayed on brush any time the plant is actively growing. A surfactant, such as R-11®, must be added, for spreading and penetration. A common poison oak or blackberry spray concentration is 1.0 percent Garlon4 (or Remedy) + 0.5 percent R-11 (1.3 ounces of Garlon/Remedy and 2/3 ounce R-11 per gallon of water), applied with spray-to-wet coverage.

Once again, uniform foliar spray application is very important to get good control of poison oak or other brush. Herbicide labels often make general recommendations for correct coverage. Spraying with a flat fan nozzle, such as an 8004 or 8006, at 20 to 30 pounds per square inch pressure is a good starting point. The term "spray-to-wet" means to cover all leaves and stems so they are glistening with spray, but not to the point of runoff. Any runoff from a foliar spray is just a waste of money. Adding a spray colorant, such as Hi-Light blue spray indicator, will help place the spray efficiently and avoid skips.

Another effective treatment is the triclopyr dormant stem spray. After leaf drop or after growth has stopped, the target plant is sprayed to wet with a concentration of 1.0 to 1.5 percent Garlon 4 or Remedy, mixed in oil (such as diesel or kerosene). The oil helps the triclopyr to penetrate the bark of the brush. Since a 99 percent oil carrier is often difficult to work with, an alternative has been developed. Mor-Act® Adjuvant, an crop oil concentrate may be mixed at from 3 to 4 percent with water as an oil substitute. Another oil alternative is the new esterified seed oil adjuvant, Hasten, which takes only a 1.5 percent concentration for the dormant stem treatment. A mixture of 1.0 percent Garlon 4 and 3.0 percent Mor-Act (or 1.5 percent Hasten), with water and a spray dye, has proven highly effective against species such as poison oak, blackberries, and willows.

Summary

Although yellow starthistle, poison oak and blackberries are problem species throughout much of California, they can be managed to minimize their negative effects on people, animals, and the environment. Cultural, biological, mechanical, thermal, and chemical control methods may be used to manage these unwanted plants. For small landowners, maintenance of a healthy landscape or pasture (for people with livestock) combined with the judicious use of herbicides, may be the easiest, least intrusive, and most effective method of managing poison oak.

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R-11, Sylgard 309, Hasten, and Mor-Act are trademarks of Wilbur-Ellis Company

California brush control programs For non-crop and wildland sites With non-restricted post-emergent herbicides						
	APPLICATION TECHNIQUES AND TIMING See Program List Below For Rates					
BRUSH SPECIES	FOLIAR-ACTIVE GROWTH PERIOD	DORMANT STEM SPRAY (WINTER)	HIGH VOLUME BASAL (ALL YEAR)	LOW VOLUME BASAL (ALL YEAR)	INJECTION OR CUT SURFACE (ALL YEAR)	SPOT OR SINGLE PLANT TREATMENT
Alder	1, 2, 3, 4, 5	6, 7	8, 9	10, 11	11, 12(?), 13	14, 15
Bear Clover	1, 2, 3, 4, 5					
Blackberry	1, 2, 3, 4, 5	6, 7				
Black/Live Oak	1, 2, 3, 4, 5	7 (Partial)	8	10, 11	11, 12(?) 13	14, 15
Bracken Fern	1, 4, 5					
Broom spp.	1, 2, 3, 4, 5	6 (Partial), 7	8	10, 11		
Ceanothus spp.	1, 2, 3, 4, 5	6 (Partial), 7	8, 9	10, 11		14, 15
Chinquapin	2		8	10, 11		
Eucalyptus	1, 2, 3, 4, 5	6, 7	8, 9	10, 11	11, 12(?), 13	?
Manzanita	1, 2, 3, 4, 5		8	10, 11		14, 15
Poison Oak	1, 2, 3, 4, 5	6 (Partial), 7	8, 9	10, 11		
Redwood	1, 4, 5				12(?)	
Salmonberry	1, 4, 5					
Tan Oak	2		8, 9	10, 11	11, 13	
Willow	1, 2, 3, 4, 5	6, 7	8, 9	10, 11	11, 12, 13	14, 15

Sample Herbicide Programs

Actual rates may vary with size and growth stage of vegetation.

All sprays are spray-to-wet coverage, except conventional high-volume basal, which is spray-to-runoff.

1. 2% ROUNDUP® PRO Herbicide + 0.5% Hi-Light® Blue Colorant.
2. 1.5 to 2% GARLON® 4 Herbicide + 1% Mor-Act™ Adjuvant + 0.25% Hi-Light Blue Colorant.
3. 2.0 to 2.67% GARLON® 3A Herbicide + 1.0% R-11+ 0.25% Hi-Light Blue Colorant.
4. 1.5% ROUNDUP PRO+ 0.75 to 1.5% GARLON 4 + 1.0% R-11+ 0.25% Hi-Light Blue Colorant.
5. 1.5% ROUNDUP PRO+ 1.0 to 2.0% GARLON 3A + 1.0% R-11+ 0.25% Hi-Light Blue Colorant.
6. 1.5% GARLON® 4 Herbicide + 3% Mor-Act™ (or 1.5% HASTEN®) + 0.25% Hi-Light Blue Colorant. *
7. 1.5% GARLON® 4 Herbicide + 98.5% Diesel (or Kerosene) + Bas-Oil® Red Dye.
8. 2 to 5% GA RLON® 4 Herbicide + 98-95% Diesel (or Kerosene) + Bas-Oil® Red Dye.
9. 2 to 5% GARLON® 4 Herbicide + 12 to 16% Mor-Act + 0.25% Colorfast® Purple Dye.
10. 25% GA RLON 4 Herbicide + 75% Diesel (or Kerosene) + Bas-Oil® Red Dye.
11. 100% PATHFINDER® II Herbicide.
12. 100% ROUNDUP® PRO Herbicide + Hi-Light Blue Colorant on or into cambium.
13. 100% GARLON 3A or GARLON 4 Herbicide + Hi-Light Blue Colorant on or into cambium.
14. 100% VELPAR® L at 2-4 ml per 1" of stem diameter at breast height or 3' of canopy width.
15. PRONONE® Power Pellets at 1-2 pellets per 1" of stem diameter at breast height or 3' of canopy width.

* REMEDY may by substituted for GARLON 4 on properly labeled sites, e.g., rangeland.

For more information, contact your Wilbur-Ellis representative, or call (800) 982-4337. 01/05/00

Control of Jubatagrass (*Cortaderia jubata*)

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Jubatagrass is an invasive, perennial grass native to the Andes of Bolivia, Peru, Ecuador, and northern Argentina. According to the California Exotic Pest Plant Council, it is one of the most widespread, invasive, wildland, pest plants in California (Randall et al. 1998). It is currently established in several sites along the California coast, from Humboldt to San Diego County (Hickman 1993, DiTomaso et al. 1999). Jubatagrass produces a large amount of lightweight seed (50,000-100,000 seeds produced per inflorescence, weighing from .001g-.004g per seed) (Drewitz unpublished data). These qualities allow for long distance wind dispersal facilitated by a tall inflorescence (3-6 ft above tussock). This leads to rapid establishment in areas where vegetation has been disturbed or removed. It can then displace natives, reduce conifer seedling recruitment and growth, decrease the aesthetic value of an area, restrict animal and human access, and present fire hazards (Harradine 1991).

In 1998, the California Exotic Pest Plant Council funded several projects on jubatagrass education, research and control. As a result of this funding, a multipart research study is in progress at the University of California at Davis looking at jubatagrass seed biology, seedling establishment, control methods, and invasion prevention techniques (mulching). The results of our research on control methods are reported.

Traditionally, management of jubatagrass has been limited to mechanical removal and high volume ('spray-to-wet' equivalent to 200 to 250 GPA) spot applications of glyphosate. This study was initiated to develop alternative economical control options for jubatagrass in sensitive coastal habitats. Several herbicides, rates, treatment times (spring and fall), formulations, and application methods were evaluated for jubatagrass control at Vandenberg Air Force Base in Santa Barbara County, California. Each treatment was replicated at least 8 times and evaluated one year following application.

Spring and fall spot applications of glyphosate at 4% (product), low volume (89 GPA) resulted in approximately 80% jubatagrass control. Regrowth was reported one year after application. Rates below this did not provide acceptable control. Low volume fall applications of fluazifop at 2% and imazapyr at 1% and 2% gave approximately 95% jubatagrass control. Minimal (2%) regrowth and no regrowth was found the following year with the described fluazifop and imazapyr treatments, respectively. In some coastal habitats, jubatagrass co-exists with sensitive endemic broadleaf forbs and shrubs such as *Arctostaphylos* and *Ceanothus*. Under these conditions, the graminicide fluazifop provides a safer option than non-selective herbicide treatments.

By utilizing a low volume spot application, time spent spraying and refilling the spray tank was decreased when compared to a high volume (‘spray-to-wet’) spot application. In an economic analysis this resulted in decreased labor cost. Thus, the total cost of application with these low volume alternative treatments is comparable to a conventional high volume glyphosate application.

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The Effects of Mowing on the Distribution of Glyphosate within the Canopy of Perennial Pepperweed (*Lepidium Latifolium* L.)

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Perennial pepperweed is an invasive herbaceous perennial that can quickly establish and in many sensitive areas throughout the west. In these sensitive areas (e.g. wetland, riparian) few herbicides are registered for use in controlling this weed, and provide limited control when used exclusively (Renz & DiTomaso 1999). Fortunately when combined with early season mowing, glyphosate can provide excellent control given ample resprouting occurs (Renz & DiTomaso 1999). Several mechanisms can be responsible for this enhanced control including: 1) increased deposition of glyphosate onto shoots, 2) altered distribution of glyphosate to tissue that favors accumulation below ground, 3) increased absorption of the glyphosate, and 4) increased translocation rates of the glyphosate below ground. Previous results indicate translocation rates are not altered due to mowing (Renz & DiTomaso 1999), however applications are delayed to allow shoots to resprout. This delay synchronizes treatments with maximum translocation rates into below ground organs (Renz & DiTomaso 1999). Experiments in 1999 addressed how mowing altered the deposition and distribution of glyphosate within the canopy of perennial pepperweed.

A randomized complete block design was established at 2 sites. Site 1, was a floodplain with light soils and a shallow water table (within the Yolo Bypass). Site 2 was a seasonal wetland with heavy, drier soils with a much deeper water table (within the Sacramento National Wildlife Complex [Colusa]). In both sites plots were not mowed, mowed at the flowerbud or mowed at the full flower stage. Plants were allowed to resprout to the rosette, flowerbud or fruiting stages (approximately 30 days each) before applications were made. Applications were made to control areas (not mowed) at the initial flowerbud[1], full flower and fruiting stages.

Applications consisted of 3.33 kg a.e./ha of glyphosate along with 1% (v/v) of a water soluble dye (Hi-Light Blue). After the solution dried, shoots were harvested from three 0.0625 m^2 areas within each plot and separated into basal third, middle third, top third of the canopy and flowers/fruit if present. The dye was removed from organs by washing tissue with a known volume of 0.01 % (v/v) Triton X-100. An aliquot was taken from the rinsate of each sample and with the use of a spectrophotometer, concentrations of dye present were calculated. These values were compared to the calculated value of total dye applied to each area, and data was converted to percent of total dye recovered.

Areas mowed at the full flower stage responded similarly to areas mowed at the flowerbud stage, thus data will not be discussed. In both sites, either significantly more or

[1] At Colusa applications were also made at the early flowerbud stage (before axillary buds lost dormancy).

equivalent amounts of dye were recovered on shoots in areas not mowed compared to mowed areas (see table). Mowed areas in site 2 had less total dye recovered compared to site 1. This is likely due to drier conditions and reduced resprouting compared to site 1. Resprouting is essential for this control strategy to be successful and appears to be closely related to soil moisture. However, there was no significant difference in the amount of dye recovered in any of the stages in mowed areas at either site.

At both sites 61 - 88 % of the dye recovered was found within the top part of the canopy (including flowers/fruit) at the flowerbud, full flower and fruiting stages in areas not mowed. In contrast, 67 - 100 % of the dye recovered was deposited in the basal third of the canopy in areas mowed that resprouted back to the flowerbud stage. This difference in location of glyphosate deposition may play a significant role in enhanced control as research has indicated that basal leaves preferentially translocate systemic herbicides into below ground organs (Hill & Weaver 1961; Hunter 1995; Stamm Katovitch et al. 1998).

The combination of delaying herbicide applications, decrease in the number of above ground sinks (fruits and flowers) and deposition of herbicide to the basal portion of the canopy are currently believed to be factors involved in the enhanced control with mowing and glyphosate. Future research will focus on determining differences in uptake and translocation of radioactive glyphosate to further elucidate the mechanisms responsible.

Distribution of dye within the canopy of perennial pepperweed (*Lepidium latifolium* L.)

			% Dye recovered				
Site	**Mowed**	**Sprayed**	**Basal**	**Middle**	**Top**	**Flower/fruit**	**Total[1]**
YB	NA	flowerbud	4	9	30	0	44 b
YB	NA	full flower	4	9	19	29	60 ab
YB	NA	fruiting	4	7	30	50	92 a
YB	flowerbud	rosette	41	0	0	0	41 b
YB	flowerbud	flowerbud	40	4	4	0	48 b
YB	flowerbud	fruiting	19	10	10	11	51 b
Colusa	NA	early flowerbud	3	10	71	0	84 a
Colusa	NA	flowerbud	4	21	40	0	65 ab
Colusa	NA	full flower	1	4	23	19	48 bc
Colusa	NA	fruiting	2	6	21	15	44 bc
Colusa	flowerbud	rosette	16	3	3	0	22 c
Colusa	flowerbud	flowerbud	21	2	3	5	31 bc
Colusa	flowerbud	fruiting	16	4	4	4	29 bc

1 Significant differences were tested with tukey's ($p < 0.05$)

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Evaluation of Microbial Products Used in Lake Management

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Commercial water treatment products were studied in laboratory, greenhouse and field experiments. Nutrient concentrations and viable cell counts were determined for the microbial products Algae-Tron™, Aqua-5™, Biorestoration Formula-2™ and LakePak™ WSP®. Pond enclosure studies were conducted to quantify the effects of Aqua-5™, BactaPur™, LakePak™ WSP®, copper sulfate and the aquatic herbicide Reward® (diquat) on bacterioplankton, sediment bacteria, zooplankton, aquatic vascular plants and algae. Bacterioplankton numbers were significantly increased by applications of the products Aqua-5™, LakePak™ WSP® and Reward®. The copper sulfate and Reward® treatments significantly affected chlorophyll *a* concentrations, aquatic vascular plant biomass and zooplankton populations, however, applications of the microbial products Aqua-5™, BactaPur™, LakePak™ WSP® at recommended rates, did not significantly affect those water quality variables. Under these experimental conditions, there was no indication that the inoculation of lakes and ponds with commercial preparations of bacteria would be beneficial.

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1. Hill and Weaver. 1961. Absorption and translocation of 2,4-D and amitrole in shoots of the Tokay grape. Hilgardia 31: 327-368.

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Integrated Strategies for the Attrition of Yellow Starthistle on Northern California Rangeland

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Introduction

Over the past 30 years, yellow starthistle (*Centaurea solstitialis* L.) has become a serious threat to California grasslands. Recent 1996-1998 CDFA surveys have estimated that roughly 40% of the townships in California have some level of infestation, with potential acreage estimates of 12 million acres (Pitcairn et al. 1998).

Yellow starthistle control strategies have included chemical (DiTomaso et al. 1999b), classical biological control (Balciunas and Villegas 1999), burning (DiTomaso et al. 1999a), mowing (Benefield et al. 1999), and grazing (Thomsen et al. 1993). Each of these strategies alone may reduce total seed production. However, the inherent issue in dealing with yellow starthistle lies in its ability to readily reinvade annual grasslands following successful control. Therefore, any short- term management plan will likely fail given enough time. A successful long-term management plan must attempt to address the issue of reinvasion following control. The current paradigm in California and much of the Western United States suggests that reestablishing perennial grasses is a sustainable long-term strategy for preventing or suppressing noxious weed invasion (Sheley et al. 1996). However, this paradigm has not been widely tested.

We initiated a long -term experiment in 1997 using an integrated system with the herbicide clopyralid and the perennial grass pubescent wheatgrass to test this idea. The focus of this paper is an update on the experiment following three years of treatment.

Materials and methods

The experiment was conducted on yellow starthistle infested range near Yreka, California. Treatments consisted of three factors: clopyralid applied in the spring for 1, 2, or 3 years, range reseeding of 'Luna' pubescent wheatgrass (*Thinopyrum intermedium* ssp. *barbulatum*) in the early spring the first year, and rose clover (*Trifolium hirtum*) seeding in the fall following the last clopyralid application. Range reseeding of wheatgrass consisted of a glyphosate application on February 29, 1997 followed by wheatgrass (12 lb/A) drill seeded the first week of March with a no-till range drill. Rose clover was broadcast seeded at 10 lb/A in September. Spring clopyralid applications were made on March 18, 1997 (1.0 oz ae/A), March 17, 1998 (1.5 oz ae/A) and March 18, 1999 (1.5 oz ae/A). Treatments were applied to 50 by 50 ft plots and arranged in a randomized complete block design with four replications.

Treatment evaluations consisted of the following: late spring vegetative cover evaluations of yellow starthistle, wheatgrass, annual grasses, and other forbs; and summer evaluations of yellow starthistle plant height, density, biomass, and seedhead production. Vegetative cover was determined by five random 1 m^2 quadrats per plot for a total of 20 quadrats per treatment.

Yellow starthistle plant height, density, biomass, and seedhead production were determined by harvesting three 0.25 m^2 quadrats per plot, for a total of 12 quadrats per treatment.

A complete factorial analysis was performed on the data. Multiple comparisons (α=0.05) were done at the level of the highest order interaction. Data were pooled where main effects were not significant. All values are reported in original form.

Results and Discussion

Results from 1999 indicated significant differences in vegetative cover in plots receiving 1, 2, or 3 annual applications of clopyralid (1997, 1998, 1999). Yellow starthistle was completely absent in plots receiving clopyralid for three consecutive years and occupied less than 3% cover in plots receiving clopyralid for two years (1997, 1998) (Table 1). However, yellow starthistle dominated plots receiving clopyralid only in 1997.

Wheatgrass cover increased to 43% in plots treated with clopyralid for three years and was significantly higher than in wheatgrass plots treated with clopyralid for one or two years. Forb cover, including filaree and tumble mustard, was significantly higher (13-19%) in plots treated with clopyralid alone for two or three years compared to the control or wheatgrass treatments. Finally, annual grasses dominated plots treated with clopyralid for two or three years (69-79%) and were significantly reduced in clopyralid plus wheatgrass or control treatments.

These results suggest that repeated applications of clopyralid may shift dominance back to annual grasses and may effectively eliminate yellow starthistle. However, an annual grass system is susceptible to reinvasion by yellow starthistle. Additionally, seedbank samples for 1999 have yet to be quantified. However it is expected that three consecutive clopyralid applications may eliminate over 95% of the yellow starthistle seed bank.

Pubescent wheatgrass appears to be very effective in providing strong interspecific competition with yellow starthistle after establishment. Yellow starthistle cover was significantly reduced in wheatgrass plots that received one clopyralid application (16%) compared to plots without wheatgrass that received one clopyralid application (52%) (Table 1). Additionally yellow starthistle biomass and seedhead production was reduced in the presence of wheatgrass competition (Table 2). Total yellow starthistle biomass was significantly lower in wheatgrass plots treated for one year with clopyralid than in plots only treated with clopyralid for one year. The same difference was observed between the two year clopyralid treatments (Table 2). Seedhead production was also decreased in a very similar fashion.

These results suggest that yellow starthistle may readily overcome one and possibly two years of clopyralid treatment due to recruitment from the seedbank. However, established wheatgrass appears to be very effective in suppressing seed production by yellow starthistle escapes and may provide a more effective long-term solution than applying clopyralid alone.

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Table 1. Vegetative cover response to clopyralid and wheatgrass in 1999.

Treatment	Yellow starthistle	Wheatgrass	Annual grasses + bulbous bluegrass	Other forbs[a]	Bare ground
	--- % Cover[b] ---				
Untreated	45 a	0 c	43 b	5 cd	7 c
Wheatgrass only	42 a	5 c	40 bc	6 cd	7 c
Clopyralid (1 yr)	52 a	0 c	34 bc	8 c	6 c
Clopyralid (2 yr)	2 c	0 c	69 a	19 a	10 bc
Clopyralid (3 yr)	0 c	0 c	79 a	13 b	8 c
Clopyralid (1 yr) + wheatgrass	16 b	34 b	30 c	6 cd	14 ab
Clopyralid (2 yr) + wheatgrass	2 c	32 b	43 b	6 cd	17 a
Clopyralid (3 yr) + wheatgrass	0 c	44 a	35 bc	4 d	17 a
LSD (α = 0.05)	12	9	12	4	6

[a]Group includes only non leguminous forbs. No legumes were significantly different across treatments.
[b]Means within columns followed by the same letter are not significantly different (alpha = 0.05).

Table 2. Yellow starthistle response to clopyralid and wheatgrass in 1999.[a]

Treatment	Biomass (g / 0.25 m^2)	Seedheads produced (no. / 0.25 m^2)
Untreated	42.3 ab	194 a
Clopyralid (1 yr)	56.4 a	223 a
Clopyralid (2 yr)	23.8 bc	109 bc
Clopyralid (3 yr)	0 d	0 d
Wheatgrass only	30.0 b	145 ab
Clopyralid (1 yr) + wheatgrass	9.8 cd	47 cd
Clopyralid (2 yr) + wheatgrass	2.2 d	10 d
Clopyralid (3 yr) + wheatgrass	0 d	0 d
LSD (α = 0.05)	18.6	82

[a]Means within columns followed by the same letter are not significantly different (alpha = 0.05).

Effects of Rate and Time of Application of Glyphosate on DP5415RR Cotton in Israel

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The traditional weed control programs in cotton have been dependent on soil-applied and post-directed herbicide. With the adoption of glyphosate-resistant (Roundup Ready™) cotton varieties, glyphosate has become a major component of the weed management program. This herbicide provides control of a broad-spectrum of grass and broadleaf weeds. Being cheap and "environmentally friendly" further facilitate its acceptance by the farmers (Askew and Wilcut 1999).

The transgenic cotton contains a CP4 gene construct that exhibits excellent vegetative tolerance to glyphosate (Jones and Snipes, 1999). However, over the top application after the 4th leaf stage was reported to result in lower pollination, boll abortion, deformed bolls and yield reduction (Kerby and Voth, 1998; Vargas et al., 1998). Recent experiments indicated possible negative interactions between environmental factors and response of Roundup Ready (RR) cotton to glyphosate (Jones and Snipes 1999). The aims of our study were to investigate, under Israeli conditions, the response of DP5415RR cotton to glyphosate applied at different growth stages and its behavior following treatment with herbicides applied PPI, PRE and POST. We also examined the risk of gene transfer by cross-pollination to other cotton cultivars.

Material and Methods

DP5415RR cotton was examined in four locations throughout Israel during the 1998 and 1999. RR and non-transgenic cotton cultivars were planted in commercial cotton fields prepared for planting according to local practices. Plots were 4 cotton rows wide and 15 to 20 m long replicated 4 to 6 times in a randomized complete block design. Herbicides were applied PPI, PRE or POST (over the top) as needed using a motorized knapsack sprayer, delivering 100 L ha^{-1}. Glyphosate (Roundup Ultra®) was applied POST, either early (2 to 3 leaves), medium (4 to 5 leaves), late (8 to 10 leaves) or early + late (split treatment) at rates of 0, 0.72 and 1.44 kg ae ha^{-1}. Plant mapping was carried out just before the harvest and included number of bolls and their position on the sympodium, boll weight and number of seeds/boll. Total cotton-seed yield/plot was recorded following mechanical picking as well as quality traits of the fibers.

Flowers and bolls were sampled from each plot throughout the season and their morphology was examined, using scanning electron microscope (SEM), using a Jeol scanning microscope. (Model JSM-5410LV, Japan).

Seed cotton was collected by hand from adjacent non-transgenic cotton ('Sivon') border rows for analysis of pollen dispersal from transgenic plants, up to 50m eastward (wind direction) and westward. At each distance ca. 100 bolls were examined. Seed cotton was ginned and a sub-sample of 200 seeds was planted in a sand:peat mixture and transferred to the greenhouse. Cotton seedlings at the fully expanded cotyledons were sprayed with glyphosate (1.44 kg ae ha^{-1}) using a chain belt-driven laboratory sprayer. Surviving plants were counted and considered resistant.

Results and Discussion

Response of weeds and RR cotton to herbicides: 1999 experiments have shown that RR cotton responded to diuron, fluometuron, trifluralin, prometryn, pendimethalin and pyrithiobac similar to DP5415 (data not shown). No visual damage or growth retardation was observed on the cotton plants treated with glyphosate at all rates and times of application tested. Similarly, no significant detrimental effects were found in seed cotton yield or any quality traits tested (Fig. 1). The average seed-cotton yield in the untreated control, over the three locations was 5.73 mt ha^{-1}.

All glyphosate treatments provided effective and acceptable weed-control until harvest. Excellent control of the following annual weeds: heliotrop (*Heliotropium arbainense*), prostrate pigweed (*Amaranthus blitoides*), redroot pigweed (*A. retroflexus*), *Moluccella laevis, Chrozophora tinctoria, Datura ferox,* puncturevine (*Tribulus terrestris*), and black nightshade (*Solanum nigrum*) were observed. However, toward the end of the season, some infestation with common cockelbur (*Xanthium strumarium*) and Palmer amaranth (*Amaranthus palmeri*) was observed in the plots treated "early" in the season. Good control of perennial weeds such as johnsongrass (*Sorghum halepense*), bermudagrass (*Cynodon dacylon*), purple nutsedge (*Cyperus rotundus*) and field bindweed (*Convolvulus arvensis*) were observed particularly when high rate of glyphosate was applied.

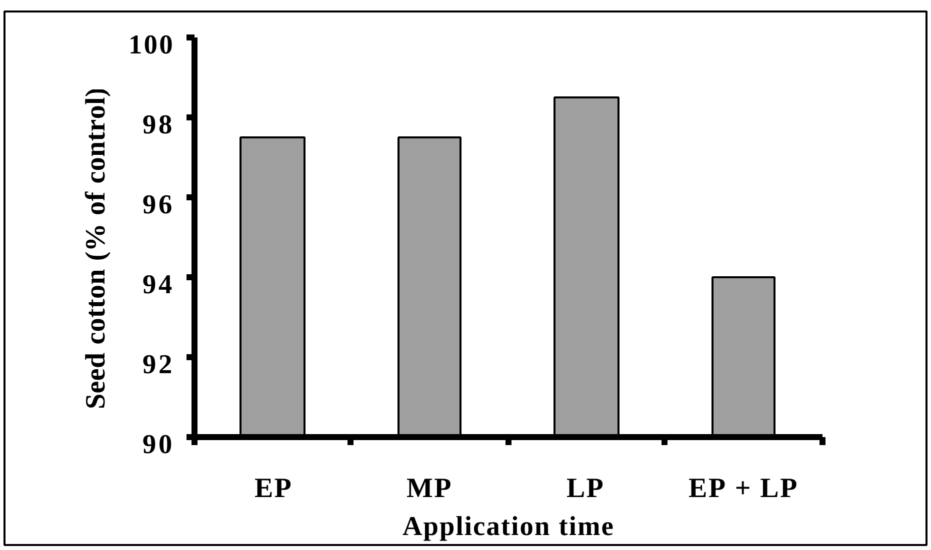

Figure 1. Seed-cotton yield as affected by glyphosate (1.44 kg ae ha^{-1}) applied at various growth stages (Average of 3 sites for 1999 experiments).

Effect of late application of glyphosate: The first flowers developed on plants treated 'late POST' or the combined treatment 'early + late' at high rates of glyphosate, appeared abnormal with partially developed anthers that contained little pollen and a pistil with a stigma sticking out much above the stamens (Fig. 2-3). These symptoms were less abundant and weaker at early application and low glyphosate rates. No such effects were observed in control plants or in flowers developed later in the season. Some of the early bolls developed on plants treated 'late' and at the high rate were deformed mostly with one degenerated compartment resulting in a 'moon shaped' bolls.

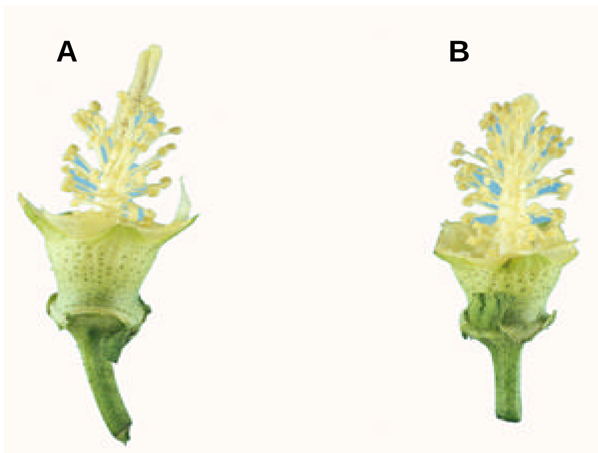

Figure 2. First flowers of RR cotton treated (A) and untreated (B) late with glyphosate (1.44 kg ae ha^{-1}).

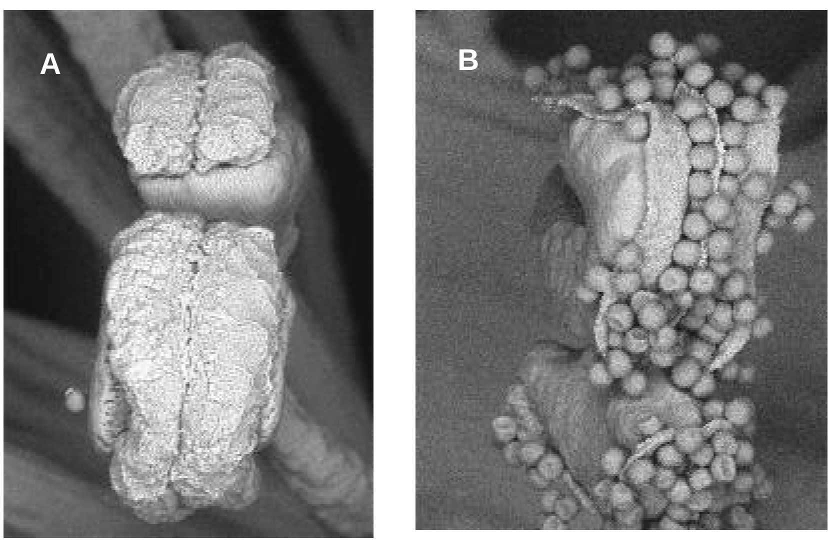

Figure 3. Scanning electron micrograph (SEM) of anthers taken from first flowers developed on RR cotton plants treated late with glyphosate (1.44 kg ae ha^{-1}). (A) treated; (B) untreated.

The late treatment and the split treatment with high rates (1.44 kg ae ha^{-1}) resulted in a significant increase in the number of bolls per plant, with a parallel decrease in the boll weight and number of seeds per boll (Fig. 4). This was particularly apparent in bolls developed on the first and second position sympodia of the 5th to 10th fruiting branches. It seems that the plant attempts "to compensate" itself in response to the initial injury.

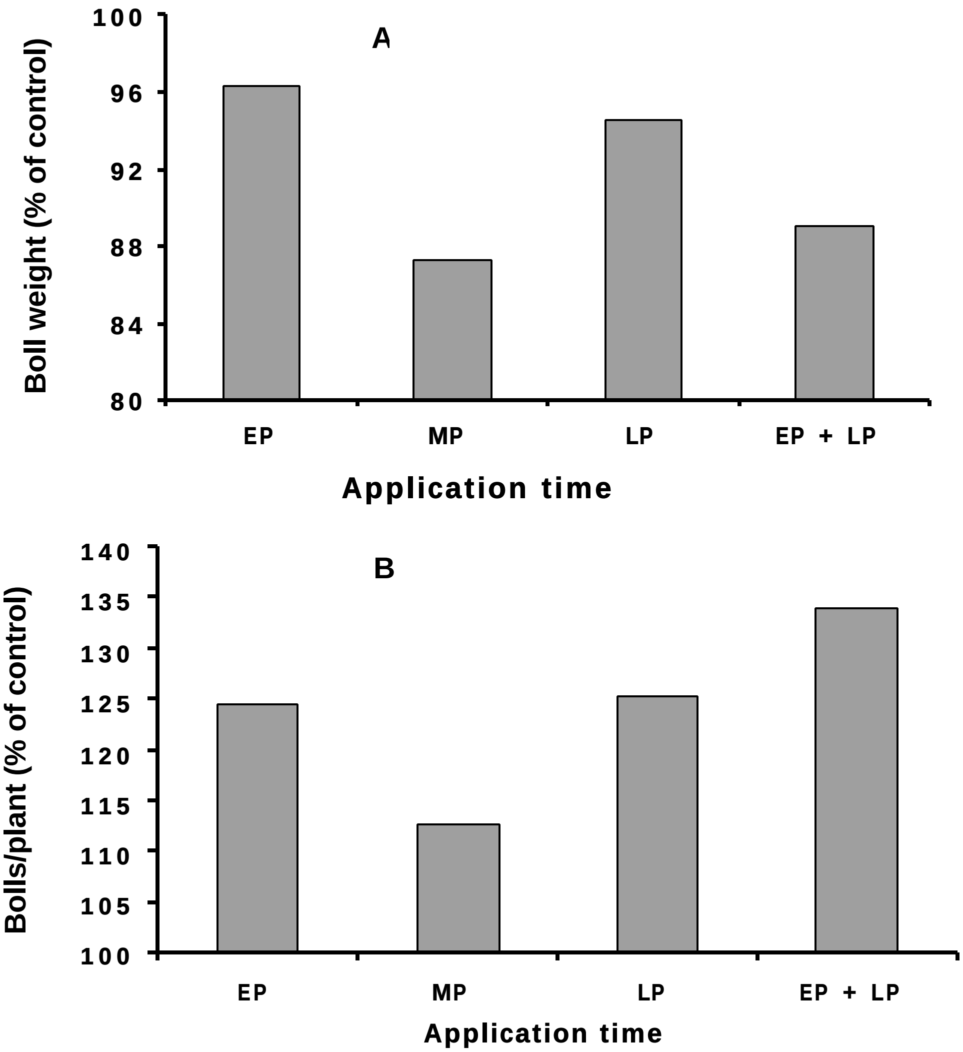

Figure 4. Boll weight (A) and number of bolls per plant (B) as affected by glyphosate (1.44 kg ae ha^{-1}) applied at various growth stages (Average of 3 sites, 1999 experiments).

Cross-pollination between DP5415RR and the local cotton cultivar 'Sivon' (Acala type) was examined within the range of 50m from the RR plot. The proportion of cross-pollination was up to 10% at 1m distance and none further than 35m (Fig. 5).

Interestingly, the proportion of cross-pollination at plots located westward of the RR plot (against the wind direction) was larger then that observed in the eastern side, indicating that pollen was moved mostly by insects (especially bees) rather than wind.

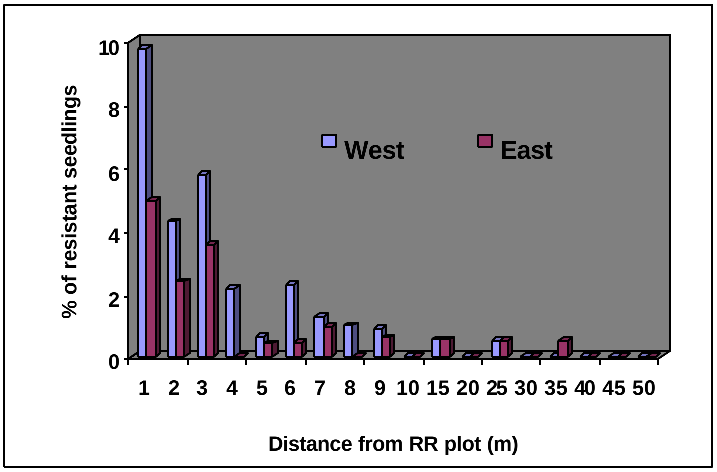

Figure 5. Frequency of transgenic pollen dissemination into border rows located east and west to the test plot Negba 1998.

Over the top application of glyphosate at the recommended rate (0.72 kg ae ha^{-1}) and at the double rate (1.44 kg ae ha^{-1}) applied at up to 4 to 5 leaves stage in DP5415RR provides good and season-long annual weed control. Crop safety is excellent without any visible damage to the vegetative parts or reduction in seed cotton yield and quality. Late application of glyphosate (8 to 10 leaves) may result in reduction in boll size and number of seeds per boll with a parallel increase in boll number per plant. No significant reduction yield was observed. The risk of gene transfer from the RR cotton to other non-transgenic cotton cultivars is limited to 10 m.

Acknowledgement

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Presidential Address
Contributions of the Past and Opportunities in the 21st Century

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It is my pleasure to welcome you to the 52nd annual conference. Matt Ehlhardt and his program committee have worked hard putting together an outstanding program. This is an historic occasion as we enter this next century and millennium. Considerable debate has gone on about when the new millennium actually begins, but nevertheless it is important to view these dates as milestones and take this opportunity to reflect on our advances in weed control as we look forward to the challenges of the next century.

History of Weed Control

The history of weed control has been a story of slow and painful progress. From about 10,000 B.C. to 6000 B.C. man cultivated crops by primitive methods using bare hands to pull weeds as demonstrated by a member of the Orloff clan. This system is still used today in high value crops. About 6000 B.C. he fashioned hand tools to prepare land and fought weeds with hoes and digging sticks. Slash and burn agriculture is still used. And in about 1000 B.C. the use of animal-powered implements was introduced and still used today in many parts of the world such as Mexico and Pakistan. From then little progress was made until the 20 century.

Momentous accomplishments in weed control were made during this last century. Beginning in the early 1900's we saw the advent of the age of mechanization using petroleum powered tractors for tillage operations. New tillage implements were used during this time, including the rolling cultivator, sweep type cultivators, chizels, and bulldozers powered by petroleum. And in the final decade of the century we made a big jump, and now have computer guided cultivation systems under development. In the future we will see smarter sprayers. We will make even better use of computer technology. This will require greater knowledge of plant physiology and weed biology.

Chemical Weed Control

Chemical weed control has made amazing strides since its inception. Natural chemicals were used prior to the 1900's, but contained high rates of hazardous elements such as arsenic. In the 1900-1920's petroleum oils and sodium chlorate were introduced. The 1940's saw the introduction of the herbicide era with the discovery of 2,4-D. This brought tremendous saving to humans in general and to the agricultural industry. The 1950's marked the development of several new herbicides including monuron, endothol, simazine, and atrazine. In the 1960's dinitroanilines, thiocarbamates, paraquat and diuron were introduced. In the 1970's Roundup and selective herbicides like Hoelon and Avenge were important breakthroughs for controlling grass weeds in small grains. In the1980’s selective grass herbicides were developed for use in broadleaf crops. Ultra- low rate herbicides also came into use and are now becoming the norm for new herbicides.

In the 1970's the “*Green Revolution*” occurred that had a major impact in developing countries. With advances in plant breeding at the International Center Wheat and Corn in Mexico (CIMMYT), wheat varieties were developed with 2-3 times the yield potential. This germplasm has been used throughout the world. These varieties often were more responsive to higher nitrogen and pest management inputs. A similar situation occurred at the International Rice Research Institute (IRRI) yielding new rice varieties that improved yield 2-4 times. These new short statured varieties helped growers around the world keep up with food demands and stay economically viable.

Biotechnology

The 1990’s marked the age of yet another weed control breakthrough, biotechnology and the introduction of herbicide resistant crops. By 1999 this technology had become so popular that there were nearly 45 million acres of agronomic crops planted with the Roundup resistant trait across the United States-38 million acres of Roundup Ready soybeans, 4.2 million acres of Roundup Ready cotton, and 2.1 million acres of Roundup Ready corn. Major cost savings were realized, particularly with BT cotton and BT corn. Cotton growers in the southern region reduced weed control costs from $80/A to $40/A and also reduced the total volume of herbicides used by approximately 40 percent. Sixty percent of the cotton belts was planted to herbicide tolerant cotton. Of this acerage 7 percent was planted to BXN cotton. In California there were over 40,000 acres of Roundup resistant cotton and 12,000 acres of Buctril resistant cotton planted in 1999.

Many of the weed management approaches mentioned are now being incorporporated in an integrated weed management system. In addition to advances in weed control, we reap the benefits of this centuries’ other agricultural developments such as new varieties, laser leveling, and improved irrigation’s techniques. Because of these technological developments in agriculture, Americans spend less than 13% of their income on food while other countries spend 25 to 50 percent. Prior to 1910 American farmers produced enough food per acre to feed 7 people. Today the American farmer produces enough on 1 acre to feed and clothe 165 people. Consequently our society has healthier food choices and more disposable income. The advances in production technology have kept up with population growth during the last 2 decades, but too many still went hungry. These problems exist not because of food shortages, but because of distribution problems or war.

Key events in weed management in this past century

It is interesting to look back at the programs developed and issues that surfaced in this last century. Weed control as a science in California began in the late 1920's at UC Davis. The California Weed Science Society began as a conference in Sacramento in 1949 and evolved into a society in 1994. The Growers Weed ID book was introduced in 1968. The California Weed Science Society “Principles of Weed Control in California” textbook was first published in 1985.

The 3rd edition will be published this year. The society's members have played a major role in weed science as researchers, educators, innovators, and regulators. Personally it has been a privilege to know many of the key weed researchers and innovators. Many of these individuals have been honored by this society, and we again recognize them for their efforts and contributions.

The 1980's began the period of food safety concerns. Parts per million became parts per trillion. We were suddenly discussing what level of risk was acceptable. We talked about how much an individual would have to eat to be at risk. Many new regulations were introduced such as mandatory reporting, plant back restrictions, pest management zones, required training and certification of Pest Control Advisors and applicators. During this period some older herbicides were lost, and new herbicides were introduced that had lower use rates and better environmental safety.

Nitrate and pesticide pollution concerns also came to the front in the 1980's and will likely continue to increase in importance in this next century. Reduced tillage programs were implemented in many parts of the United States which reduced nitrate losses from soil erosion. This practice also brought fuel savings, reduced soil and wind erosion, and in some cases conserved moisture. This system also brought about a shift from predominantly mechanical tillage to an increased emphasis on herbicides.

Integrated pest management (IPM) was developed in the 1970's, and became fully implemented in the 1980's. Instead of relying solely on chemical control, this approach used herbicides as one of the tools in an overall management system. The term was confused by some who thought chemicals were not a part of this system. Fortunately we have arrived back to the correct understanding of the phrase, which is integrating cultural, mechanical, biological, chemical tools for cost effective weed control with lowest negative impact on the environment. *IPM* today helps to sustain the old and the new weed control technologies.

During the late 80's and early 90's the concept "*Sustainable Agriculture*" was introduced. The term was ill defined and too many people it implied that current production systems were not "*sustainable*". It became associated with organic farming that really only served a niche market. This approach was a giant step backward and alienated many from both philosophical camps. Furthermore, an inability to control weeds led most growers back into conventional integrated weed management programs after trying organic farming methods.

Herbicide resistance surprised many and has developed with several weed species during the past two decades. Even the Roundup Ready system is facing resistance issues with a few weeds and are already seeing a specie shift in the southern cotton growing area where this technology has been used the longest. This challenge has forced companies and researchers to rethink weed control management strategies and has emphasized the importance of not relying on a single method of control. To this end we have seen new uses and tactics such as tankmixes, and herbicide and crop rotation.

During the 1990's we saw the introduction of herbicide resistant crops. The potential benefits of Genetically Modified Organisms (GMO's) are enormous however there remains many fears and unknowns as to what all scientists will do with this technology. People must feel secure about their food and while, they don't understand the science are very concerned about any form of gene manipulation. The next big yield increases in the near future will likely depend on biotechnology. What we have seen to date in biotechnology is only the tip of the iceberg compared with coming developments such as drought tolerance, salt tolerance, and improvements in protein or nutritional aspects of crops. Our lack of imagination may be one of the only limitations to future developments. However, on the other side, we have only seen the beginning of what will probably be a long battle over the social aspects of biotechnology. In words from a past president of this conference, UC Farm Advisor, Ron Vargas "responsible biotechnology is not the enemy but ignorance and starvation are."

While we struggle with environmental issues and philosophical concerns over biotechnology, we still must find a way to feed an ever-growing population. The world population is expected to double in the next 50 years. China is expected to reach 1.3 billion, India- 1.7 billion, and the United States- 394 million people. However, farmland is becoming more and more scarce. In developing countries where mere subsistence farming is practiced and where firewood is needed for heating and cooking, deforestation is happening at a rapid pace. Even in California farmland is lost at an alarming rate-as much as 50,000 acres per year to non-farm uses. As the population continues to increase and farmland continues to disappear, it is imperative that we move through these challenges. Consequently, we must produce more food and fiber on the same or lesser amount of farmland.

A recent conference on Capital Hill on Oct. 18, 1999, brought together leaders from United States Congress, USDA, and consultant groups to explore ways of collaborating more closely in the fight against poverty, hunger, malnutrition and environmental decline. At this meeting U.S. Secretary of Agriculture Dan Glickman said "Science will march forward, especially agricultural science, and help create a world where no one needs to go hungry, where developing countries can become more food self-sufficient and therefore become freer and more democratic; the environmental challenges of clean air, clean water, global warming, and climate change must be met with sound and modern science".

Dr. Norman Borlog, recognized as the father of the "Green Revolution" said at the same conference in Washington D.C. "The world must face up to the greatest challenge it has ever confronted in terms of feeding an exploding population. Forty million people are being added to the world's population every 6 months, and the vast majority of these people will be born into lives of poverty and bare subsistence". The most effective way to help them and in so doing, help all people, regardless of where they live, is to increase agricultural productivity-In other words, what alleviates poverty is producing more food and fiber with the same or fewer inputs-and that is what leads to great prosperity.

Summary

In this next millennium weed management will continue to be a fundamental component of any agricultural production system. As Steve Orloff demonstrates in the next few slides weeds adapt to changing productions systems and will always be a problem. Challenges during the last decade will still face us in this next century. It was once stated that in the modern age, we think we've conquered the planet but we're not quite the masters of the universe. As civilizations rise and fall weeds will always be with us. Nature will continue to be dynamic and clash with mankind. As Genesis 3:17-19 reads "And to Adam, God said, 'Because you listened to your wife and ate the fruit when I told you not to, I have placed a curse upon the soil. All your life you will struggle to extract a living from it. It will grow thorns and thistles for you, and you shall eat its grasses. All your life you will sweat to master it, until you're dying day. '"

With man's God-given intellect we must continue to find solutions to the problems that lie ahead. We must continue to maintain and improve our weed control tools, not only to increase the productivity of farmland, but also to increase land use opportunities and productivity for things other than agriculture such as wildlife, recreation, and natural resources.

Californians must be part of the research and technology change that will improve our livelihoods and those of our neighbors around the world. We have talked about the history of weed control and have seen that the most improvements occurred in the 20^{th} century and advanced at a rapid pace in the last two decades. As industry and researchers break new ground with new technologies, and issues arise with our urban neighbors and consumers, we must participate in the debate and get involved so we won't be led by the ignorant. Hopefully the different groups can come together as we meet the challenges and progress forward in this next millennium. Thank you for this opportunity to serve the society as President this past year. God Bless you all and I hope you find this conference to be rewarding.

Issues Related to the Development and Use of Engineered Herbicide-Tolerant Crops in California

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Introduction

The 21st century has been dubbed the "Biotech Century" by supporters and detractors alike. In the long term in agriculture, genetic engineering will play an increasingly important role, providing alternatives to the farmer, manufacturer, and consumer. At present, there are issues with genetically modified organisms, or GMOs, related to consumer and environmental safety and labeling. Although this might result in a temporary slowing of the progress in the development of modified crop species, this is not likely to stop the use of the technology in the long-term. The products of the new genetic technologies, if used wisely, will provide a variety of improvements in crop species in the long term.

Methods have been devised to identify the genes involved in specific traits in addition to the ability to introduce one or a few of these genes into many different crop species. These gene introductions can result in very specific changes in a particular trait without affecting the overall performance or characteristics of the plant. Some examples of these altered traits include improved disease and pest resistance, changes in post-harvest or processing traits, alterations of nutritional or antinutritional qualities, and improvements in agronomic traits, like enhanced nitrogen utilization and herbicide tolerance.

Indeed, products produced from such biotechnological approaches are no longer just a promise; much is reality. Currently there are crops in the field and products in the marketplace that have been genetically engineered and are being eaten by consumers. In the summer of 1999, the percentage of actual production acreage that was genetically enhanced in the U.S. was 50% of cotton, 55% of soybean, 40% of maize and 3% of potato (1).

The products that are in commercial production today represent only the first, rather crude attempts to use engineering to improve crop plants. More, much more is on the way. According to U.S. Department of Agriculture records, over 4,500 genetically-enhanced plant varieties have been field-tested in this country, more than 1,000 in the last year alone. About 50 engineered varieties have already been approved for unlimited release (deregulated), including 13 varieties of corn, eleven of tomatoes, four of soybeans, two of squash, and even one type of radicchio. Hundreds more are in the pipeline, among them plants that will produce industrial compounds, such as industrial oils, substitutes for gasoline and biodegradable plastics. There is also work in progress to use plants such as corn, potato, and banana as mini-factories for the production of vaccines and other medicinals; foods that can help prevent a variety of diseases, such as Type II juvenile diabetes.

To date, herbicide-tolerant crops (HTCs) created through biotechnology are the most frequent application of genetic engineering to crop plants. This is because herbicide resistance is a simple, easily engineered trait that to date involves only a single gene. The biochemistry of tolerance to certain herbicides is well understood, and it has allowed companies to link the sale of GM HTCs to the sale of their proprietary herbicides. At present, most engineered herbicide-tolerant varieties involve two herbicides: glyphosate marketed by Monsanto as Roundup; and phosphinothricin, or glufosinate, marketed by AgrEvo under various brand names such as Basta, Finale, and Liberty. Examples of California crops that are being engineered for glyphosate tolerance are corn, cotton, lettuce, rice, soybean, sugarbeet, tomato and wheat. Crops engineered for phosphinothricin tolerance include canola, chicory, alfalfa, corn, melon, rice, sugarbeet, tomato, cotton, and soybean (2).

Another combination of herbicide and HTC is the Imi-rice variety coupled with imidazilinone-type herbicides being developed by Dupont. The development of this HTC resulted not from genetic engineering *per se* but from the chemical induction of a mutation that results in herbicide tolerance. Currently, "Roundup-Ready" cotton is the only HTC to have been commercially grown in California. During the 1999 growing season, 5% of California's cotton was the Round-up Ready variety (3).

HTCs can play an important role in agriculture if they are properly managed since they provide some distinct advantages for the farmer in combating weed problems and providing the opportunity for lower or no-till agriculture. As the utilization of this technology continues, herbicide-tolerant field and vegetable crops may become commonplace in California production systems. These products are not likely to be "magic bullets" that will provide quick solutions to the problems of weed control. However, they will provide useful, complementary tools in the grower's arsenal by offering weed management alternatives, which can help address weed control problems. Along with this benefit, however, come issues relating to proper weed management and concerns relating to the economic, environmental, and consumer acceptance issues involved with their use.

Technical background

Both glyphosate and glufosinate are potent, broad-spectrum herbicides that are highly effective against the majority of grasses and broad-leaf weeds. The particular biochemical pathways affected by these herbicides occur only in plants and microorganisms, which explains the relative lack of toxicity of these chemicals to other living organisms.

Glyphosate - The herbicide glyphosate (N-phosphonomethyl-glycine) is chemically a simple tertiary amine. Its primary cellular target is an enzyme, EPSP synthase (5-enolpyruvyl-shikimate-3-phosphate synthase), involved in the synthesis of aromatic amino acids and other essential aromatic compounds in the plant. Three main genetic engineering strategies have been implemented to confer glyphosate tolerance in transgenic plants: 1) using a bacterial gene that specifies a mutant form of the target enzyme, which is no longer susceptible to glyphosate; 2) producing larger quantities of the native target enzyme or using a more active, mutant enzyme in an attempt to compensate for the enzymatic activity that is disabled by the herbicide; or 3) introducing a bacterial gene responsible for glyphosate degradation, termed glyphosate oxidoreductase or GOX, which produces an enzyme that catalyzes glyphosate degradation.

Glufosinate – Phosphinothricin, the active component of glufosinate, is structurally similar to the amino acid glutamine and, as such, selectively inhibits the biosynthetic enzyme that produces glutamine, *i.e.* glutamine synthetase. This inhibition leads to the intracellular accumulation of ammonia, the cessation of photosynthesis and the disruption of the chloroplast. Tolerance has been engineered in plants by using an enzyme, PAT (phosphinothricin acetyl transferase) that inactivates the herbicide by acetylation. The gene encoding this enzyme is derived from a soil bacterium, which naturally makes a phosphinothricin-containing compound.

Generation of herbicide-resistant weeds

A major concern with HTCs is that their use will promote the overuse of their associated herbicide. Overuse of a particular herbicide often leads to the generation of herbicide-resistant weeds. Such weeds would render the herbicide obsolete, thus removing it from the farmer's weed control arsenal. There are certain characteristics of herbicides or their use that make them more likely to promote the development of herbicide-resistant weeds. These include single target sites for the herbicide, long soil residuals, season-long use to control germinating weeds and/or frequent and long-term application of a particular herbicide without alternating or combining it with other herbicides having different modes of action. Mono-herbicide application (continual application of a single herbicide or herbicides with similar modes of action) is known to increase the rate at which herbicide-resistant weeds arise. It is likely that continual use of either glyphosate or glufosinate without rotation will lead to the development of herbicide resistant weeds. Therefore, the employment of HTCs needs to be carefully managed if their long-term use is to be assured.

Glyphosate is considered low-risk for leading to the evolution of herbicide-resistant weeds. Its mode of action, chemical structure, limited metabolism in plants, use-pattern, and lack of residual activity are often cited as reasons why this herbicide is unlikely to select for resistance. However, this is low-risk, not no-risk, and glyphosate resistance in rigid ryegrass (*Lolium rigidum*) has been discovered in both Australia and the United States. In Australia, glyphosate-resistant rigid ryegrass was identified near an orchard in 1996 (4). This orchard had intensive selection pressure, with two or three applications of Roundup per year for 15 years to control weeds within rows of trees. Further studies showed that the resistant weed population was nearly 10-fold more resistant to glyphosate than susceptible biotypes (5). In California, glyphosate-resistant rigid ryegrass was also discovered in 1998 in a field that had received repeated applications of glyphosate (6). Another more recent study reported on research attempting to determine the mechanism of resistance in ryegrass (7). There were no significant differences in uptake, translocation or metabolism between resistant and susceptible weeds suggesting that changes in the glyphosate-binding site on the EPSP synthase enzyme or overexpression of the enzyme might be the source of resistance in this biotype.

In addition to the glyphosate-resistant ryegrass examples, Monsanto scientists have described a glyphosate-resistant goosegrass (*Eleusine indica*) (8). The problem weed appeared in 1997 in oil palm plantations of Malaysia where as many as eight annual applications of glyphosate have been made for the past 10 years. This resistance is caused by a single amino acid substitution in the glyphosate-binding site of the EPSP synthase enzyme, which causes the goosegrass to be up to five times more tolerant of glyphosate than susceptible plants. The glyphosate resistant goosegrass has appeared on four oil palm plantations and already infests approximately 12,500 acres. Goosegrass is one of the major annual grass weeds in the tropical and subtropical regions of the world, and is considered among the most troublesome weeds in the world. The appearance of glyphosate resistance in major world weeds, like rigid ryegrass and goosegrass, emphasizes the importance of good, integrated weed management and careful use of selective herbicides to preserve the efficacy of glyphosate and other important herbicides.

Another way that encourages the emergence of herbicide-tolerant weeds is through the spread of herbicide tolerance genes to wild species, to sexually compatible weeds or to non-engineered plants, such as those being cultivated under organic standards. Of all traits being introduced by genetic engineering, herbicide tolerance is the one most likely to result in observable gene movement to other plants since observation of the presence of the tolerance gene is easily seen following herbicide application. Genes for tolerance could certainly be transferred to related weed species from the engineered crops; however, the situation can be managed to prevent or minimize the problem. Some of the weeds that are potential recipients of herbicide tolerance genes from cultivated varieties are among weeds that are most difficult to manage; examples include weed species that cross with the major cereal crops, such as Johnson grass and red rice. In the United States, most crops do not have weedy relatives with which they can outcross; exceptions are canola, carrots, certain cucurbits, lettuce, oats, radish, rice and sugarbeet.

Farmers must be very cautious about using herbicide tolerant varieties in areas with sexually compatible weed species. Weeds in the general vicinity of the herbicide-tolerant crop, with which the modified plants might outcross, are likely to be kept under control by herbicide application and therefore not reach a reproductive state at all or certainly not at the time when pollen would be shed from the engineered plant, thereby minimizing the likelihood of sexual exchange between the two species. Therefore, unless pollen travels over long distances and pollinates weeds located at a considerable distance from the cultivated plants, where herbicide application does not occur, this problem can be minimized or eliminated by careful application of herbicide. Another means of managing the transfer and perpetuation of the herbicide tolerance gene in weed populations is to alternate the type of herbicide used or to use another herbicide to control the weed population during the season. A third solution would involve the use of so-called gene protection systems, the best known of which has been called the terminator technology. The latter system results in plants that cannot reproduce themselves because embryo development in the transgenic plant is halted. By using plants engineered with such a system in areas having sexually compatible weed or wild species, it would be impossible to perpetuate the herbicide tolerance gene in other plants.

Weed-shifts are another problem that may make harder-to-control perennial weed species a problem. Weed-shift refers to a change in species composition in an ecosystem due to the systematic elimination of those species that are well controlled by the herbicide and proliferation of those species that are naturally tolerant of the herbicide. This can result from the repeated use of herbicides with the same modes of action and occurs because the application of a single herbicide creates a favorable environment for weeds not completely destroyed by the herbicide.

Development and utilization of germplasm tolerant to a single herbicide, without comparable development of cultivars tolerant to other herbicides with dissimilar modes of action, would likely exacerbate both the herbicide resistant weed and weed-shift problems. One way industry can promote the use of multiple herbicides on the same acreage is to work collectively to develop similar cultivars that have tolerance to herbicides with different modes of action and spectra of control. Farmers could then utilize crop rotation with the different engineered crops. If farmers can purchase their preferred cultivars with tolerance to herbicides with different modes of action, then herbicide rotation is more likely to occur. Alternatively, different tolerances to herbicides could be engineered into the same cultivar, and the herbicides then used in rotation. The difficulty with this approach is that at present the different chemistries belong to different companies and it is not likely that they would agree to introduce their genes together in the same plant. Either approach is likely to reduce problems due to weed shift, the emergence of herbicide resistant weeds and herbicide-tolerant volunteers arising from the previous crops sharing the same herbicide tolerance. The successful long-term use of HTCs must involve herbicide rotation in order to minimize many of the problems listed above. Herbicide alternatives not linked to the engineered crop will also likely still be available and used in order to maximize the utility of HTCs.

If farmers are to benefit from these technologies and companies to recoup their development costs, herbicide-tolerant crops must be used as a part of an integrated weed management program. For example, the use of a particular herbicide and its associated HTC must not be continuous. Properly informed farmers and well-implemented and monitored regulatory policies will help curtail mono-herbicide application and mono-herbicide tolerant crop use. While a good choice in theory, herbicide tolerant crops of certain species might not be available that have tolerances to herbicides with different modes of action. Therefore, replanting of a particular HTC over several seasons might be likely occur if the farmer realizes savings on inputs. Additionally, in the near-term it is likely that most crops used in rotations, like soybean and corn, for example, will be engineered for tolerance to the same herbicides. This also increases the likelihood of continuous mono-application of a herbicide with the same mode of action.

Anticipation of problems, such as those listed above, has led to the organization of inter-company groups, such as the Herbicide Resistance Action Committee (9), which exchanges information on the development and spread of herbicide-resistant weeds and develops guidelines for managing resistant weeds. Inter-company cooperation in the development of HTCs, as outlined above, is imperative to avoid weed-shift problems and the development of herbicide-resistant weeds. In addition, companies must work closely with university and extension personnel during the development and deployment of HTCs in order to determine how they and their associated herbicides perform in particular areas and how to avoid potential environmental problems.

Economic

Proponents of HTCs assert these crops should prove profitable over nonGM crops because of reductions in herbicide costs and increased crop yields. However, evidence to date is sketchy and hard to come by that these claims are true. An Iowa State University report, for example, states that in 1998 Iowa soybean farmers using Roundup-Ready (RR) seed saved roughly 30% on their herbicide costs, but that yield drag caused a loss of 2 bushels per acre (10).

This meant that total cost per acre for GM and nonGM soybean was about the same. Yield drag in these varieties is believed to be due to the fact that the particular soybean varieties into which the RR gene is introduced are not varieties that are expected to give optimal yields at all locations.

Charles Benbrook, an independent biotechnology consultant, recently published a review on RR soybean drag based on the results of over 8200 university-based soybean varietal trials performed in eight Midwestern states (11). His report concluded that in 1998 RR soybean varieties yielded 5 to 10 percent less on average compared to all varieties tested. Benbrook suggested that so far the RR seed technology is at best an economic wash. He stated that despite their cost RR soybeans are popular with farmers because they are tired of dealing with the complexity, cost and periodic failures of other soybean weed management systems.

Current RR soybeans yield less probably because the engineered traits were not introgressed into crop varieties that perform best in different growing regions. In the future companies developing HTCs should work with breeders, public and private sector, to introgress herbicide tolerance traits into cultivars adapted to perform optimally for specific growing regions. And the breeders should realize some economic benefits for participating in this aspect of the development of the optimized-engineered variety.

Environmental

Numerous herbicides are widely used at present as part of weed control programs. Of these herbicides, glyphosate and glufosinate are considered, in general, low use-rate, low-toxicity, rapid-turnover herbicides. Therefore, the increased use of these herbicides should result in lower environmental impact than occurs at present with the higher impact herbicides. Glyphosate and glufosinate have minimal mammalian toxicity and show little, if any, leaching into groundwater. This latter benefit should prevent additional groundwater pollution in California caused by the herbicides, atrazine, simazine and diuron. Rotation of cropping systems with engineered and non-engineered varieties of the same crop species could also encourage the rotation of herbicide usage, thereby reducing environmental buildup of the utilized herbicides.

Will the existence of engineered herbicide-resistant crops increase the use of certain herbicides and will their existence perpetuate farming's dependence on herbicides? The adoption of HTCs will certainly result in an increase in sales of the herbicides to which tolerance is being engineered. An increase in sales does not imply, however, that farmers are applying more herbicide per acre. In fact, a recent USDA report indicates that in 1997 herbicide-tolerant technology significantly reduced herbicide treatments for soybeans and, to a lesser extent, for cotton in most regions of the U.S. (12).

Consumer Acceptance of Products of Biotechnology

Genetic engineering or biotechnology is a new technology that is being used to modify foods. When new technologies are introduced into food production, there are often consumer concerns. For example, there were furors over pasteurization, microwave ovens and food irradiation. Biotechnology will not be an exception. Over the last decade, numerous scientifically conducted polls were conducted to gauge consumer acceptance of foods produced with biotechnology. Up until recently these surveys in the U.S. have found that between 2/3 and 3/4 of consumers are supportive of biotechnology.

The trend toward acceptance was seen in a survey conducted in the U.S. by the International Food Information Council (IFIC) in February of this year. In that survey, the majority of U.S. consumers were willing to "purchase a food modified by biotechnology to taste better or fresher" (62%) or a food "modified by biotechnology to be protected from insect damage and requiring fewer pesticides" (77%).

Another recently released poll was conducted by Gallup on September 23-26, 1999. Respondents in the Gallup poll were asked to rate the likelihood that biotechnology poses a serious health hazard to consumers: 53% thought it did not present a serious hazard, 20% were unsure, and 27% thought it posed a serious hazard. Despite this expressed fear, respondents expressed confidence in the U.S. Food and Drug Administration, the regulatory arm that monitors genetically engineered food products. Seventy-six percent of Americans had a great deal or fair amount of confidence in the federal government to ensure the safety of food.

Interest in labeling, as evidenced in the Gallup poll, has risen dramatically over previously conducted polls with over 2/3 of respondents in favor of labeling. This is despite the possibility of an increase in price. The increased interest in labeling and the rising consumer concern in the U.S. is likely due to the fact that anti-GMO sentiment was high in Europe and consumer concern was being fed by scare scenarios of the effects of GMOs. Newspaper accounts of this turmoil were seen in the U.S. almost daily.

The intense feelings of European consumers against GMOs came about because of some fundamental differences in issues and occurrences between Europe and the U.S. Perhaps the most significant events influencing consumers feelings about GMOs were the food scares that occurred recently, including mad cow disease and dioxin contamination. The pronouncements and decisions made by governmental officials during these controversies were perceived by many to be based on political expediency rather than on public safety concerns. This undermined consumers’ confidence in the government to assure food safety with biotech foods and led to more open minds for activists’ claims.

Once tensions and accusations reached a certain peak in Europe, activists decided to focus their anti-biotechnology efforts on Canada and the U.S. A very significant early event in their campaign in the U.S. was getting baby-food giant, Gerber, to agree not to use GMOs in their baby food. After this pronouncement several other large companies followed suit. Perhaps the most significant was Archer Daniels Midland (ADM), one of the country's largest grain handlers. ADM decided in late summer of this year to demand that their suppliers segregate GM from non-GM grain. This they said had to do with “a change…in consumer demand”. International trade had become a question: what products would and would not be accepted in Europe? Would they have to be guaranteed to be GM-free? Soon food processors, like ADM, wanted crops segregated and paid premiums to farmers for GM-free grain. But the momentum is not all in that direction. More recently another large processor, Cargill, has promised to take all grain, segregated or not, and find markets for it. Kellogg also has stood firm in its intent to use GM ingredients in its cereals.

How will the whole labeling and public acceptance scenario play out? It is difficult to make predictions for the short-term (2-5 years), but it is likely that in ten years the technology will pervade agriculture. Why? The goals that can be achieved uniquely with this technology will build on the information that will be gained through the study of the genome. This new information will provide new avenues for crop improvement that cannot be achieved in any other way. These benefits will be realized by the consumer and in improvement in the environment.

The first products of the technology are crude; the Roundup Ready soybean is not the best that can be done in terms of an HTC. Many of these products will not achieve the potential necessary for user or consumer acceptance. But the strategies will be improved and refined, just as the computer has moved from a machine that took up city blocks to one that fits on your wrist. Some products of the technology will find favor with users and consumers; some will not. Some will be a commercial success; some will not. But in the long-term, biotechnology is likely to find applications and result in products that will be important tools in the farmer's toolbox and that will be accepted and likely even sought after by consumers.

Summary

Over the past decade progress in the generation of engineered herbicide-tolerant crops has been rapid with the major acreage crops in the United States, namely corn, cotton, and soybean. These herbicide-tolerant varieties can play an important role in production agriculture if they are properly managed since they provide some distinct advantages for the farmer in combating weed problems and providing the opportunity for lower or no-till agriculture. While these approaches are important for high-acreage crops, their importance for minor acreage crops, including many of California's fruit, vegetable and nut crops, is likely to be limited in the near term. The engineering of minor-acreage crops is not likely to progress at the same rate as that for the major crops because the economic gains do not justify the expenditure by agrochemical companies in developing them. Minor-acreage crops are likely to benefit indirectly from efforts in major acreage crops since progress in these crops will also likely yield new tools or herbicides for use with minor-acreage crops. As engineered herbicide-tolerant crops become available to growers, questions relating to their use will be raised and answered. Currently consumer fears and international trade issues will be one important factor affecting the desirability and utility of HTCs. With time these issues will be resolved at which point the focus will be more on the development of appropriate management systems to control weed shift, weed resistance and outcrossing; these approaches will change as growers integrate this technology into their production systems. Despite the definitiveness of the change, the precise manner in which the availability of these crops will lead to change and exactly what those changes will be are difficult to predict. Only experience with these crops in the fields will give precise answers to the economic and environmental questions raised by their use.

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Milestone ™*: A New Herbicide for Citrus and Grapes

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Dupont Agricultural Enterprise. (pending registration).*

Milestone™ (Azafenidin) is a new broad-spectrum herbicide for the citrus and grape industry. Milestone™ is a low use rate, long residual herbicide that has been under development by E.I. duPont de Nemours and Company Agricultural Enterprise for preemergence weed control in citrus and grapes.

Milestone™ represents a new weed management tool that is absorbed through the roots and shoots of susceptible plants and inhibits the enzyme Protoporphyrinogen oxidase, which is involved in the biosynthesis of chlorophyll. This type of chemistry is known as porphyrin biosynthesis inhibitors that indiscriminately react with cellular components, resulting in cell membrane disruption.

Milestone™ is a highly effective herbicide characterized by low use rates. The use rate will be 8 to 16 ounces active ingredient per acre for citrus and 8 to 12 ounces active ingredient per acre for grapes. Milestone™ requires water (rainfall or overhead sprinkler irrigation) for activation. Preliminary testing reveals that approximately ½ inch of rain is necessary for activation. Once activated, subsequent rainfall or irrigation does not readily move Milestone™. Moisture soon after an application enhances activity. At a use rate of 8 to 16 ounces active ingredient per acre applied preemergence, Milestone™ provides four to eight months of residual weed control depending on weather conditions and weed pressure. Some of the key weeds that are controlled by Milestone™ are; common groundsel *Senecio vulgaris*, spotted spurge *Euphorbia maculata*, common mallow *Malva neglecta*, redstem filaree *Erodium cicutarium*, annual sowthistle *Sonchus oleraceus*, bearded sprangletop *Leptochloa fascicularis*, barnyardgrass *Echinochloa crus-galli*, lovegrass *Eragrostis diffusa* and crabgrass *Digitaria sanguinalis*.

Milestone™ has been evaluated with some of the most commonly used postemergence herbicides in California citrus and grapes with no antagonistic effects or reduction of activity from these combinations. Milestone™ has also been evaluated for use through low volume irrigation systems (microsprinklers) with very promising results in efficacy and tree safety. Results from extensive California trials (63 citrus and 51 grape) on various varieties and rootstocks indicate that Milestone™ is safe to citrus trees and grapes at the recommended field use rates.

Based on toxicological studies, Milestone™ has low acute oral and dermal toxicity. Skin exposure studies have resulted in no irritation to rabbits. Milestone™ was not mutagenic in the Ames test. Milestone™ when labeled is expected to carry the signal word “Caution”.

Milestone™ is environmentally sound, it has a low water solubility (18ppm) and results from various environmental studies indicate Milestone™ is safe to the environment. Breakdown of Milestone™ with the environment occurs primarily by way of microbial degradation.

However, soil type and organic matter content do not appear to significantly affect product performance. The results of soil mobility and binding studies indicate Milestone™ to have intermediate to low soil mobility (Table 1).

Table 1: Soil Mobility and binding.

Soil	% Organic carbon	Kd	Koc	TLC mobility
Fargo silt loam	2.55	5.66	222	low
Tama silt loam	1.33	2.48	186	low
Sassafras sandy loam	0.81	1.67	205	intermediate
Miaka sand	0.23	1.31	579	intermediate

Milestone™ degrades at moderate rate in soils. In field dissipation studies in the United States and Europe the half life (DT_{50}) of Milestone™ varied from 4 to 129 days (Table 2).

Table 2: Field Soil Dissipation.

Disappearance time-days	California	Florida	N. France	Italy
DT_{50}	129	4	73	80
DT_{90}	428	171	242	198

Milestone™ is formulated as a paste-extruded 80% active ingredient, water-dispersible granule. This formulation has demonstrated many favorable attributes in extensive testing under varied and adverse conditions. The formulation exhibits: rapid and complete breakup and dispersion in the spray tank, compatibility with potential tank-mix partners, resistance to attrition, good resuspension after settling and stable shelf life.

Milestone™ will provide citrus and grape growers with an important tool for control of a broad range of weeds and do so in environmentally friendly manner.

Ryegrass in Almond Orchards Found to be Glyphosate Resistant, A Management Perspective

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In 1996 in Australia, a weedy biotype of annual rye-grass (*Lolium rigidum*) survived labeled rates of glyphosate, the active ingredient in Roundup herbicide. After examination of thousands of samples, only four locations were confirmed as having the resistant population - indicating the phenomenon is not widespread. Monsanto and Charles Sturt University researchers embarked on a collaborative research project to better understand the mechanism of survival to glyphosate for this particular biotype of ryegrass. Results of these studies were presented by Dr. Jim Pratley, Professor of Weed Science at Charles Sturt University, at the Weed Science Society of America meeting in February, l999. Observations include that the resistant ryegrass is easily controlled by tillage or other herbicides and the resistance is caused by a complex inheritance pattern, unlikely to occur across a wide range of other species. It is worth mentioning that glyphosate remains an effective weed management tool in the areas where this resistant population was identified, for control of most weed species.

Monsanto is also working in cooperation with Professor Dave Bayer, University of California, to investigate additional reports of resistant ryegrass in northern California. Similar to the Australian locations, these fields are small and isolated. Investigations appear to begin at the point of irrigation and move into the orchards a short distance becoming less dense as distance from the source increases. Again, the use of mowing and other herbicides have been very effective in managing the ryegrass. For the affected almond orchards residual weed control programs recommend Surflan (2-4 pounds ai/A) tank mixed with Roundup ULTRA (0.75-1.0 pounds ae or 2-3 pints/acre) when emerged weeds are present. The minimum application volume for Surflan is 20 gallons per acre, therefore nonionic surfactant (0.5% of spray volume) is also recommended.

For residual free programs (also ryegrass escapes), a Roundup/Poast (sethoxydim) tank - mix is recommended. Fourth quarter tank mix rates are 0.75 pounds ae or 2 pints/Acre Roundup Ultra and 0.2 pounds ai or 1 pint/acre Poast. After January 1, we recommend 1.0 pound ae or 3 pints/acre Roundup Ultra and 0.4 pounds ai or 2 pints/acre Poast. Crop oil concentrate (0.25% of spray volume) is recommended with this tank-mix.

Middles are maintained mechanically (mowing) to prevent seed production.

Despite generating a large amount of information, the exact biochemical nature of the resistance has yet to be determined. None of the traditional resistance mechanisms (uptake of herbicide, translocation of herbicide in the plant, glyphosate breakdown in the plant, or altered biochemical site of action) have shown to be responsible for the resistance. Current hypothesis is that the resistance mechanism is more complex than that observed for most resistances.

Monsanto's current position on resistance is that resistance to glyphosate is a rare event, far less frequent in occurrence and breadth than other herbicides. However, Monsanto does recommend that growers follow the following guidelines in developing weed management strategies:

Use good cultural and sanitary practices

- clean off equipment when leaving every field
- use only certified seed in annual cropping systems or cover crops
- use appropriate crop, tillage, cultural practice rotation to manage weed
- spectrum and competitive ability
- mow/spray non-crop vegetation to prevent seed production
- use label recommended rates
- avoid mixtures recommending glyphosate at below label rates

Report any incidence of ***repeated*** Roundup non-performance on a particular weed to your PCA and local Monsanto Representative

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Rely: A New Herbicide for Trees and Vines

Matt Ehlhardt and Dale Comer
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Rely with the active ingredient of glufosinate-ammonia was first registered by the Federal EPA for weed control in trees and vines in 1995. California registration is expected in 2000.

Rely's herbicidal activity is through contact with plant foliage. It is effective on a broad spectrum of broadleaf and grassy weeds and has no soil activity. The mode of action of its active ingredient, glufosinate ammonia, is as a competitive inhibitor of glutamine synthetase. This enzyme, involved in nitrogen metabolism, catalyzes the reaction where ammonia, formed during photorespiration, combines with glutamate to form glutamine. By inhibiting this reaction, free ammonia levels are increased, glutamine production is reduced as well as photosynthesis.

Applied at a rate range of 0.25 to 1.0 lbs.a.i./acre, trials were conducted to determine the optimum rate range and stage of growth for application and control of winter and summer annual weeds in almonds, walnuts and grapes grown in California's Central Valleys. Results showed that while all plants are susceptible, different species respond to different rates and are stage of growth sensitive. Most grasses require higher rates, 1.0 lb or greater, unless they are smaller than 6" tall or have yet to begin tillering. Broadleaf weeds do demonstrate greater sensitivity than grasses but still are rate and size dependent. Redstem filaree, for example, was controlled by 0.75 lbs of Rely when treated before the 6" stage of growth. By delaying application until a later stage, control at this rate dropped from 85% to 70%. Wild radish control with 0.5 lbs went from 93% to 78% by treating after the plant had developed beyond a 6" growth stage.

Application volume studies demonstrated little effect on activity when treatments were made from 5 to 40 gpa. Above 40 gallons activity did drop off slightly and is believed to be due to runoff and lack of herbicide absorption. Trials initiated to study the effect of additional surfactants showed no benefit to adding non-ionic surfactants or fertilizer additives (ammonium sulfate) to Rely.

Combinations with soil residual herbicides were evaluated. Results showed no antagonistic effect on either the post-emergent activity of Rely or pre-emergent activity of the various pre-emergent herbicides studied.

As a contact herbicide injury to perennial crops is limited to the area contacted by the spray solution. To avoid potential injury the label recommends not treating trees within one year of transplanting. A trial to determine the sensitivity of young trees was established where first leaf almonds and apples were planted in the spring and treated at 1, 2 and 4 lbs.a.i./A two months after transplanting. Bark injury and foliar damage was evaluated at 6 WAT and 12 WAT and again in the second season after transplanting. No treatment resulted in unacceptable injury in the first or second year after application.

Sonar Use in California to Manage Exotic Plants: Hydrilla, Eurasian Watermilfoil, and Egeria

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The aquatic herbicide Sonar* (containing the active ingredient fluridone) has been registered for use as an aquatic herbicide since 1986; however, due to additional data requirements by CALEPA, Sonar was not registered for use in California until 1996. Due to the fact that Sonar is relatively new in California, the objective of this article is to describe some of the factors that make Sonar relatively unique among aquatic herbicides, present experimental data that has been used to improve use strategies with Sonar, and to discuss recent developments with Sonar use in California for control of hydrilla (*Hydrilla verticillata),* Eurasian watermilfoil (*Myriophyllum spicatum*) and egeria (*Egeria densa*).

Sonar specifically inhibits the phytoene desaturase enzyme in the pathway responsible for producing carotenoids (Bartels and Watson 1978). This inhibition of carotenoid synthesis results in photooxidation of the chlorophyll molecule due to the lack of the protective carotenoids. Loss of chlorophyll in actively growing tissues results in a bleached appearance of apical meristems. The inhibition of new growth results in the slow death of the plant. Depending on the growth stage of the target species during treatment, control can take from 30 to 90 days. While the extended time required to achieve control can often be frustrating to plant managers, the slow death of the plants prevents water quality problems that are often associated with rapid decomposition of plant biomass following herbicide treatments.

The fact that Sonar specifically targets a plant enzyme system results in very low toxicity to mammals and aquatic vertebrates and invertebrates. The low use rates of Sonar (maximum of 150 µg/L) in combination with low non-target toxicity greatly minimize any restrictions on water use. Sonar can be present in potable water at the maximum label rate without restrictions on drinking, swimming, fishing, or livestock watering. It should be noted that irrigation with Sonar treated water can lead to phytotoxicity on certain sensitive species, and the label should be consulted to determine time frames to be followed prior to irrigating.

Early inconsistencies with use of Sonar for control of nuisance aquatic plants were not readily explained. A series of laboratory evaluations initiated in the early 1990's began to help explain the activity of Sonar. These evaluations clearly demonstrated that Sonar required long exposure periods (60 to 90 days) to control hydrilla; however, it was noted that similar levels of control were achieved across a broad range of initial concentrations (Netherland et al. 1993). While the onset of symptoms occurred more quickly at the higher treatment rates, the slow activity of Sonar resulted in treatment rates of 10 and 50 µg/L providing very similar control by the end of the studies. Treatments at high initial rates followed by short exposure periods generally provided very poor control compared to much lower treatment rates followed by longer exposures (Netherland and Getsinger 1995). These laboratory data were eventually reconciled

* Trademark of SePRO Corporation

with field data, and it was clear that large-scale control of hydrilla with Sonar was due to exposure to low doses over long periods of time (Fox et al. 1996). The ability to target low doses presented the opportunity to control large areas of hydrilla in a cost-efficient manner. Moreover, the slow death of hydrilla prevented dramatic changes in water quality and subsequent concerns of fish kills. As the knowledge on Sonar rates and exposures increased, work was initiated to treat flowing systems by adding small amounts of Sonar over time to maintain a lethal concentration (Fox et al. 1994) The combination of work and research by Industry, Government, and University personnel was crucial in development of Sonar.

Despite not receiving registration until 1996, a solid research program with Sonar has existed in California since the early 1980's (Anderson 1981). Upon receiving registration, Sonar was incorporated into the Hydrilla Eradication Program. The discovery of hydrilla in Clear Lake (43,000 acres) was particularly disturbing due to the potential for rapid spread within the lake as well as this lake potentially providing a source for spread to other aquatic systems. Sonar SRP (granular formulation) has been incorporated in treatment of hydrilla in Clear Lake. Treatment strategies have included low dose sequential applications in areas where infestations are found. Research and developmental work continue on improving strategies for treating hydrilla in flowing water or treating small areas in large reservoirs. Nonetheless, these areas continue to present significant challenges when using Sonar.

As Sonar use to treat large areas or entire water bodies increased in the mid 1990's, questions on the impacts on native plant communities began to arise. This was especially true in northern tier states where glacial lakes support abundant and diverse submersed aquatic plant populations. Sonar applications to entire waterbodies in Minnesota and Michigan for the control of the invasive exotic Eurasian watermilfoil (EWM) produced mixed results, with some treatments providing good selectivity within the treatment season, and others controlling the majority of species in the lakes (Smith and Pullman 1997). In order to determine the potential for Sonar selectivity, a series of mesocosm studies were conducted at various rates in a mixed community of plants. Results demonstrated that a rate-based selectivity existed, with a 5 µg/L treatment controlling EWM with minimal impact on native species, while simply increasing rates to 10 µg/L resulted in near complete control of all test species (Netherland et al. 1997). While these studies confirmed a rate-based selectivity with Sonar, they also showed that a fairly narrow window existed between selective and non-selective control within the year of treatment. These results likely explain the variability in results noted in initial field trials, as it is likely that Sonar residues spanned a fairly broad range.

A thorough study directed by the US Army Engineer Waterways Experiment Station was initiated in Michigan to document the selective potential of Sonar following whole-lake treatments. The key factor in these treatments was achieving an initial treatment rate of 5-6 µg/L on a whole-lake basis. The FasTEST immunoassay was extensively employed in these studies to confirm that initial treatment concentrations were achieved, as well as providing information on the amount of Sonar needed in sequential applications to maintain the 5 µg/L target concentration. Results demonstrated that treatments could be refined to achieve a theoretical target dose on a whole lake basis. These results also pointed out the importance of collecting accurate lake volume information to determine precise treatment rates. In addition, incorporation of the FasTEST provided a valuable analytical tool that was used to conduct extensive sampling. EWM was successfully controlled with little to no impact on native diversity or frequency.

These treatments demonstrated that the concept of targeting an exotic species while not damaging native plant species within the year of treatment was valid. This particular use of Sonar allows aquatic manager to get away from the concept that all herbicides do is “kill weeds” and it allows them to use a herbicide to restore balance to the lake ecosystem.

While EWM is present in California, and can cause significant problems in water bodies where it is present, it is not considered as serious a threat to California waterways as either hydrilla or egeria. Nonetheless, some systems such as Big Bear Lake, a 3000 acre lake located in the San Bernadino National Forest, support extensive EWM colonies. Spot treatments on a 30 acre cove on Big Bear Lake provided little control following a Sonar SRP treatment in August of 1996; however, a subsequent treatment in July of 1998 provided good EWM control through 1999. Treatment strategies to control small areas in large water bodies are continuing to be refined in California.

An increasing new threat in California is the spread of the exotic monocot egeria in the Sacramento Delta. While egeria has been present in the US for many years, it has just recently become a serious problem in many waterways. For this reason, experience with Sonar on egeria is limited compared to experience with hydrilla and Eurasian watermilfoil. In addition, the flow and tidal influence of the Sacramento Delta can reduce contact times and will likely require innovative treatment strategies for the myriad of treatment sites and scenarios in the Delta.

Initial laboratory studies suggest that egeria is quite sensitive to Sonar, with concentrations of 8 and 12 ppb likely to be lethal. Maintaining a concentration of 4 ppb proved to be growth regulating (i.e. biomass slowly increased over time). Current research includes mesocosm evaluations to determine optimal treatment rates and timing of treatments under various flow regimes. Expansion of the concept of pulsing treatments tested by Lars Anderson (USDA-ARS). Pulse treatments allow Sonar residues to fall to zero for a given interval before retreating at a threshold concentration. This concept would allow extension of the overall exposure period and would potentially provide improved application technology in high-flow environments.

In the field, current treatments in the Merced Irrigation District are employing a pulse concept for control of egeria and several other species that interfere with conveyance of the water. In addition, Blodgett Lake, CA was treated in November to evaluate the concept of Fall treatments for egeria control. If fall treatments prove to be successful, irrigation concerns following treatments in the Sacramento Delta could be reduced. Moreover, due to the phenology of egeria, fall treatments may prove to provide improved control. Lastly, Sonar A.S. was evaluated in the Sacramento Delta this year under the guidance of Lars Anderson (USDA-ARS). A sequential treatment strategy was followed to allow residues to dissipate prior to the addition of an additional low rate of Sonar. Currently, only the SRP formulation (granular) is approved for use in the Sacramento Delta (riverine system); however, submission for approval of the liquid A.S for use in the Sacramento Delta would allow increased flexibility in treatments.

In summary, several aquatic exotic weeds are currently causing problems in California, and it is likely that these problems will continue to worsen. While Sonar has proven to provide excellent control of several of these species, treatment strategies, optimal rates, and timing of treatments need to be further developed in some of the challenging systems that exist in California.

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Aquatic Vegetation Management in Southern Oregon Irrigation Canals

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The Rogue River Valley Project was developed by the US Bureau of Reclamation in the 1950s to improve irrigated agriculture in the vicinity of Medford, Oregon. The Project includes over 140,000 acre-feet of storage and over 170 miles of primary irrigation canals. Aquatic weeds, primarily Sago pondweed (*Potamogeton pectinatus*) and Curly leaf pondweed (*P. crispus*) in the canals block flow and limit water delivery. Historically, mechanical and chemical methods were used for weed control in canals. Copper compounds, acrolein, and xylene were the most commonly used herbicides.

A spill of acrolein-treated water from the Talent Lateral Canal into Bear Creek and the resultant death of Coho salmon and steelhead prompted the Talent Irrigation District to investigate alternatives to acrolein for weed control in the 65 cfs canal. Shading, handpulling, sediment removal, sediment amendment, and manipulation of canal morphology were evaluated in 1998. In 1999, triploid grass carp were stocked in two, 600-m sections of the canal.

Sediment amendment with straw and acetic acid during winter drawdown provided very good control of vegetation during the following growing season. Use of sediment amendment for weed control in canals will be evaluated further. Shading the canal to reduce incident light by 26 to 55 percent provided about a 50 percent reduction in plant biomass through the middle of July. An 80 percent reduction in light reduced biomass to about 16 percent of the control. Handpulling, sediment removal, and manipulation of canal morphology did not result in adequate control.

Twelve-inch grass carp stocked at 55 and 100 fish/half mile of canal (92 and 167 kg/ha) did not provide adequate weed control. Mechanical methods were used twice during the irrigation season to maintain canal supply capacity in the section of canal stocked with grass carp. Failure of grass carp to provide weed control was attributed to unusually cold water temperatures in 1999. Daily minimum water temperature greater than 10 C did not occur until mid-July in 1999. During normal years, daily minimum water temperature exceeds 10 C in early May. Effective use of grass carp for weed control in Oregon irrigation canals will require close monitoring of water temperature and perhaps a pre-stocking herbicide treatment to ensure that the fish can maintain control of vegetation during the irrigation season.

PG&E's Integrated Vegetation Management Program

Pamela R. Money

PG&E has a number of facilities where they utilize Integrated Vegetation Management, including the following facilities; Electric Transmission, Electric Distribution, Gas Transmission, Gas Distribution, Hydro, and Service Centers. These range from small facilities requiring annual bareground applications to rights-of-way that are several hundred feet wide and hundreds of miles long. Some examples of these facilities are powerhouses, switchyards, substations, dams, canals, gas metering sites, gas valve regulator sites, subject poles, service centers, and rights-of-way. These facilities are scattered throughout PG&E's service territory and range from urban areas, to agricultural areas, to the high Sierras. PG&E has 4.5 million electric customers; 3.7 million gas customers; 18,516 miles of electric transmission lines; 108,170 miles of electric transmission lines; 5,700 miles of gas transmission pipelines; 36,700 miles of gas distribution lines; 3 gas storage facilities and 1,000 substations. PG&E's service territory encompasses 70,000 square miles.

Integrated Vegetation Management provides the necessary tools for PG&E to accomplish our specific goals at the different types of facilities throughout our diverse service territory. IVM utilizes cultural, mechanical, manual, biological, and chemical techniques to accomplish specific goals. These goals range from bareground at switchyards, powerhouses, substations and subject poles; to selective vegetation management along rights-of-ways, canals and dams; to control of weeds in landscaped areas around service centers. The reasons for the varying goals are as varied as the sites themselves, but generally speaking fall under one or more of the following broad categories; safety, service reliability, legal requirements, and aesthetics. Often there are numerous reasons for managing a certain facility in a certain manner.

Vegetation management of Electric Transmission Rights-of-Ways provides a unique set of opportunities and challenges. PG&E is required to manage the vegetation along these ROWs by law. In order to supply safe, reliable electric power PG&E must manage the vegetation, including not only those plants that are tall enough at maturity to reach the conductors, but also vegetation that poses a fire hazard or interferes with access to the facility. The goal of this vegetation management program is to keep electric transmission facilities safe and to prevent interruptions caused by vegetation while maintaining a harmonious relationship with varied land uses and the environment.

The most common methods for initial removal of undesirable vegetation from within a right-of-way are mechanical and manual. Several factors must be considered before a method can be chosen, including the following; slope, vegetation density, and accessibility. Mechanical equipment is most cost effective where the vegetation is dense and the slope is not a limiting factor. Hand cutting or mechanical mowing vegetation perpetuates the growth of incompatible vegetation because of the biological response of resprouting. When a stem is cut, multiple sprouts can grow from the severed stump or the root system (so-called "root-suckering"). These sprouts are fast-growing because they are fed from a root system which is already well established. A repetitive cycle of cutting and sprouting results in an increasing density of tall growing species. The combination of mechanical methods and the selective use of herbicides is very effective in controlling resprouting tree and woody brush species that present problems for the access and maintenance of electric transmission facilities.

It is a common public misconception that mechanical/manual methods (chain saws and mowing) are safer and have less environmental impact than the use of herbicides. Often overlooked are the environmental and safety concerns associated with repeated cutting of vegetation such as: soil compaction from heavy equipment, soil erosion, damage to sensitive wetland areas, worker and environmental exposure to petroleum products (which are more toxic than many herbicides used for right-of-way maintenance), the potential for physical injury from sharp tools and equipment to both workers and wildlife, the increased fire risk, and the repeated, significant alteration of potential wildlife habitat. The goal of an IVM system is to manage vegetation and to balance benefits of control, public health and safety, environmental quality, and cost.

The long-term goal of a vegetation management program is to provide for public and worker safety and to provide reliable service by converting right-of-way plant communities from predominately tall growing plant species to communities dominated by low growing plant species. This can be accomplished by selectively controlling tall growing plant species while preserving low growing grasses, herbs and woody shrubs over a period of many years. With proper management, the low growing vegetation can eventually dominate the right-of-way and retard the growth of the tall growing vegetation, providing control of incompatible vegetation and reducing the need for future treatments.

A description of each IVM technique currently utilized on PG&E ROWs follows:

Mechanical: Large mechanical equipment is either rubber-tired or track equipped. Mechanical mowing is generally used for the initial control of dense woody species or on 2 - 5 year cycles in areas where herbicides are not a viable option. Rubber-tired equipment, such as the “Hydro-ax” and the “Row King,” are used to cut and chip woody species where slopes are less than 25 percent. The rubber tired machines can also be used along improved road surfaces such as asphalt or gravel. Track mounted equipment, including the Slashbuster and the Brontosaurs, is used on unpaved surfaces up to 40 percent slope. These large mechanical brush mowers can be used to cut and masticate woody plants to within 12 inches of the ground surface which reduces fuel hazard. Mechanical treatment usually results in vigorous resprouting of woody species.

Manual: Chainsaws, polesaws, machetes, string trimmers, McLeods and chippers are used for manual vegetation management. Chainsaws, pole-saws, and machetes are used to remove woody species, such as oaks, conifers, and brush greater than 1 inch in diameter. The string trimmers and McLeods are used to clear grasses and smaller woody species. Manually cleared vegetation is then either lopped and scattered; piled and burned or chipped, depending on fuel hazard, soils, and access. Manual treatment usually results in vigorous resprouting of woody species.

Cultural: Mulches can be used to help control annual grass and broadleaf species. Seeding is also used to develop and maintain a desired species of vegetation.

Biological: Cattle and goats are two biological methods that have been used to control vegetation. Goats have been used at Diablo Canyon power plant to control woody plant species and to help convert the vegetation cover to grasses. Cattle leases have been used in some sites to graze predominately grass species along right-of-ways. Goats and cattle are not completely effective when used alone because of grazing preferences, but can be extremely effective when used in combination with selective herbicide applications.

Chemical (herbicides): The use of herbicides is regulated by the Federal Environmental Protection Agency (EPA), the California Environmental Protection Agency, the California Department of Pesticide Regulation (CDPR) and the local County Agricultural Commissioners. Herbicide applications require the following:

1) annual safety and product training for each herbicide used

2) the use of safety equipment, including goggles, gloves, long pants, long sleeved shirts, shoes and socks

3) a written Pest Control Recommendation by a Licensed Pest Control Advisor (PCA)

4) monthly reporting of each use of herbicide county

5) annual inspections by the County Agricultural Commissioner

Foliar and contact application methods

Foliar backpack applications can be selective or non-selective, depending on the type of herbicide and the application method. Foliar applications are usually most effective when made when the target vegetation is actively growing. The herbicide triclopyr can selectively control woody plants without affecting desirable grasses. Even non-selective herbicides, such as glyphosate, can be used for selective control through the use of low volume directed back-pack applications or by timing the application so that the desired annual species have already produced seed.

Basal stem treatments are another selective contact treatment. Basal stem treatments are usually made using 5 gallon backpack sprayers. Herbicides are mixed with an oil carrier to allow adequate bark penetration and are applied to the lower two feet of a woody plant. Basal stem applications have a longer application season and can provide good control from March through November. Applications are frequently made during the dormant season because they are easier once the plants have lost their leaves. Dormant applications have the advantage of being a low profile approach since the target species never leafs out in the spring and there is no brownout.

Cut stump treatments are used to prevent woody species from resprouting. After trees and brush are cut with a chainsaw or loppers, the stump is treated with herbicide. Most cut stump treatments can be made year round.

Injection is an application method in which capsules containing herbicide are injected into the woody cambium and the herbicide gradually translocates to the roots and stems. This is another low profile application, since the applicator carries a 4, or 6 foot lance and not a backpack sprayer.

Vegetation Management Guidelines By Facility

PG&E's IVM program incorporates mechanical and manual techniques to remove undesirable vegetation along with the use of Federal Environmental Protection Agency (EPA) and California EPA registered herbicides to control the resprouting of woody species. IVM is a process aimed at identifying an appropriate combination of techniques that together result in effective control, acceptable operating costs, public and worker safety and an acceptable level of environmental protection.

PG&E is required under FERC regulations, the Public Utilities Commission and the Public Resource Code to manage vegetation along electric transmission facilities to allow for safe access, maintenance and operation of those facilities. PG&E employs an IVM program that includes the use of chain saws, string trimmers, mechanical brush mowers, mulchers and herbicides. Chain saws and string trimmers are initially required to remove large woody species and dense annual species. Low-volume directed herbicide treatments are used to control woody species, including oak, alder, willows, maple, blackberry, poison oak, and other vigorous resprouting species. Conifer regeneration can be controlled with manual techniques or selective herbicide treatments. After the initial control the annual maintenance requires only targeted applications of herbicides to maintain safe and reliable access for operations. Specific facility treatments are described below:

- **Access Roads.** Facility operation and maintenance require a variety of access roads with surfaces that vary from unimproved dirt to asphalt. The road surface and sides are generally managed in bare ground for fire safety and for protection of the surface material. The sides may have a drainage ditch that is kept clear of vegetation to keep water off the road surface. Some road drainage systems are lined with gravel to reduce erosion. Trees and woody brush are generally maintained at least 5 feet from the edge of the road to allow for adequate visibility. Roads are also required for access to individual towers.

- **Culvert Heads.** The area on the upstream side of the culvert must be kept clear of vegetation to allow for proper operation of the culvert. This is typically done with a combination of manual and chemical techniques. Culverts with flowing water will be treated only with those herbicides that are registered for aquatic use. No riparian vegetation will be treated.

- **Towers, and Poles.** The area around the individual towers or poles is managed either for bare ground, or for grasses. All woody vegetation, including trees and brush, that hinders access to, or prevents effective inspection of poles, towers and supports, or that constitutes a safety hazard is targeted for control.

- **Power Line Rights-of-Way.** One of PG&E's goals is to manage transmission lines rights-of-way to achieve a plant community of low growing woody and herbaceous plant species. Tree species capable of growing into overhead conductors are removed from within the right-of-way. Tree species typically targeted for removal include, but are not limited to: pines, firs, cedar, maples, oaks and alders. Where lines span over deep canyons it is not necessary to remove trees or other vegetation that is not capable of growing into lines, or creating flame heights or heat of sufficient intensity to damage the facilities.

Best Management Practices

Best Management Practices (BMPs) have been prepared to minimize the overall risk to people and the environment while providing for safe and reliable electric transmission operations. They are included as part of these guidelines to assist in the planning and implementation of successful vegetation management.

The purpose is to provide principles for current and future vegetation managers that will minimize overall risk to people and the environment while providing safe and reliable service. The approach is designed to protect wildlife, groundwater, surface water, soils, utility customers, utility workers and the general public. The objectives are:

- Program prescriptions will be selected which balance environmental concerns, public needs, safety and cost effectiveness.

- PG&E will use Integrated Vegetation Management methods that are supported through scientific research and industry standards as being safe and effective for use in right-of-way vegetation management programs.

- PG&E will adopt Best Management Practices (BMPs) for all vegetation management activities. These practices will be based on the latest scientific research among utilities, manufacturers, applicators, regulators and universities. These BMPs will be distributed to applicators, regulators and the public.

- PG&E will set as a long term goal of vegetation management programs the reduction of the level of active herbicide ingredient per unit of land area. This is to be accomplished through the proper selection and use of application methods, equipment and technology which will promote and facilitate reduced application rates. Use records can be used to track application rates.

- PG&E will encourage the accelerated approval of any use/risk reduction recommendations to be included on the labels of herbicides used for vegetation control.

These Best Management Practices should be applied to all vegetation management activities including manual, mechanical, cultural, and biological techniques as well as herbicide applications. Where they focus on herbicide applications they are intended to supplement and not replace the herbicide labels.

Utilizing a combination of manual and mechanical techniques followed by selective herbicide applications is the most cost effective environmentally sensitive approach in many situations. Numerous long term studies have demonstrated an increase in species density and richness (Bramble and Byrnes, 1982) on electric transmission ROWs that have been maintained by herbicides since 1953. Additionally, they documented greater use of the ROW that was maintained with herbicides by wildlife; including deer, rabbits, squirrels, turkeys, red-tailed hawks, numerous songbirds, and butterflies (Bramble and Byrnes, 1972; Bramble, 1974; Asplundh Environmental Services, 1977; Bramble et al, 1997).

There are numerous challenges utilities encounter in ROW vegetation management, including the following: rare, threatened, endangered, or sensitive species; cultural or heritage resources; and public perceptions. Some of these issues center around the initial clearing, while others are associated with the follow-up herbicide application. Some of the keys to a success are communication, good agency relationships (USFS, California Department of Fish and Game, County Agricultural Commissioners, California Department of Forestry and Fire Prevention, etc.), utilizing high quality contractors, and education (internally as well as externally). The only way PG&E will continue to be able to utilize herbicides as part of their IVM program will be to utilize them in the most professional manner possible. The following outlines some of the details that must be considered before implementing an IVM program.

1. The following factors should be considered in the planning of any vegetation management activity:
    - Target species
    - Rare and endangered species
    - Height and density of brush
    - Land use: within and adjacent to the right-of-way
    - Legal restrictions
    - Natural and man-made restrictions
    - Safety
        - Worker Safety
            - Potential for physical injury from chain saws
            - Exposure to poison oak
            - Exposure to poisonous snakes
            - Required Safety Equipment
            - Exposure to chemicals (petroleum, herbicides)
            - Tripping Hazards
        - Public Safety
            - Exposure to poison oak
            - Exposure to poisonous snakes
            - Tripping Hazards
            - Exposure to chemicals (petroleum, herbicides)
            - Potential for facility failure
        - Fire Safety
            - PRC 4435 and 4431, Federal Regulations
        - Environmental Safety
            - Water Quality
            - Wildlife Species and/or Habitat
            - Soil Compaction

        - Soil Erosion
        - Fire Potential
    - Cultural Resources
        - potential for disturbing recorded sites
    - Facility Safety
- Cost Effectiveness

2. Only Federal and California EPA registered herbicides will be applied.

3. Operator ID numbers and Site ID numbers will be obtained for each facility from the County Agricultural Commissioner.

4. Licensed Pest Control Advisors will write “Pest Control Recommendations” for each application.

5. All herbicide applications will be supervised by a Licensed Pest Control Operator.

6. All fire regulations relating to manual, mechanical, or burning activities will be strictly adhered to.

7. All herbicide applications will be made in compliance of all label requirements as well as all appropriate federal, state and local laws.

8. County Agricultural Commissioners will make appropriate inspections of all applications.

9. The amount of each herbicide used will be reported monthly to the County Agricultural Commissioner by the Licensed Pest Control Operator.

10. PG&E will conduct annual Worker Safety Training sessions for all employees and contractors involved in the herbicide applications and manual/mechanical clearing.

11. PG&E, in consultation with the National Forest, Bureau of Land Management and other appropriate agencies will evaluate the need for rare and endangered species surveys in all areas requiring vegetation management. Where it is determined to be appropriate or necessary, these surveys will be conducted prior to the start of activities.

12. Selective application techniques should be used wherever practical so that desirable vegetation is not adversely affected.

13. Back-pack equipment will be used for all directed foliar applications.

14. Applications along culverts with water flowing will have a one foot buffer established so directed applications will not enter the water, unless the product is registered for aquatic use.

15. Herbicide containers will be reused, recycled or otherwise disposed of in a proper manner.

16. Minimum operating pressures will be used. Coarse nozzle tips should be used to minimize drift.

17. Pesticides will not be transported in the same compartment with persons, food or feed. Pesticide containers will be secured to the vehicle during transportation in a manner that will prevent spillage into or off the vehicle.

18. The contractor will have a written training program for employees who handle pesticides. The written program must describe the materials and the information that will be provided and used to train the employees.

19. Training must be completed before an employee is allowed to handle any pesticide and be continually updated to cover any new pesticides that will be handled. Training must be repeated at least annually thereafter.

20. These special precautions will be observed during periods of inclement weather:

    - Applications will not be made in, immediately prior to, or immediately following rain when runoff could be expected.
    - Applications will not be made when wind and/or fog conditions have the potential to cause drift.
    - Basal bark applications will not be made when stems are wet with rain, snow or ice.

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Green Kyllinga

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Green kyllinga (*Kyllinga brevifolia)* is a weedy sedge that is becoming a major problem in turf and ornamental plantings in California. Green kyllinga has been reported as a weedy problem from Florida across the southeastern U. S. into Arizona and California and Hawaii. In California it has been reported in San Diego, Los Angeles, Sacramento, and in the San Joaquin and the Sacramento valleys. Due to its similarity in size and growth pattern, it is often confused with yellow or purple nutsedge. However, its fertile -globular flowers, extensive rhizomes, and absence of underground tubers make it easily distinguishable from these species.

Impact

Green kyllinga can be a major weed problem for turf managers. It forms a weak sod that gives poor footing for athletic fields and golf courses. Although green kyllinga is most often a problem in bermudagrass swards, it has been found in cool season turf cultivars as well. Green kyllinga has a texture and color that varies from normal turf cultivars and reduces the aesthetic quality of the turf. Green kyllinga grows faster than most turf cultivars. This gives infested turf an undulating or irregular surface as little as two days after mowing.

Once a few plants become established, spread can be rapid. In warm weather rhizomes can expand more than one inch per day growing into thick mats in but a few weeks. Seed and rhizomes are spread by mowing, foot traffic, and renovation.

Management

The primary method of control is to prevent new infestations. Mowers and cultivation equipment should be thoroughly cleaned before moving from infested to weed free areas. If solitary plants of green kyllinga are found they should be dug out and the area monitored for several months to make sure that removal was complete. Areas with infestations should be isolated until control can be accomplished. Turf should be well maintained to assure maximum turf vigor. This will aid in making these plantings as competitive as possible to slow invasion of the weed. Dense turf will shade the soil surface making the establishment of green kyllinga seedlings difficult.

No single control procedure has been successful in controlling green kyllinga in turf.

Early digging of solitary infestations has been successful when practiced diligently. Spot spraying isolated plants with glyphosate can be helpful, but the turf is killed leaving open areas, making kyllinga reestablishment easier. The open spots should be overseeded to establish a vigorous turf.

Preemergence (pendimethalin, prodiamine, bensulide, and benefin) herbicides have controlled green kyllinga in green house studies at Riverside. These herbicides should be applied in April prior to kyllinga germination to limit germination in late spring and early summer. Obviously Preemergence herbicides will do little to control established, perennial plants.

Results with postemergence herbicides in trials in San Diego, Riverside, and Sacramento have been variable. Control in a 1998 San Diego study was best with two applications of halosulfuron (0.05 lbs ai/a) applied four weeks apart in late summer achieving 98% control. However tests in Sacramento were not as promising with multiple applications over a two- year period (six applications--four in 1998 and two in 1999) resulting in only moderate green kyllinga control in one study (82% reduction in green kyllinga for the best single herbicide treatment – halosulfuron @ 0.03 lbs ai/a). In another Sacramento study where three sequential applications were made at monthly intervals during the summer of 1999, halosulfuron applications (0.03 and 0.05 lbs ai/a) resulted in 28 and 8% green kyllinga cover compared to 62% cover in the untreated checks.

Multiple applications of MSMA can also reduce infestations. In San Diego three sequential applications of MSMA reduced green kyllinga by 63%. In Sacramento multiple applications for the two and one year study resulted in 66 and 43% reductions of green kyllinga respectively.

The sequential application of MSMA followed by halosulfuron in three to four weeks may hold some promise; preliminary greenhouse studies at Riverside have indicated similar results to two applications of halosulfuron. More work is planned for the summer of 2000.

The IPM-CHAMP Plan for the Crystal Springs Golf Course

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The Crystal Springs golf course is a public facility owned by the City of San Francisco and is contained within the Hetch-Hetchy reservoir preserve, an 80,000 acre area to which all other public access is prohibited. The golf course property is located up a short slope from the shore of the Crystal Springs lake, which is the last reservoir in the system that supplies domestic water to the Bay area.

In order to obtain and then continue a long-term lease of the property, the operator was required to develop a pesticide and nutrient management plan which would then serve as the manual for day-to-day operations. The goal of the plan was to ensure that the operation of the facility posed no risk to the ecosystem or to the public health of the citizens. The plan is referred to as the IPM-CHAMP (integrated pest management - chemical application management program). The plan is not a pesticide-elimination program but rather a wise-usage program with emphasis on non-chemical methods.

The plan delineates the property into several zones (i.e. greens, roughs, buffer, etc.) each with differing requirements for management intensity and pest tolerance. The pest activity in the various zones are routinely monitored and if the threshold for a particular zone is exceeded, then an action decision is triggered. The plan ensures that first attempts of pest mitigation are non-chemical but that chemical usage is available as a last option.

The plan contains a short-list of chemical materials that are available for potential usage by the operator. This list does not include materials that are known or believed to be potentially problematic to the environment or public safety.

The plan is record-intensive to provide an auditable trail of all activities that involve pest-related issues or factors that may influence pest activity. It requires a balance sheet inventory system for chemicals the includes 100% recording and is regularly audited for compliance. The entire system and operation is audited twice per year by the author and at-will by City officials.

With the adoption and implementation of the plan, the City of S.F. Public Utility Commission is confident that the golf course is operated in an environmentally-sound manner and poses no threat to public interests. In recognition of this sentiment, the Crystal Springs golf course has been the recipient of numerous regional and national awards relating to environmental stewardship.

Creeping Yellow Fieldcress (*Rorippasylvestris*) Biology and Control

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Yellow fieldcress (*Rorippa sylvestris*) is a perennial weed in the family Brassicaceae. It grows in moist areas and is found in greenhouse, container and field nurseries. It was introduced into the United States from Europe about 1818 and has become common in ornamental plantings in recent years, especially with the increased popularity of herbaceous perennials. It has spread widely, probably through repeated introductions with herbaceous ornamental propagation material. Yellow fieldcress has been recorded in most northeastern and northwestern states, across the southern provinces of Canada, in some states along the eastern seaboard, and as far south as Texas. It has been found in California in several locations in 1998 and 1999.

Yellow fieldcress is a potentially serious problem because of its competition with desirable plants and its ability to spread within the container and nursery industry once it is established. It is often introduced as a root segment. From this root segment many new plants can be produced in a short period of time. The shoots are very pliable when young and when hand pulled, it leaves behind many root segments to form many new plants. Though plants from a single introduction are mostly sterile and generally do not set seed, there is some indication that fertilization can occur between clones or through out-crossing with *R. palustris* , another fieldcress in California.

Yellow fieldcress grows best in California during cool weather, but will tolerate hot weather if watered well. It tolerates cold weather, even sub-zero temperatures. Light quality and quantity does not seem limiting for growth, since it grows well in shade as well as full sun.

Cultivation of the weed probably will make it spread, since propagation from a 3 cm (1 inch) root segment was the best method to prepare experimental plants in containers. In one experiment, when plant and shoot development was monitored for 10 weeks, there were 753 new shoots on the root pieces developed from one 3 cm segment. Burying it to 24 cm (9.5 inches) depth delayed emergence but did not keep it from emerging from a 3 cm root segment. Root growth has been observed to 3 feet in a sandy soil in southern California.

Mulches

Covering a root segment with a geotextile (Typar) stopped the emergence from the surface of a container, but the plant emerged from around the edge or out of the drain hole of the container. The geotextile plus trifluralin herbicide (Biobarrier) stopped emergence but the root piece was not killed under the cover. It is not known how long the root would have to be covered without light to kill the plant.

Drying

Established plants in containers were evaluated for killing by drying by withholding water for periods of seven, 10, 14,18 and 21 days before watering again. Plants were controlled only after 21 days of draught. When ornamental bulbs were placed in the same containers, the bulbs were killed at the same draught duration.

Preemergence herbicides

Preemergence herbicides have been evaluated for the control of the 3 cm root segment. The herbicides, isoxaben (Gallery) at the use rate of 1 lb ai/A and dichlobenil (Casoron) at 3 lb ai/A were effective for long term control. Often the root piece remained alive under the herbicide, but it would not grow and emerge. When trifluralin was incorporated to 2 inches in the soil at 2 lb ai/A shoot suppression occurred. There was excellent control simazine in one study at 2 and 4 lb ai/A. Oryzalin (Surflan), prodiamine (Barricade), napropamide (Devrinol) and oxadiazon (Ronstar) did not control fieldcress as well as isoxaben. Metolachlor (Pennant), oxyfluorfen (Goal) alone or with dithiopyr (Dimension) was not effective longer than 30 to 60 days. Any combination of herbicides containing isoxaben controlled emerging shoots. At the rates used of some of these herbicides, there would be limited safety to the ornamentals, unless they were established, woody, plants.

Post emergence herbicides

Post emergence herbicides have been evaluated on young established yellow fieldcress. The most effective herbicides for the control of established field cress was MCPA or 2,4-D at 1 to 2 lb ai/A or triclopyr at rates of 1 to 1.5 lb ai/ A. Glyphosate at rates of 1 to 2 lb ai/A was not effective, but rates of 4 lb ai/A was effective for control. Halosulfuron (Manage) plus surfactant was not effective at use rates of 0.03 lb/A but was marginally effective at 0.06 lb/A for 60 days. A combination of triclopyr at 0.25 and dicamba at 0.25 was also effective for fieldcress control. Bentazon (Basagran), glufosinate (Finale), clopyralid (Stinger) did not give effective control. These herbicides could be used non-selectively to reduce or remove yellow field cress between crops or before planting new crops. They would be safe to use in perennial herbaceous or most woody ornamental crops.

Yellow creeping fieldcress could become a severe weed in California's ornamental industry if allowed to establish. We do not have selective methods of control in many ornamental crops. Crop rotation with treatments between crops or taking out crops and fumigating the soil before replanting may be the best current method for control. Though we have a few isolated sites in California now, we should eradicate these sites and be careful to not allow it to become established. The time to do this is now, and not let it become more widespread.

Alternatives to Methyl Bromide in Floricultural Crops - Project Update

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Methyl bromide is an important soil fumigant for California's floriculture industry. Many growers have relied heavily on its use to produce certain crops economically. It is generally highly effective in controlling important soil inhabiting pathogens, insects, weeds, and nematodes. However, because it has been identified as depleting atmospheric ozone, production and use will end in 2005 under international treaty. The industry is not adequately prepared with chemicals or other alternatives, and therefore, developing methyl bromide alternatives is a high research priority.

The purpose of this paper is to give a brief overview of the characteristics of the floriculture industry, describe the industry's critical uses of methyl bromide, describe some possible chemical alternatives, and discuss ongoing field research evaluating alternative chemicals and alternative soil sterilizing techniques such as steaming and solarization.

Floriculture industry characteristics

California floriculture's farm gate value exceeds $500,000,000. It consists of greenhouse and field production of flowers and foliage in containers or for cut stems. Production is mostly located along the California coast where the ocean's influence moderates temperatures in winter and summer and provides for relatively high winter light. The location is important for maximizing flower and plant quality, minimizing heating and cooling requirements, and providing a close proximity to urban markets and air and truck transportation. Many different high-value crops are produced that require the highest quality standards so they can be marketed in an increasingly competitive market. Some growers may be growing over 300 different floricultural crops.

Methyl bromide is important to the floriculture industry

Each crop and site has its own complement of soil inhabiting diseases, insects, nematodes, and weeds. Given the numerous crops, site diversity, intense competition that strains profit margins, and the absolute need to maintain very high flower quality, this industry faces extraordinary challenges in researching methyl bromide alternatives and adapting them into practice. Where do you start first?

Floricultural crops that are grown in containers are either not using methyl bromide or they are already using steam as an effective means to sterilize soil. Container soils are often steam sterilized or do not require sterilization if they are composed of reasonably pure components such as peats, composted barks, or coconut coir.

Floricultural crops that are grown in field or greenhouse soil probably have the greatest needs for soil sterilization and therefore methyl bromide alternatives. Field or greenhouse crops are usually planted in many small-acreage plots, making it difficult to micro-manage with complicated soil sterilization procedures. Rotation of crops is frequently not possible because of the limited production area available to the grower. The frequent need for repeated plantings in the same production area could lead to increasing problems with soil inhabiting pathogens, weeds, insects and nematodes.

Methyl bromide has been used as an effective herbicide to control many significant weeds found in flower crops. Preemergence herbicides are not available for many of the field flower crops because of insufficient information about a crop’s tolerance to preemergence herbicides, the lack of crop tolerance to the existing herbicides, or lack of chemical registrations. There are no registered preemergence herbicides in greenhouses. Growers in greenhouse and field flower crops usually rely on methyl bromide to control weeds, or when there are no adequate selective preemergence herbicides, growers must resort to expensive hand labor to weed crops.

There are several important California bulb crops such as calla (Zantedeschia spp.) that can become weeds in subsequent crops. Methyl bromide fumigation is a standard practice between these crops because previous crops may contaminant other pure stands of subsequently planted calla cultivars or other cut flower crops. In addition, these rogue callas can contaminate subsequent calla crops with fungal and bacterial diseases. These diseases are the major limiting factors of calla production.

Methyl bromide is used to control many major soil inhabiting diseases. Of particular importance are *Fusarium oxysporum* and *Verticillium spp*. These serious fungi are not controlled by post-plant fungicides so they must be controlled before the crops are planted. Often chloropicrin is added at concentrations above 30% to enhance the fungicidal effect. Carnation fusarium wilt caused by the fungus *Fusarium oxysporum f. sp. dianthi* is particularly devastating. If the fungus is not controlled, the entire crop can be killed in as little as one year.

Methyl bromide is used to control soil-inhabiting nematodes. In greenhouses, there is only one registered post-plant product for nematode control and it is frequently only marginally effective.

Presently there are few significant soil-inhabiting insects. There could become bigger insect problems when methyl bromide fumigation is not available. Some producers of dried flowers and foliage kill stored-product insects with methyl bromide fumigation. Some insects can be controlled post-plant with soil applied insecticides.

Possible chemical alternatives to methyl bromide

Funding has been limited to look at alternatives to methyl bromide specifically for floricultural needs until recently. Much of the knowledge of chemical alternatives come from research in other agricultural industries, particularly from the strawberry industry.

Although many alternatives in controlling pests in the soil or post-harvest situation exist for specific situations and crops, there is no known substitute for the broad spectrum of pest control and ease-of-use characteristics with methyl bromide fumigation. These chemical alternatives were Chloropicrin, Telone II, Vapam/Basamid, methyl iodide or combinations of these. A summary of the advantages and disadvantages and registration status for ornamentals follows.

Methyl iodide has similar efficacy and application techniques as that of methyl bromide. However, it apparently is broken down by sunlight quickly into non-reactive components that would not harm the ozone layer. The company MIF Partners, L.L.C has licensed the University of California Patent covering the use of methyl iodide for soil fumigation. The company is seeking registration but the registration processes is, of course, time consuming, costly, and there are many uncertainties in the process.

Choropicrin is known primarily for its use as an additive to methyl bromide. In small proportions (2%) it is the warning agent in an otherwise odorless methyl bromide application. In greater proportions (33 to 43 %) it is an important additive to increase control of certain soil inhabiting pathogens. Alone or in combination with other methyl bromide alternatives, it has its strength for disease control and limited activity for weed and nematode control. Chloropicrin, known more infamously as tear gas, has obvious potential application problems especially near the farming-urban interface. As chloropicrin application rates increase there is evidence that application buffer zones might need to be expanded.

Telone II (1,3 dichloropropene), a soil fumigant used primarily for nematode control, also has some limited disease and weed control characteristics. Telone in combination with chloropicrin has achieved broad-spectrum pest control similar to methyl bromide in some experiments. The draw back is that the fumigant is a significant air pollutant, has objectionable odor, and has been taken off the market already once. In crops where it is registered it has restrictions limiting its use within a geographical township. It has no greenhouse and limited ornamentals registration. The registrant is looking at reducing loss into the atmosphere with drip applications and high barrier tarps.

Vapam (metam sodium) and Basamid (dazomet) react with soil moisture to form methyl isothiocyanate, a fumigant that can provide good control on soil inhabiting nematodes and certain weeds. Disease control has been somewhat limited. The effectiveness of these products is dependent on good application techniques. Vapam, a liquid, requires the use of the proper amount of water and application technique to move the fumigant into the soil. Basamid, a granule, requires the proper incorporation of the granule and soil moisture, and it is effective only to the depth of incorporation. Both need tarping for maximum effectiveness and several weeks, for a waiting period, before treated soil can be planted. Basamid is registered for greenhouses but Vapam is not. Both are registered for ornamentals.

Control of Fusarium wilt in carnation with chemical and heating alternatives

One of the critical uses of methyl bromide in the floriculture industry has been for control of fusarium wilt of carnation caused by the soil-inhabiting fungus *Fusarium oxysporum f.sp. dianthi*. In two separate experiments, in 1995 and 1996, investigations were conducted to look at alternatives to methyl bromide. Experimental plots in a commercial carnation nursery were established in ground beds that were initially heavily infested with *F. oxysporum f. sp. dianthi*. Treatments included: (1)Methyl bromide (1 and 1.5 lb/100sq.ft), (2) Methyl iodide (1 and 1.5 lb/100sq.ft), (3) Basamid (up to 1.22 lb/100 sq. ft.) (5) Ohmic heating. Ohmic heating was created by producing an electrical field across the plots with a 220V, 20 amp circuit. A series of 3 foot long steel rods were driven into the ground to a depth of 2 feet along the sides of the plots. Rods on one side of the plot were connected in series to serve as anodes and the other side of the plot the rods were connected in series to serve as cathodes (6) Soil steaming. Pressurized steam was distributed with a single pipe manifold laid down the center of the plot and covered with a heavy plastic tarp used for this purpose.

The long-term efficacy of treatments was determined by periodic assessments of carnation mortality in each plot. For the first six months, mortality was lowest in the ohmic-heated and methyl iodide fumigated beds, highest in the Basamid treatment, and intermediate in the methyl bromide treatment. This pattern became very pronounced after 12 months, with up to 70% mortality in the Basamid treatment. However, with the onset of warm summer temperatures, disease progressed rapidly in all treatments, resulting in virtually 100% disease throughout the plot after 15 months.

After two field experiments, it is clear that no treatment provides effective control of Fusarium wilt for carnations grown in ground beds. Indeed, since the conversion to hot gas application techniques that became necessary in 1995 methyl bromide itself is no longer effective in providing more than 6-12 months protection. (Before 1995, most flower producers hired commercial methyl bromide applicators to shank-inject and tarp methyl bromide with tractor driven rigs. This method apparently was highly effective but there were concerns about the safety of the application method to the tractor driver. As a result, in 1995 greenhouse applications were restricted to only a “hot gas” application method. In this method, methyl bromide is heated outside the greenhouse and distributed with manifolds and tubing under the plastic tarps that cover the treatment area).

Control of Fusarium wilt in carnation with soil steaming and raised beds

Experiments were conducted on methods to effectively steam-treat raised production beds. This work has included evaluation of steaming duration, manifold number and placement, effects of soil moisture, effects of the presence of soil clods, and methods to prevent or slow re-colonization of steamed beds. There has been success in eliminating pathogens from raised beds with steam treatments. The solution to Fusarium wilt control lies in conversion to raised beds and steam sterilization.

Soil solarization and enhancement along the cool California coast

Soil solarization has been used to control weeds, soil inhabiting pathogens, and some nematodes in the inland valleys of California where high solar radiation and air temperatures provide the needed heating to make it effective. The cool coastal locations of the floriculture industry limit the use of solarization as an alternative to methyl bromide fumigation. The purpose of several experiments over the last two years was to evaluate the effectiveness of solarization treatments alone and supplement those treatments to enhance their effectiveness in the cooler region of the central California coast.

Three coastal experimental sites were established, one of them along the immediate coast within a couple hundred yards of the surf. The fields were cultivated and normal bed widths were formed. In most experiments, calla bulbs were placed in the soil to determine the herbicidal effect on the bulbs and the effectiveness of the treatments on diseases that the bulbs apparently carried. The standard solarization treatment consisted of a single layer of clear polyethylene tarp (Climagro 1.1 mil) placed over a moist bed for 4 or 6 weeks. Weed control was evaluated 4 or 6 weeks after solarization started. After 4 or 6 weeks, weeds were removed and counted within a 0.25^{2} quadrat, dried and weighed. Temperatures were monitored at 5 and 15-cm depths in solarized and untreated plots.

Other treatments consisted of (1) composted chicken manure (8T/A) spaded into the bed to 3 inch depth, with or without solarization, (2) corn gluten meal 20 to 40 lb/1000 ft^2 spaded into the bed to 3 inch depth, with or without solarization, (3) broccoli residue (5 dry T/A) with or without solarization, (4) acetic acid (5% vinegar, 300 gpa) applied into 1-inch holes, six inches deep, spaced about 6-inches apart and 6 weeks solarization (5) liquid ammonia (300 gpa) applied into 1-inch holes, six inches deep, spaced about 6-inches apart and 4 weeks solarization (6) metham 50 and 100 gpa applied into 1-inch holes, six inches deep, spaced about 6-inches apart, with or without solarization.

Preliminary data indicate that there were no treatments that effectively killed calla bulbs. Soil solarization significantly controlled most annual weeds, however, purslane was usually left not completely controlled. Solarized broccoli was the outstanding treatment in all 3 coastal areas. This treatment was just as effective as metham in the two experiments where they were compared.

Recent Weed Management Research in Asparagus

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Introduction

The asparagus industry in California has experienced a substantial increase in new-planted acreage over the past four years. When all of the new asparagus reaches the full cutting season stage, statewide acreage will be approximately 35,000 acres. The current value of the crop is nearly $130 million.

Because asparagus is a limited acreage specialty perennial crop, it is difficult to get promising new herbicides registered. Most of the existing herbicide choices available to producers are relatively old with the exception of Solicam (norflurazon), as a preemergence choice on established asparagus, and Poast (sethoxydim) and Fusilade (fluazifop) for postemergence grass control use. Concerns about the eventual fate of older preemergence herbicides like Karmex (diuron) or Lorox (linuron), a preemergence/postemergence material, due to regulatory scrutiny, the Food Quality Protection Act (FQPA), and commitment by chemical manufacturers to maintain specialty crop registrations, require an effort by researchers and growers to convince companies to include asparagus (or other vegetable commodities) in their product development programs for registration of promising new herbicides. This becomes increasingly important for the control of perennial weed species like yellow nutsedge (*Cyperus esculentus*), field bindweed (*Convolulus arvensis*), bermudagrass (*Cynodon dactylon*), Johnsongrass (*Sorghum halepense*) and more recently introduced problems like velvetleaf (*Abutilon theophrasti*), hoary cress (*Cardaria* spp.) and perennial pepperweed (*Lepidium latifolium*).

Methods

Over the past two years, two preemergence and three postemergence weed management trials have been conducted on asparagus in San Joaquin County, evaluating both new and old herbicides for weed control efficacy and crop safety. Preemergence chemicals evaluated included Karmex, Devrinol (napropamide), Aim (carfentrazone), Authority (sulfentrazone), Visor (thiazopyr), Goal (oxyfluorfen), Prowl (pendimethalin), Permit (halosulfuron), Frontier (dimethanamid), Milestone (azafenidin) and Valor (flumioxazin). The postemergence herbicides evaluated included Lorox (linuron), Sencor (metribuzin), Stinger (clopyralid), Permit and Shadeout (rimsulfuron).

Both preemergence trials and two of the postemergence trials involved treatment of newly planted one-year-old asparagus crowns. The third postemergence trial involved different rates of Permit plus X-77 spreader as directed sprays in post cutting season, fern stage asparagus for the control of yellow nutsedge.

All treatments were applied with a handheld CO_2 backpack sprayer using 8002 nozzles at 40 psi in a spray volume of 30 gal/A water. The plot design of all trials was a randomized complete block with four replications. The asparagus cultivar involved in all trials was $UC157_{F1}$. All rates of applied herbicides are expressed as lb/A a.i. (active ingredient).

Results

A pre/postemergence weed control trial at Victoria Island Farms, west of Stockton, CA, on newly planted one year old crowns was established on March 19, 1998. All treatments were soil incorporated by winter rainfall. Postemergence treatments of Permit plus crop oil concentrate were made on April 27, 1998. The soil type at the trial site was an Egbert muck. Best preemergence control of the weeds present – common lambsquarters (*Chenopodium album*), London rocket (*Sisymbrium irio*), prickly lettuce (*Lactuca aerriola*), redroot pigweed (*Amaranthus retroflexus*), prostrate knotweed (*Polygonum aviclare*) and barnyardgrass (*Echinochloa crus-galli*) occurred with a combination of Karmex (2 lb/A) plus Prowl (4.00 lb/A) followed by Prowl (4.00 lb/A) alone, and Milestone at 1.00 lb/A alone. All treatments demonstrated excellent crop safety. The postemergence treatments of Permit at 0.065 lb/A plus ½% crop oil concentrate alone or over the earlier preemergence Permit treatment (0.083 lb/A) provided good control of prickly lettuce and redroot pigweed but was somewhat weak on prostrate knotweed, common lambsquarters and barnyardgrass. Safety to the 14 to 20 inch tall crop fern was excellent.

A postemergence weed control trial on 14 to 20 inch tall newly planted asparagus fern was established at Victoria Island Farms on April 27, 1998. All applications were applied over the crop fern and the weeds present – first true leaf to 6 inch tall common lambsquarters, 4 to 8 inch tall London rocket, 3 to 5 inch tall prickly lettuce, 2 to 3 inch tall redroot pigweed, 2 to 14 inch diameter prostrate knotweed and 1 to 3 inch tall barnyardgrass. Best weed control occurred with a 1.00 lb/A rate of Sencor, followed by a 0.50 lb/A rate of Sencor and a 1.00 lb/A rate of Lorox. All trial treatments were weak in controlling prostrate knotweed and barnyardgrass. Permit at 0.031 lb/A or 0.065 lb/A plus ¼% X-77 spreader was additionally weak on common lambsquarters but was very effective in controlling a very limited population of 4 to 5 true leaf yellow nutsedge in the trial. All treatments provided excellent safety to the crop fern.

A 1999 preemergence weed control trial, evaluating nine herbicides and/or combination treatments was established at Victoria Island Farms, west of Stockton, CA, on March 2, 1999. The soil type at the trial site was an Egbert muck and all of the treatments were soil incorporated with a combination of winter rainfall and sprinkler irrigation. Best weed control of the volunteer sunflower, swamp smartweed and common lambsquarters was attained by a 0.375 lb/A rate of Valor, followed by Permit (0.083 lb/A) and Milestone (0.50 lb/A). All other treatments were only partially effective on volunteer sunflower and the combination treatment of Karmex (2.00 lb/A) plus Devrinol (2.00 lb/A) only provided marginal control of swamp smartweed. None of the treatments caused injury to the crop, although there appeared to be a very slight slow down in asparagus crop growth with the combination treatment of Visor (1.00 lb/A) plus Goal (0.25 lb/A).

A postemergence weed control trial, evaluating five herbicides on newly planted one year old asparagus crowns, was established at Victoria Island Farms on April 12, 1999, west of Stockton, CA. The soil type at the trial site was an Egbert muck. All treatments were applied over the 6 to 18 inch tall crop fern and the weeds present – first true leaf to 14 inch tall volunteer sunflower, second true leaf to 6 inch tall swamp smartweed, 2 to 5 inch tall common lambsquarters, 3 to 6 inch rosette prostrate knotweed and a limited population of 4 to 6 inch rosette curly dock. Best weed control of all weed species present was obtained with Sencor at 1.00 lb/A. Lorox (1.00 lb/A) plus ½% crop oil concentrate was weak on prostrate knotweed and swamp smartweed, with only partial activity on volunteer sunflower. Stinger at 0.25 lb/A only effectively controlled volunteer sunflower. Permit at 0.065 lb/A plus ½% crop oil concentrate was weak on prostrate knotweed and swamp smartweed with only fair activity on common lambsquarters. Shadeout at 0.065 lb/A plus ½% crop oil concentrate was weak on prostrate knotweed with only partial control on common lambsquarters, swamp smartweed and curly dock. Some fern phytotoxicity occurred with Stinger and Shadeout plus crop oil concentrate. All other treatments gave excellent crop safety.

A trial, designed to evaluate different rates of Permit plus ¼% X-77 spreader for the postemergence control of yellow nutsedge, was established at Marca Bella Farms near Tracy, CA on July 14, 1999. The soil type at the trial site was a Sacramento clay/Piper sandy loam mix. The treatments were applied over 4 to 9 true leaf (4 to 18 inches tall) yellow nutsedge but directed to the base of the post-cutting season 6 foot tall asparagus fern. All rates (0.023 – 0.065 lb/A) of Permit plus X-77 spreader gave good to excellent control/suppression of yellow nutsedge if the weed stage of growth was less than 6 inches tall. Greater than 6 inches tall, best suppression/control occurred with the high rate (0.065 lb/A) of Permit plus X-77. Another application of all rates was not conducted due to an inadvertent cultivation of the trial site just prior to the treatment date. All of the single application treatments showed excellent safety to the crop.

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New Herbicides for Vegetables

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Introduction

A number of issues pose threats to the existing vegetable herbicides, among them the Food Quality Protection Act, the Clean Air Act as well as the withdrawal of herbicides by the manufacturers. Clearly the loss of any herbicide would have severe repercussions to vegetable weed management programs. There are several strategies for dealing with the potential loss of herbicides in vegetables:

1. Search for new replacement herbicides.
2. Develop integrated weed management strategies to "protect" existing vegetable herbicides. These strategies would utilize chemical and nonchemical weed control tools as well as knowledge of weed biology to make the best use of existing vegetable herbicides.
3. Develop herbicide resistant vegetables.

Of course to create the greatest number of options we should consider all three strategies. However all strategies do have major limitations. This presentation will focus on strategy no. 1. There are severe limitations to this strategy, among them the small number of herbicides old or new that fit the very narrow set of criteria necessary for a vegetable herbicide. The objective of the research discussed here is to search for vegetable herbicide tolerance in a pool of new low-risk herbicides.

Materials and methods

Broccoli, cantaloupe, carrot, lettuce, onion, spinach, and tomato were screened for tolerance to low-rate herbicides at four locations in California. Preemergence rates tested at all locations were: carfentrazone at 0.05, 0.1, 0.15 and 0.2, dimethenamid at 0.94 and 1.2, fluamide at 0.525, 0.6, and 0.675, flumioxazin at 0.0625, 0.125 and 0.25, halosulfuron at 0.032 and 0.047, isoxaben at 0.25 and 0.5, rimsulfuron at 0.0156 and 0.0313, and sulfentrazone at 0.15 and 0.25 lb ai/A. Postemergence rates tested at all locations were: carfentrazone at 0.01 and 0.03, cloransulam at 0.0078 and 0.0156, dimethenamid at 1.5, halosulfuron at 0.032 and 0.047, imazamox at 0.032 and 0.04, rimsulfuron at 0.0313, sulfentrazone at 0.15 and 0.25, and triflusulfuron at 0.0156 and 0.0313 lb ai/A. Tests were conducted at the University of California, Coachella Valley Agricultural Research Station at Indio, CA, the University of California, Davis, Vegetable Crops Unit at Davis, CA, the USDA Station at Brawley, CA and the USDA Station at Salinas, CA. Stand counts, crop phytotoxicity estimates and crop biomass were taken at all sites.

Results

Preemergence. Broccoli and carrot were not tolerant to any of the herbicides tested. Cantaloupe was tolerant of halosulfuron at 0.032, while lettuce was tolerant to carfentrazone at 0.05 and 0.1 lb ai/A. Onion injury resulting from carfentrazone at 0.05 lb ai/A was acceptable. Treatment with carfentrazone at 0.05, dimethenamid at 0.94, and fluamide at 0.525, 0.6 and 0.675 lb ai/A all resulted in acceptable levels of spinach injury. Tomato was tolerant to carfentrazone at 0.15, dimethenamid at 0.94, and halosulfuron at 0.032 and 0.047 lb ai/A. All combinations not previously mentioned resulted in unacceptable crop injury

Postemergence. Broccoli, carrot and onion were not tolerant to any of the herbicides tested. Herbicides with acceptable tolerance in cantaloupe were: halosulfuron at 0.04 and rimsulfuron at 0.031 lb ai/A. Lettuce was tolerant to imazamox at 0.032 and 0.04 lb ai/A. Spinach treated with cloransulam at 0.008 and 0.016 and dimethenamid at 1.5 lb ai/A resulted in acceptable levels of injury. Processing tomato was tolerant to halosulfuron at 0.032 lb ai/A. All combinations not previously mentioned resulted in unacceptable crop injury.

Discussion

Constraints to the development of new vegetable herbicides. There are a number of constraints to the development of new vegetable herbicides: (1) the small potential market, (2) the high liability exposure for manufacturers, (3) complex crop rotation sequences. Given the large acreages of the major crops and the small acreages of vegetable crops, there is very little incentive for private industry to focus efforts on developing new vegetable herbicides. Furthermore, the high value of vegetable crops means that by selling herbicides into these crops an agricultural chemical company is exposed to high liabilities. For example the average acre of soybean in 1998 was worth $208 and the average acre of lettuce was worth $5,300 (Anonymous, 1999). To sell a soybean herbicide at $20/A and a lettuce herbicide at $50/A the manufacturer would be exposed to sales: liability ratios of approximately 10:1 and 100:1 for soybean and lettuce, respectively. These strong disincentives for herbicide manufacturers is exactly the reason that the IR-4 program exists, that is to facilitate minor crop registrations.

Physical limits to the number of new vegetable herbicides. A chemical company might screen 80,000 compounds to find one compound that is eventually sold on the marketplace (Lichtner, 1999). In the research reported above, 11 registered herbicides were screened for vegetable herbicide tolerance. This means that approximately 880,000 compounds were screened originally to find these 11 herbicides. For example, in cantaloupe we found tolerance in 2 out of 11 compounds screened. This means that about 440,000 compounds must be screened to find one cantaloupe herbicide. By similar reasoning about 880,000 compounds must be screened to find one lettuce, onion or spinach herbicide, 440,000 compounds must be screened to find one tomato herbicide, and more than 880,000 compounds must be screened to find a broccoli or carrot herbicide. The total number of chemical companies has been steadily declining in recent years. Does this mean that the total number of potential vegetable herbicides screened annually is also declining?

Conclusion

1. Screening for herbicide tolerance in vegetables is a long-term project with a low rate of success. It will take at least 10-15 years to find replacements for existing vegetable herbicides.
2. The existing vegetable herbicides that we have are extremely valuable tools. We need to use them judiciously, and do everything we can to protect them. Integrated methods of weed control appear to be the best approach. For example, by understanding the biology of our weeds, making optimal use of mechanical cultivation, and adjusting our herbicide rates and choices according to expected weed pressures, we may be able to limit some of our herbicide use in vegetables. A great deal more research must go into this approach.
3. The development of herbicide resistant vegetables may be the most rapid method to increase the number of herbicide options available in vegetables. We should consider this option.

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Weed Control in Tomatoes with ShadeOut®: A Progress Report

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The relatively recent registration of tomato herbicide, rimsulfuron (ShadeOut®), adds flexibility to the weed management program in tomatoes. Applied as a post plant/pre emergent herbicide, a timely rainfall or sprinkler irrigation is required for incorporation. Weed control as well as crop safety has been the most consistent with the pre emergent-timed application.

Post emergent applications have been attractive either as a follow up treatment or as the primary timed application. Reduction in nightshade infestation has been achieved. Research to improve nightshade control as a post-emergent application has been a target of recent efforts.

In a field test in the Dixon area of the Sacramento Valley, ShadeOut was combined with various oils as a post emergent application. Time of application was either at the cotyledon or the 2-true leaf, growth stage of direct seeded tomatoes. The trial was in cooperation with area growers, Timothy and Viguie Farms, in a commercial field of variety BOS 351 on double seed lines per bed. The rate of ShadeOut was 0.5 oz ai per acre in ~25 gallons of water per acre. The surfactants evaluated were Latron B 1956 at 0.25%, HerbiMax at 1%, Hasten at 0.25%, Tegopren at 0.125% or Activator 90 at 0.25%. The concentration of the surfactant was on a volume of surfactant to volume of water basis. The plot design was a randomized complete block with 3 replications.

Tomato seedlings and weeds, primarily hairy nightshade, were evaluated for crop vigor and weed control at various dates after spraying. To evaluate influence on seedling growth due to application timing, a selection of every 5^{th} plant for a plot total of 20 plants were removed from the Activator 90 treatments. We compared the grower pre-emergent application to our non-treated control, and the two seedling growth stage applications. All plots were hand weeded during a normal growth stage for the operation. Time of weeding was recorded and calculated on a cost per acre basis. Near the time of commercial harvest, the central 10' of the original 30' long plots were hand harvested for yield measurement.

In this test, hairy nightshade control increased with application timing at cotyledon stage over 2 true leaf timing, 8.5 vs. 7.3. Surfactants increased weed control when combined with ShadeOut compared to ShadeOut alone, 8.3 vs. 5.3. Tomato vigor was reduced when ShadeOut was combined with a surfactant, 9.8 vs. 8.9, but was affected less at the cotyledon growth stage as compared to the 2 true leaf growth stage, 9.8 vs. 8.3. Hand weeding expenses reflect the weed control benefits well with a reduction in hand weeding expense from $145 to $41 per acre when ShadeOut was applied. Differences in plant vigor were temporary and did not affect yields. Earlier timed application at the cotyledon stage also resulted in a higher yield than the later application at the 2 true leaf stage, 48.3 vs. 46 tons.

Seedling growth was comparable to the non-treated control when ShadeOut was applied as a pre-emergent. Cotyledon stage application was less injurious to seedling growth as compared to a 2 true leaf stage application.

In other field tests by UC advisors and specialists, Bob Mullen in several San Joaquin County-located field trials demonstrated that multiple applications of ShadeOut beginning with 0.25 oz ai at 1st true leaf and followed with 0.5 oz ai within 1 week provided good nightshade control. Efficacy was best with Activator 90 and Hasten while Quad 7 resulted in the lowest fruit yield. In a larger field test, Activator 90 and Silwet L-77 caused the most leaf chlorosis while Hasten appeared to be the safest. Bob's work with nutsedge control indicates that while ShadeOut has activity on sedge, other newer materials are better.

Kurt Hembree in Fresno evaluated influence of irrigation timing following ShadeOut applications as a post planting/pre-emergent treatment. In evaluations of surfactants, there were no weed control differences amongst oils tested, no significant crop injury, and no influence on yield.

Jesus Valencia in Stanislaus continues to evaluate oils and has been able to control larger seedling nightshade in his work with ShadeOut.

Tom Lanini demonstrates that ShadeOut has activity on dodder, but multiple applications as well as higher rates are required to achieve partial, temporary reduction in dodder growth. Tom and Kurt Hembree's work demonstrates that resistant varieties are superior choices for dodder management.

Past work by Mike Cahn in Sutter Basin has been consistent in achieving better nightshade control with post emergent applications compared to pre-emergent in the clay soils in his area.

Check with these advisors for more specific information.

In summary, in the one Dixon-located trial in 1999, weed control as well as crop safety was better when applied at the cotyledon growth stage as compared to the labeled 2-true leaf stage for post emergent treatments. Surfactants with ShadeOut increased weed control, while slightly increasing crop injury. Injury appeared to be temporary. It was not clear in the Dixon trial evaluation which oils were the best and which should be avoided.

Potential Replacements for Dacthal in Onions

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Background

Controlling weeds in onions is difficult for the following reasons: 1) the crop is not competitive with weeds; 2) planting configurations used do not allow for efficient use of cultivation on the bed top; and 3) the growing season for onions frequently spans the season for winter and summer growing weeds. To further aggravate the situation, hand weeding costs for onions can be extremely expensive because of the high density plantings that are used (i.e. 180-220,000+ seed per acre) and numerous seedlines per bed (i.e. 4-6). As a result of this situation, growers have come to rely upon a preemergence herbicide program to help control the initial flush of weeds that compete early in the cropping cycle. Preemergence herbicides that are available for use on onions include Dacthal, while Prefar is only available for use on dry bulb onions. For postemergence use, there are several options such as Buctril, Goal, Prowl, topical applications of liquid fertilizers, as well as grass herbicides such as Fusilade, Poast and Prism. There are limitations on the growth stage that various postemergence materials can be applied to onions, which limits their ability to control the early weed flush; This underscores the need for an effective preemergence program in onions to maintain yields and keep hand weeding costs in check.

Alternative Preemergence Options Evaluated

Carfentrazone is an aryl triazinone that is used under the trade names Affinity and Shark. It is used as a post emergence material in corn, rice and cereals. In large scale screening trials of potential new herbicides conducted by Dr. Steve Fennimore and others, it was shown to be tolerant on onions. When used preemergence it burns the tissue of plants as they emerge through the soil. Onions can tolerate some of this type of injury because the flag leaf protects the emerging first true leaf. The selection of soil type that this material is used on is critical because on an extremely light soil it was not safe at any rate, however on a soil with only slightly higher clay and organic matter content, it provided excellent safety to onions (table 1). Carfentrazone showed good crop safety at 0.075 lb a.i./A on a wide range of soil types. At 0.10 lb a.i./A significant yield loss was seen only at the site referred to in table 1. However, at 0.015 lb a.i./A, significant yield loss was also observed at one site. More investigations are needed to further evaluate the safety of carfentrazone at the 0.10 lb a.i./A rate on various soil types. This is the rate that provides significant weed control, but more data on its safety at this rate needs to be developed. It is particularly effective on shepherd's purse, which is not controlled by Dacthal and has activity on several other weed species (see table 2).

Prowl: Prowl is registered as a postemergence application on dry bulb onions at the 2-6 true leaf stage. We evaluated Prowl as a post plant, preemergence application on onions. Prowl can be safe on onions if used preemergence, however the rate, soil type and planting depth of the onions all factor into the level of safety that is achieved. We evaluated the following rates of Prowl this year on our trials on green and dry bulb onions: 0.25, 0.50 and 0.75 lb a.i./A. It appears that the 0.75 lb a.i. rate is probably too high to give good safety to the onions (see table 3). The 0.50 lb a.i./A rate was safe at all sites except at the sandiest site, and the 0.25 lb a.i. rate was safe at all five sites evaluated. The other key factor that affects the safety of Prowl when used preemergence on onions is the depth of planting. In one trial we observed that onion seed needs to be placed a minimum of 0.5 inch deep to maintain an adequate stand (see table 4). Prowl is a preemergence option that growers could turn towards rapidly because it is already labeled on the crop, however the issue of liability remains to be resolved.

Preemergence Flaming: In one trial, there was some evidence that preemergence flaming followed by a topical application of AN 20 fertilizer to burn weeds postemergence reduced the number of purslane and sow thistle (data not shown). This technique may have some promise in situations where there is a good amount of days (i.e. 5-10 days) prior to emergence of the onions. This allows a large number of weeds to emerge, which can then be killed by flaming. The weeds that emerge subsequent to this flaming application tend to be smaller and more susceptible to postemergence applications of herbicides or fertilizers one month later when the onion plants are at the first true leaf stage.

Alternative Techniques: Postemergence flaming of onions and corn gluten meal were evaluated in one trial. Corn Gluten provided moderate control of groundsel, but was weak on many other key weeds. Postemergence flaming of onions at the 1st and 2nd true leaf stages reduce onions yield by over 45% (see table 5)

Table 1. Affect of soil characteristics from two sites on crop safety of carfentrazone.

Onions	Sand	Silt	Clay	Organic Matter	Crop Safety
Dry Bulb Onions	83	11	6	0.46	None
Green Onions	64	23	12	0.73	“Safe”

Table 2. Green onion trial. Number of weeds from 13 sq ft of row – July 23.

Material	Rate a.i./A	Material/ A	Shep. Purse	Nettle	Pig-weed	Purs-lane	Lambs quarter
Untreated	----	----	34.5	2.3	3.8	1.0	5.0
Carfentrazone 40DF	0.05	0.125 lb	13.5	2.5	2.3	0.0	2.3
Carfentrazone 40 DF	0.75	0.187 lb	3.0	1.5	1.0	0.3	1.3
Carfentrazone 40 DF	0.10	0.250 lb	5.3	0.0	1.3	0.0	1.3
Carfentrazone 40 DF	0.15	0.375 lb	0.8	0.0	0.0	0.0	0.3
Dacthal	8.00	10.65 lb	19.5	1.3	3.0	0.0	0.0
Prowl 3.3 EC	0.50	1.2 pt	13.3	3.8	0.3	0.3	1.3
Prowl 3.3 EC	0.75	1.8 pt	9.5	1.3	0.5	0.3	1.0
LSD(0.05)	----	----	13.1	2.7	2.4	0.6	2.3

Table 3. Standardized yield (percent of the untreated control) of bulb and green onions under various treatments.

Materials	Rate a.i./A	Bulb Onion Sand	Bulb Onion Loam	Bulb Onion Clay Loam	Green Onion Loam	Green Onion Clay Loam
Dacthal	8.00	90.1	104.9	101.9	102.2	90.4
Carfentrazone	0.05	14.4*	98.3	89.3	105.7	97.6
Carfentrazone	0.075	6.9*	95.8	97.7	104.5	102.3
Carfentrazone	0.10	1.6*	97.5	95.3	110.3	85.7
Carfentrazone	0.15	----	----	----	103.4	80.9*
Prowl	0.25	88.3	99.6	95.8	----	----
Prowl	0.50	65.7*	91.7	96.6	102.2	95.2
Prowl	0.75	----	----	----	87.3*	90.4

* - significant yield loss

Table 4. The effect of planting depth on the stand of onions treated with Prowl at 0, 0.50 and 0.75 lb a.i./A.

Material	Depth (Inches)	October 25	December 13
Over All Rates	0.12	208.8	151.1
Over All Rates	0.25	210.7	161.9
Over All Rates	0.50	205.8	203.1
LSD (0.05)	----	n.s.	17.4

Table 5. Number of weeds and phytotoxicity ratings of onions on April 9, 1999 and yield evaluations on September 23, 1999.

Material	Material/A or Stage	Groundsel	Phyto*	Number of bulbs	Weight of bulbs
Untreated	----	15.6	0.0	235.0	144.1
Corn Gluten	900 lbs	5.2	0.0	---	---
Corn Gluten	1350 lbs	5.6	0.0	156.3	123.2
Flame	1st true leaf	2.3	7.3	71.7	58.3
Flame	2nd true leaf	3.0	5.7	119.0	80.2
Flame	1&2 true leaf	0.0	8.9	44.0	46.1
LSD(0.05)	----	10.0	4.8	96.7	65.9

* 0 – no damage to crop to 10-crop dead.

Weed Control in Vegetable Seed Crops

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Vegetable seed production is a major industry in the Lower Sacramento Valley. The major crops grown are cucurbits (cucumbers, squash, watermelon, cantaloupes/mixed melons and pumpkins). Minor seed crops include onions, carrots and brassicas. Cucurbit and onion seed crops will be discussed here.

Cucurbit seed production & weed management

In 1998, there were an estimated 22,000-25,000 acres of cucurbit seed, with an on-farm value of over $40 million, produced in a five-county Lower Sacramento Valley area. The acreage was approximately 45 % cucumbers, 25 % watermelon, 20 % squash and the remainder mixed melons and pumpkins. Most of the production of cucumbers and squash is hybrids, while the mixed melons and watermelon are open pollinated. Grower returns are higher for hybrids than for open pollinated types. Cucurbits are relatively low-value crops, compared to other options, but the income is predictable and consistent. There is a tendency to under-utilize chemical inputs (including herbicides).

Some of the major issues facing the California vegetable seed industry include: cheap labor in emerging or third world countries. This is especially important for hybrid production of watermelon and mixed melons which, owing to their reproductive morphology, require large inputs of hand labor. The result has been the movement of hybrid watermelon and mixed melon seed production off-shore; a high dependence on exports. In some cases, world politics enter into the equation. Many of the mid-east countries (Iran, Iraq, etc.) were formerly important cucurbit seed customers, but US policies have negatively impacted these relationships; inadequate land availability to allow additional industry expansion in the Lower Sacramento Valley. Cucurbit seed fields require ½ mile + isolations from other varieties within the same genus, and that is becoming difficult to attain.

Important weed considerations in local cucurbit seed fields include: velvetleaf (*Abutilon theophrasti*), Wright groundcherry (*Physalis acutiflolia*), black nightshade (*Solanum nigrum*), pigweeds (*Amaranthus sp*), barnyardgrass (*Echinochloa crusgalli*) and field bindweed (*Convolvulus arvensis*).

There are limited cucurbit broadleaf herbicide options. Prefar®(Gowen) is the only preplant material currently registered. It may be applied either preplant incorporated or post-plant surface applied, followed by an irrigation within 36 hours. There are plant-back restrictions for many rotational crops that may impact the decision to use this material. Relevant weeds that are controlled include barnyardgrass, lambsquarters, purslane and pigweed. Curbit®(UAP) is registered for post-plant, pre-emergence applications. It must receive at least one-half inch of irrigation within two days following application to move it into the soil profile and activate the material. It also has a plant-back restriction for sugar beets that should be considered if this crop is in the rotational program. Curbit® controls johnsongrass (from seed), lambsquarters, pigweeds and purslane. The third broadleaf option is trifluralin. This product is applied as a directed spray, between plant rows, when the plants have at least 3-4 true-leaves. It is incorporated and treated soil is thrown around the base of plants. There is also a sugar beet plant-back restriction for trifluralin which needs to be considered. Additional plant-back restrictions for corn, sorghum or crops not listed on the label apply. Trifluralin controls annual bluegrass, barnyardgrass, johnsongrass (from seed), chickweed, lambsquarters, pigweed, purslane and Russian thistle.

Conversely, there are good herbicide options for grass control in cucurbits. Prefar® and Curbit® have already been discussed. Poast® is a third option, and is commonly used. However Poast® does not control annual bluegrass, so trifluralin may be required if this is a problem.

The picture for herbicidal broadleaf control in cucurbit crops is not good, and there are many important species that are not currently controlled. As noted in the above discussion, there is relief for pigweed. That leaves velvetleaf, groundcherry, nightshade and field bindweed as potential problems that will have to be controlled by non-herbicidal means. Some of these techniques include: pre-irrigations followed by cultivations to sprout and destroy weed seeds; rotating with other crops that receive greater herbicidal inputs and have low weed populations; post-emergence cultivations; hand hoeing, when the crop is normally thinned. Cucurbit seed crops are planted densely and almost always require a thinning crew to go through anyway; and, the use of a butane-powered flamer when the crop is mature and the foliage has died back. Because the crop is being grown for seed, and external cosmetics are unimportant, this technique is possible *after the fruit is mature*. It is unclear, however, how effective this is in killing the maturing weed seed.

Onion seed production and weed management

Onion seed production is a minor, but an important crop locally. It was grown on 1500-2000 acres in 1998, and had an estimated farm-gate value of $8 million. About 40 % short-day types, 40 % long-day types and 20 % intermediate-day types are produced in the area. This is a crop that costs a lot to produce, but has the potential for equally high returns. Consequently, growers will do whatever is necessary to maintain or enhance plant growth and seed yields, so chemical inputs are an accepted part of the program.

The major issues facing the Lower Sacramento Valley onion seed industry are: high germination requirements for seed delivered to contractors, and difficulty always attaining it. Minimum germination requirements are 85 %, or more, and if the delivered seed does not meet this criteria it is heavily re-cleaned until it does; high production costs and high risk. By the time the seed is delivered to the contractor, the grower may have in-excess of $3000 per acre invested. There are many disease or environmental factors that can injure or destroy onion seed crops and the risk is very high; a very labor-intensive crop that has needs for large numbers of laborers for intermittent periods. The Lower Sacramento Valley area does not have a large labor pool; disease management. There are two potentially-serious foliar diseases experienced locally.

They are Botrytus blast (*Botrytus squamosa*) and downy mildew (*Perinospora destructor*). Downy mildew is the worst of the two, and under conditions favorable for the disease, can cause severe damage and seed yield reductions; and, weed management. Onions are planted in August-October and harvested in July. Therefore, they experience summer and winter annual, biennial and perennial weeds. Add to that the recognized limitations onions have competing with most weeds, and you have the formula for disaster. Many fields have been “walked-away” from for out-of-control weeds.

Important weeds in local onion seed fields include: field bindweed, burclover (*Medicago polymorpha*), yellow starthistle (*Centaurea solstitialis*), purslane (*Portulaca oleracea*), black nightshade, barnyardgrass, shephardspurse (*Capsella bursa-pastoris*) and annual bluegrass (*Poa annua*).

Although Dacthal® is still available, if you inventoried it or are fortunate enough to find some on the market, eventually stocks will be depleted unless someone starts manufacturing it again. In the absence of this important tool, the only current preplant material available is Prefar®. While there are clearly situations where the use of this material should be considered, it will not control many of the important weeds. There is some preplant use of metham sodium for early-season weed control.

While, on the surface, there appear to be a number of post-emergence broadleaf materials available, they have some serious usage restrictions that leave a 6-8 week vulnerable period from seeding to at least the 2nd true-leaf stage. Goal®(Rohm & Haas) is an effective contact material that *usually* only mildly damages the onions, but it can not be used until the 2nd true-leaf stage. Under common cool, wet weather conditions, crop injury may be severe and applications should be delayed until the plants are larger. Goal® controls black nightshade, pigweed, purslane and shephardspurse. Buctril®(Rhone-Poulenc) is another contact option, but also can not be used until the 2nd-5th true-leaf stage. Additionally, it must be applied in 50 or more gallons of water per acre or injury may result. It also is impacted by weather conditions, and prolonged fog causes serious onion injury. Buctril® controls black nightshade, lambsquarters and shephardspurse, and suppresses pigweed, velvetleaf and yellow starthistle. Prowl®(American Cyanamide) is a third selective post-emergence option, but can not be applied until the 2nd-6th true-leaf. Irrigation or rainfall within a week is needed to incorporate/activate the material. The same cautions about use under cool, wet weather apply to Prowl®. Prowl® can control barnyardgrass, lambsquarters, pigweed, purslane and velvetleaf. The grass spectrum is well-covered by Poast®, Fusilade®(Zeneca) and Prism (Valent). Poast® is most commonly used, but does not control the annual bluegrass that Prism® picks-up.

So the herbicidal control picture is a mixed-bag: There are post-emergence materials that will control most of the serious weeds, but there is a 6-8 week gap in control and post-emergence applications may be negatively impacted by weather conditions common in the area during the desired spraying time. Both of these factors create the need for additional, non-herbicide control measures. These include: pre-irrigations and cultivations. It is common to pre-irrigate and cultivate up to three times before planting, to germinate and destroy weed seeds; hand-hoeings. One of these may be coupled with the thinning operation, but the other two are solely for that purpose; soil solarization. The use of soil solarization has been demonstrated to be a viable weed control options for onion seed production. The ground is fallow during the prime time of year for obtaining optimum results from solarization. High costs have been the primary factor holding this technology back. There is also the need to have effective post-emergence weed control with solarization; the use of foliar ammonium fertilizers. Concentrated ammonium fertilizers, such as ammonium sulfate, effectively control many common weeds in emerging and seedling onions. The onions waxy cuticle imparts selectivity. However, *ammonium fertilizers are not registered for use as pesticides in California*. If they are being used as foliar fertilizers, a side-benefit is enhanced weed control. Some of the more succulent weed species, such as purslane, are not effectively controlled with foliar fertilizers. There is also the need for a later-season control program, as foliar fertilizers may injure more mature onions.

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Simulated Drift of Herbicides on Grapes, Tomatoes, Cotton, and Sunflower

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A field study was established in 1999 on the Vegetable Crops Farm at Davis California to evaluate the effects of simulated drift of clopyralid, 2,4-D, triclopyr ester, triclopyr amine, glyphosate, and dicamba on grapes, processing tomatoes, cotton, and sunflower. Herbicides were applied at 0.1X of the common use rate in California and were treated at the two leaf stage (grapes treated when new shoots were 10 inches) or at flowering (Table 1). A nonionic surfactant was added to all treatments at 0.25% v/v. Treatments were applied with a backpack sprayer using 8001 nozzles, with a final spray volume of 10 to 12 gal/a.

Tomato injury was greatest from simulated drift of triclopyr ester at both treatment timings (Table 2). Seedling tomato plants were generally more sensitive to herbicide drift, however, flowering tomatoes suffered more injury from dicamba. Treatment timing did not statistically influence yield, with the exception of dicamba. Dicamba caused flower abortion and severely reduced plant vigor when applied at flowering, with a drastic drop in yield.

Simulated drift of 2,4-D onto cotton caused significant injury, particularly when applied at the two true leaf stage (Table 3). Dicamba and triclopyr ester caused less injury than 2,4-D at the seedling stage, but were equally injurious at the flowering stage. Clopyralid caused moderate injury to seedling cotton, but did not cause much visual injury to flowering cotton. Glyphosate seemed relatively safe to cotton at the rate applied. Cotton yields were not statistically affected by simulated drift to seedling cotton, except from the 2,4-D treatment. However, all drift treatments except glyphosate caused significant yield decreases when applied to flowering cotton, with 2,4-D, triclopyr ester and dicamba all causing over 80% yield reductions.

Sunflower plants were very sensitive to clopyralid, 2,4-D, or dicamba when applied to seedlings with two true leaves (Table 4). Triclopyr ester and glyphosate were moderately injurious to seedling sunflower and triclopyr amine caused only slight injury. Applications made at flowering did not appear visually to cause much injury. Sunflower yields were severely reduced by clopyralid, 2,4-D, and dicamba when drift occurred to seedlings. Triclopyr ester and glyphosate drift to seedlings reduced sunflower yields about 50%. When drift occurred on flowering plants, visual injury was minimal, however, 2,4-D, triclopyr ester and dicamba caused significant yield reductions. Clopyralid did not cause yield reductions when applied at the flowering stage, however, previous years work indicated the potential for yield reductions when drift occurred at flowering.

Only 2,4-D caused significant visual injury when applied to new shoots of grapes (Table 5), with the major symptom being misshapen leaves. However, when grapes were flowering, triclopyr ester, 2,4-D, and triclopyr amine all caused significant leaf burn. Dicamba also caused significant injury when applied to flowering grapes, but to a lesser degree. Grape yields responded similarly to the visual injury, with yields reduced moderately by seedling drift from

2,4-D, triclopyr ester, and triclopyr amine. However, yields were wiped out by these same treatments when drift occurred at the flowering stage. Dicamba also caused significant yield loss when drift occurred at flowering. Clopyralid and glyphosate drift did not cause yield loss at either treatment time.

These results indicate that the effects of drift vary by crop species, timing of the drift, and the herbicide. In general, tomatoes, cotton, and grapes were less sensitive to yield reductions when drift occurred at two true leaves or when new shoots were forming, while sunflower was most sensitive at the two true leaf stage. The ester form of triclopyr was much more injurious than the amine form, which is probably related to greater absorption. When sensitive crop plants are close to treated areas, take extra precautions to avoid drift, as even small amounts of herbicide can cause large yield reductions.

Table 1. Treatment information for the simulated drift study.

Herbicide	Rate (lbs/a)
Clopyralid	0.025
2,4-D	0.10
Triclopyr ester	0.10
Triclopyr amine	0.10
Glyphosate	0.10
Dicamba	0.10

Treatment dates and phenology

Grapes
April 21,1999 – New shoots about 6 to 12 inches and leaves expanding
June 3, 1999 – Flowering

Tomato
June 28, 1999 – Two true leaves
July 30, 1999 – Flowering

Cotton
June 29, 1999 – Two true leaves
July 30, 1999 – Flowering

Sunflower
May 27, 1999 – Two true leaves
June 28, 1999 – Flowering

Table 2. Tomato injury (%) on August 15, 1999 and yield (% of control) in response to simulated herbicide drift at two true leaves or at flowering.

Treatment	Injury %	Yield % of untreated
Two true leaf		
Clopyralid	2.5	79.7
2,4-D	35.0	78.6
Triclopyr ester	60.0	38.6
Triclopyr amine	27.5	55.5
Glyphosate	36.2	55.2
Dicamba	12.5	110.1
Untreated	0.0	100.0
Flowering		
Clopyralid	28.8	71.8
2,4-D	16.2	69.9
Triclopyr ester	47.5	27.2
Triclopyr amine	25.0	80.0
Glyphosate	28.8	54.5
Dicamba	47.5	33.8
Untreated	**0.0**	**100.0**
LSD .05	22.1	37.8

Table 3. Cotton injury (%) on August 15, 1999 and yield (% of control) in response to simulated herbicide drift at two true leaves or at flowering.

Treatment	Injury %	Yield % of untreated
Two true leaf		
Clopyralid	25.0	67.2
2,4-D	95.0	17.7
Triclopyr ester	42.5	82.2
Triclopyr amine	23.8	114.8
Glyphosate	8.8	116.1
Dicamba	36.2	68.8
Untreated	0.0	100.0
Flowering		
Clopyralid	3.8	56.2
2,4-D	38.8	5.5
Triclopyr ester	33.8	19.2
Triclopyr amine	17.5	41.2
Glyphosate	5.0	107.8
Dicamba	38.8	13.6
Untreated	**0.0**	**100.0**
LSD .05	12.7	42.8

Table 4. Sunflower injury (%) on August 15, 1999 and yield (% of control) in response to simulated herbicide drift at two true leaves or at flowering.

Treatment	Injury %	Yield % of untreated
Two true leaf		
Clopyralid	77.5	4.6
2,4-D	73.8	17.7
Triclopyr ester	40.0	45.5
Triclopyr amine	15.0	97.3
Glyphosate	32.5	53.0
Dicamba	87.5	2.0
Untreated	0.0	100.0
Flowering		
Clopyralid	8.8	87.0
2,4-D	11.2	56.1
Triclopyr ester	16.2	18.0
Triclopyr amine	6.2	27.6
Glyphosate	11.2	79.3
Dicamba	11.2	56.0
Untreated	**0.0**	**100.0**
LSD .05	12.0	32.0

Table 5. Grape injury (%) on August 9, 1999 and yield (% of control) in response to simulated herbicide drift at two true leaves or at flowering.

Treatment	Injury %	Yield % of untreated
New Shoots		
Clopyralid	0.0	83.7
2,4-D	15.0	61.6
Triclopyr ester	3.3	47.3
Triclopyr amine	5.0	62.3
Glyphosate	0.0	110.0
Dicamba	3.0	88.3
Untreated	0.0	100.0
Flowering		
Clopyralid	3.3	82.3
2,4-D	66.7	5.4
Triclopyr ester	76.7	0.0
Triclopyr amine	56.7	0.0
Glyphosate	3.3	97.6
Dicamba	25.0	33.2
Untreated	**0.0**	**100.0**
LSD .05	14.7	37.3

Sugarbeet Weed Management Issues for the Different Planting Zones of California

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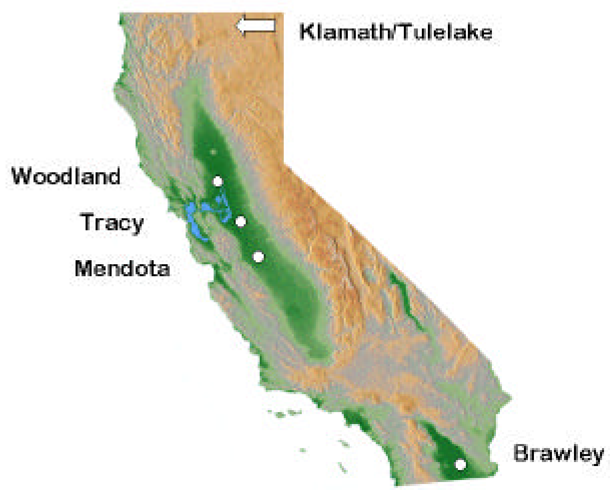
The sugarbeet industry in California has existed for over 100 years. The acreage has been at a low point in recent years due to disease problems, factory closure and general economics of growing the crop. The 2000 expected acreage is 108,000 acres for the growing areas surrounding the 4 remaining factories and the Klamath/Tulelake area. Weed control continues to be a major contributing factor in the economics of growing sugarbeets. Figure 1. indicates the location of the current growing areas and factories in California.

Figure 1.



For each of the three valley factories (Woodland, Tracy and Mendota), there are three planting/harvest periods. This is done to lengthen the harvest time and increase capacity for each factory. By using separate areas, a beet free area utilizing time and space is established to control the virus yellows complex of diseases that commonly occur in the central valley of California.

The Brawley factory area and the Klamath/Tulelake area are completely separate from this time of planting scheme as the climate controls the time of planting and harvest in each of these areas.

Table 1. Planting and harvest dates for the sugarbeet factories and growing areas in California.

Factory Area	Planting Dates	Harvest Dates
Woodland	Jan-Mar May-Jun	Aug-Sep Mar-Jun
Tracy	Oct-Jan Jan-Mar May-Jun	Jul-Aug Aug-Sep Mar-Jun
Mendota	Oct-Jan Jan-Mar May-Jun	Jul-Aug Aug-Sep Mar-Jun
Brawley	Sep-Oct	Apr-Jul
Klamath/Tulelake	Mar-May	Oct-Nov

Sugarbeet weed management can be viewed from two perspectives of the same issue. One common perspective is to group weed control practices by the weed spectrum, season and growing season. Another is by the timing and application method for the herbicide. The following are some of the conditions for each perspective:

Weed spectrum by season/growing conditions

- Winter/Summer annual weeds
- Cool/Warm temperatures at herbicide application
- Slow/Fast growing weeds and beets.

Timing and method of herbicide application

- Pre/Post emergence herbicides
- Foliar/soil absorption and incorporation of the herbicides

Each of the three planting times for the Central Valley planting areas have their own set of growing conditions that alter weed management strategies.

Fall Planting	**Winter-Spring Planting**	**Spring-Summer Planting**
•Oct-Jan planting dates •Cooling air and soil temperatures •Winter annual weeds •Slow growing beets and weeds •Possible wet soil conditions for weed control	•Jan-Mar planting dates •Cool-cold soil and air temps early •Warming as the Spring develops •Wet soil conditions a real problem •Winter annual weeds early •Summer annual weeds from layby on	•May-June planting dates •Warm to Hot air and soil conditions •Summer annual weeds •Weeds grow faster than beets •Hot temps are problem for contact herbicides

Weed management strategies that depend on the time and method of application are fairly specific for each herbicide registered for use in California. The following table is a list of the common herbicides and their use.

Preplant		Postplant		Layby
foliar	incorporated	Pre-emergence	Post-emergence	
Roundup Paraquat	Roneet Tillam Nortron Pyramin	Nortron Pyramin Roundup	Betanex Betenal Betamix B. Progress Upbeet Stinger H 273 Poast Prism	Eptam Treflan

New developments in sugarbeet weed management include the use of transgenic herbicide resistant varieties to Roundup and Liberty. This technology is referred to as Genetically Modified Organisms (GMOs) and has come under much scrutiny by the press and public opinion. In field-testing these products on the specific resistant varieties, either Roundup Ready or Liberty Link, there is a definite advantage in weed control and more importantly reduced crop injury by using this technology. The registration process is proceeding rapidly and clearance for use in California should be coming soon. The problem is that this technology is seemingly not accepted in the sugar marketplace. At this time, Holly Sugar, the owner of all of the factories in California has chosen not to accept any GMO sugarbeets because of a lack of acceptance by their sugar buyers.

An alternative to the GMO technology that is being tested is what is called the Ultra Low Rate (ULR) or Micro-rate technology. This technology uses Mentholated Seed Oil (MSO) as a additive to the standard post emergence herbicide mixture of Betamix Progress, Upbeet and Stinger. Because the MSO greatly increases herbicide penetration into the plants, greatly reduced rates are needed to avoid crop injury. Fortunately, weed control is generally good with the reduced rates and crop injury has been minimized. There are still label restrictions that prevent this usage in California, but it is registered in several states and gaining in popularity because it greatly reduces the cost of the application with less crop injury. One problem experienced in California testing is that the common rates used in the other states missed control of lambsquarter. Further testing to resolve this problem and a supplemental product label will be needed before this ULR technology will be available to California growers.

The Future of Small Grain Weed Control in a Historical Perspective

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In 1960, the only University of California recommended herbicide for small grains was 2,4-D. The 1999 recommendations list nine herbicides. In 1962, Barban was added for wild oat control in barley and wheat.

In the 1960's one of the most troublesome broad-leaved weeds not controlled by 2,4-D was amsinckia (fiddleneck). Trials in the 1960's showed the herbicide Bromoxynil was highly effective in controlling amsinckia and it was added to the University recommendations in the 1960's. The most recent addition to the University recommendations for broad-leaved weeds was Chlorsulfuron (Glean). This herbicide has not been widely used in California mainly due to its soil residual. Chlorsulfuron is widely used in some small grain growing areas of the U.S. (Kansas).

Barban found limited usage for wild oat control and often caused injury when used during cold, overcast weather conditions. The next wild oat herbicide recommended was Difenzoquat (Avenge). This herbicide found good acceptance and was widely used. Difenzoquat has a relatively wide application time, 3 to 5 leaf stage of wild oats, and can be mixed with most of the broad-leaved herbicides. Its main limitations are it is only effective on wild oats and some varieties are sensitive. The most recent recommended grass herbicide for wheat is Diclofop-methyl (Hoelon). This herbicide has activity on wild oats and is highly effective on Italian ryegrass, it has some activity on littleseed canarygrass. Crop injury has been an occasional problem with Diclofop-methyl (Hoelon) when used in cold (lower than 40°F) and prolonged wet weather. An increasingly troublesome grass which Diclofop-methyl (Hoelon) has little or no activity on when applied postemergence is Ripgut brome.

The results of a few trials conducted in Yolo County grower fields to assess weed control and yield increases in problem fields are:

Grower: Dettling
Year: 1978
Crop: Wheat
Predominate Weed: Wild Oats

Herbicide	% Wild Oat Control	Yield Increase Lbs/Acre
Difenzoquat (Avenge)	88	1570
Dicolofop-Methyl (Hoelon)	79	1615
L.S.D. @ 5%		1442

Grower:	Giguiere
Year:	1977
Crop:	Wheat
Predominate Weed:	Italian Ryegrass

Herbicide	% Ryegrass Control	Yield Increase Lbs/Acre
Dicolofop-Methyl (Hoelon)	97	1240

Grower:	Horgan & Abele
Year:	1985
Crop:	Wheat
Predominate Weed:	Wild Oats, Littleseed Canarygrass Italian Ryegrass

Herbicide	% Control			Yield Increase
	Wild Oats	Canarygrass	Ryegrass	Lbs/Acre
Diclofop-methyl (Hoelon)	98	85	100	1170
L.S.D. @ 5%				592

Three herbicides are currently being evaluated for grass control in wheat. They are Bayer MKH6561, Fenoxaprop + mefenpyr (Puma) and Imazamox (Raptor). Preliminary testing shows Bayer MKH6561 has good crop tolerance and has activity on wild oats, littleseed canarygrass and Ripgut brome. Soil carryover of Bayer MKH6561 is currently being evaluated. Fenoxaprop + mefenpyr (Puma) has good crop tolerance and has activity on wild oats and littleseed canarygrass. Tolerance to Imazamox (Raptor) was found in wheat. This tolerance can be transferred to other wheat varieties. Imazamox (Raptor) controls most grasses, including volunteer wheat of non-tolerant varieties, and many broad-leaved weeds. All three of these herbicides will be important additions for the future of small grain weed control.

The most widespread perennial weed in small grains is field bindweed (morning glory). A trial was conducted in the dryfarmed area of Yolo County to measure the yield difference for barley between a dense field bindweed area and where the field bindweed had been controlled. The barley yield was significantly increased in the controlled plots.

Grower:	Heidrick
Year:	1966
Crop:	Barley
Predominate Weed:	Field Bindweed

% Control of Field Bindweed	Yield Increase Lbs/Acre
90	490
L.S.D. @ 5%	482

Recent Developments in Alfalfa Weed Control

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There have not been any earth shattering revolutionary changes in alfalfa weed control over the past few years. Many of the standard herbicides programs used ten or more years ago are still used today. By in large these programs continue to be effective. There have, however, been some recent developments in the area of unique weed problems and situations—both successes and failures. This paper will briefly outline current weed control practices in alfalfa and then focus on some recent developments.

Standard Alfalfa Weed Control Programs

Seedling Alfalfa

While preemergence herbicides are available for use in alfalfa, most growers opt for postemergence control programs. This approach offers the flexibility of evaluating the weed population prior to treatment in order to select the most appropriate herbicide or combination of herbicides. The most commonly used herbicides on seedling alfalfa in California include imazethapyr (Pursuit), bromoxynil (Buctril), and 2,4-DB. Depending on the weed spectrum encountered and environmental conditions at the time of application, these herbicides are used alone or in combinations. Selective grass herbicides, sethoxydim (Poast) and clethodim (Prism), are used when grassy weeds or volunteer cereals are present. Overall, acceptable control of most weed species is achieved with these programs. The keys to successful results are selecting the proper herbicide for the weeds encountered and treating at the appropriate growth stage. More weed control failures in seedling alfalfa are probably related to treating too late than any other factor.

Established Alfalfa

Standard weed management practices in established alfalfa typically involve the use of a soil active herbicide [i.e., hexazinone (Velpar), diuron (Karmex), or in the case of far northern California metribuzin(Sencor)] applied alone or in combinations. Sometimes the contact herbicide paraquat (Gramoxone) is used alone (especially in the last year of an alfalfa stand) or is tank mixed with soil residual herbicide to broaden the weed spectrum controlled and to improve control of emerged weeds. These programs have proven effective and adequately control most winter annual weeds that infest the first cutting of alfalfa. Summer annual grasses are typically controlled with a preemergence application of trifluralin (Treflan) or with post emergence applications of selective grass herbicides (Poast or Prism).

Recent Developments

Weed Control in Seedling Alfalfa

There has been ongoing research with two relatively new herbicides that are useful in seedling alfalfa. Prism (clethodim) was the most recently registered herbicide for use in seedling alfalfa. It was registered earlier in some other crops so many growers and pest control advisors are already familiar with this herbicide. Its activity is very similar to that of Poast. Its strength is that it controls annual bluegrass, downy brome, and foxtail barley, weeds that are usually not adequately controlled with Poast. Research in San Joaquin County showed better than 90% control of annual bluegrass when Prism was applied alone or tank mixed with Buctril. Control of annual bluegrass declined to 86% when Prism was combined with Pursuit (Table 1). Prism is a useful tool for selective grass control, especially when the field contains the winter annual grasses mentioned above.

Raptor (imazamox) is a new herbicide related to Pursuit. It shows significant promise for weed control in seedling and possibly established alfalfa. It is not yet registered. Its activity is similar to Pursuit with three exceptions. It has the same effect at approximately half the rate of Pursuit, it has shorter soil residual, and in general it controls a broader spectrum of weeds. The primary advantage is that it controls both grass and broadleaf weeds. This is a major advantage, as the common currently registered postemergence herbicides control grassy weeds or broadleaf weeds but not both. Therefore, costly tank mixes are often required for complete weed control in seedling alfalfa. Tables 1 and 2 show the effectiveness of Raptor on annual bluegrass and volunteer cereals. Raptor has also been found to be more effective than Pursuit for the control of fiddleneck, but is less effective for the control of red maids. However, like Pursuit, it usually does not adequately control prickly lettuce, sowthistle, common groundsel, and lambsquarters and will likely have to be tank mixed with other herbicides for complete control if these weeds are present.

Weed Control in Established Alfalfa

The most recent addition to herbicides used in established alfalfa is Zorial. It has been used for years in orchards as Solicam. It is typically applied as a winter dormant application. Zorial has little activity on emerged weeds and therefore must be tank mixed with a herbicide with postemergence activity such as Gramoxone if weeds have emerged at the time of application. For winter weed control, Zorial offers little advantage over other soil active herbicides registered in alfalfa. The possible advantage for Zorial is the potential for residual control of summer weeds, primarily green and yellow foxtail and nutsedge. It would be very advantageous for alfalfa growers if season-long weed control could be achieved in a single herbicide application. Research has shown that Zorial does control yellow and green foxtail but not to the same degree and not as late into the season as does Treflan TR-10. Zorial also suppresses yellow nutsedge but the level of suppression diminishes as the season progresses (Table 3). Zorial is not likely to cause a major shift in alfalfa weed control programs but it may be useful where residual control of moderate to low summer weed populations is desired.

Postemergence Dodder Control

Dodder is a parasitic weed that infests alfalfa hay and seed fields. Dodder weakens the alfalfa plant; reducing yield and even causing stand loss. It is also more succulent than alfalfa and thus increases the length of time needed to sufficiently cure alfalfa. Dodder is especially troublesome in seed fields, as dodder seed closely resembles alfalfa seed. The presence of dodder seed in alfalfa seed is reason for rejection from certification.

Preemergence applications of trifluralin granules have gone a long way toward controlling this weed. However, oftentimes a dodder problem is not recognized until too late for a preemergence treatment. Also, even with a trifluralin application at the proper time there are enough dodder escapes that they must be controlled to prevent further seed production. Since the loss of dinoseb in the 1980's there have been no effective herbicides for the control of attached dodder. Several trials have been conducted since that time to find a suitable replacement for the control of attached dodder but none was found.

Recent research in San Joaquin County has demonstrated that Pursuit can effectively control dodder without perceptible injury to alfalfa. Pursuit did not completely eliminate dodder but the 0.094 pound active ingredient per acre rate suppressed dodder by approximately 90% thirty days after treatment and 80% fifty days after treatment (Table 4). More importantly, the Pursuit treatment in the field trials affected dodder growth sufficiently to prevent seed production. The key to long-term dodder management is to eliminate seed production to prevent future infestations. The manufacturers of Pursuit, American Cyanamid, have submitted for a supplemental label to include dodder suppression at the 0.094-pound active ingredient per acre rate.

Flaming for Winter Weed/Weevil Control

An increasing market for organically grown products and some pesticide restrictions (i.e., Bureau of Reclamation lease lands in Tulelake) has brought about an interest in non-chemical weed control practices in alfalfa. The use of flaming for weed control has received some attention in other crops and may have some merit in alfalfa. New more efficient flamers with shields to concentrate the heat may improve the effectiveness of this technique. It may be most cost effective in areas where the alfalfa goes dormant and, therefore, there is less plant biomass to combust. It has been proposed that flaming may have the added benefit of controlling alfalfa weevil. Flaming will destroy weevil eggs that were deposited in alfalfa stems prior to the time the field is flamed. Also, it may make the alfalfa field an inhospitable environment for returning weevil adults to mate and lay eggs. The effectiveness of flaming for weed and weevil control had not previously been evaluated under intermountain conditions.

A field trial demonstrated that flaming is partially effective for weed control (Table 5). However, flaming was not nearly as effective as a standard herbicide treatment. This was especially true for perennial weeds and grasses. Perennial weeds draw on their root reserves and recover from a foliar burn; the growing point for grasses is in the crown area and more protected than that of broadleaf plants. These results suggest that flaming is a viable means of reducing weed pressure, but if complete weed control is required, flaming is not a substitute for herbicides. Similarly, flaming did reduce the number of alfalfa weevil larvae per sweep, about half as larvae as untreated plots (Table 5). These results suggest that flaming may be an adequate control measure under low or moderate weevil populations but not under high pressure.

Table 1. Postemergence Weed Control in Seedling Alfalfa, Canevari, 1999.

Treatment*	Rate lbs ai/A	Shepherd's Purse 4/16	Chick-weed 4/16	Burning Nettle 4/16	Annual Bluegrass 3/17	Common Groundsel 4/16	Red Maids 4/16
Buctril 2E	0.25	72	0	0	3	86	0
Buctril 2E	0.375	81	0	0	3	95	0
Pursuit	0.094	98	83	85	47	17	100
Buctril + Pursuit	0.25 + 0.094	90	90	45	52	73	98
Buctril + Prism	0.25 + 0.1	67	0	0	93	90	0
Prism	0.1	0	0	0	95	0	0
Pursuit + Prism	0.094 + 0.1	95	84	82	86	17	100
Raptor	0.032	99	66	86	92	0	10
Raptor	0.04	97	75	78	96	0	17
Raptor	0.048	97	91	80	98	0	63
Untreated	--	0	0	0	0	0	0

* MSO @ 1 pt/A added to all treatments; UN-32 at 1% V/V added to imazamox treatments only.

Table 2. Postemergence Control of Broadleaf Weeds and Volunteer Cereals in Seedling Alfalfa, Orloff, 1998.

Treatment*	Rate lbs/A	Alfalfa Injury 10/10	Filaree		Shepherd's Purse		Barley		Fiddleneck	
			11/5	5/1	11/5	5/1	11/5	5/1	11/5	5/1
Raptor	.024	5	97	90	100	98	90	98	99	78
Raptor	.032	11	99	100	100	100	98	98	100	90
Raptor	.047	12	99	100	100	100	93	100	100	88
Pursuit	.063	5	91	80	96	88	46	38	92	65
Pursuit + Poast	.063 + .28	2	92	82	96	90	84	92	86	59
2,4 - DB + Poast	.75 + .28	1	66	85	88	98	98	98	51	50
Pursuit + Buctril + Poast	.063 + .5+ .28	14	94	85	96	100	80	88	94	71
2,4 - DB + Buctril + Poast	0. 5 + .25 + .28	35	25	15	70	68	98	98	64	50
Pursuit + Prism +	.063 + .1	6	92	80	89	95	92	75	86	70
Check		0	0	0	0	0	0	0	0	0

* Hasten and UN 32 added at 1 pint and 1 quart per acre, respectively. Aero Dyne-Amic at 0.5% added to treatments containing Poast or Prism.

Table 3. Nutsedge and Yellow Foxtail Control in Established Alfalfa, Canevari, 1998.

Treatment*	Rate lbs ai/A	Yellow Nutsedge Control			Yellow Foxtail
		5/4	6/30	7/31	7/1
Zorial 80 WG	2.0	47	33	33	67
Zorial 5 G	2.0	37	37	23	57
Zorial 5 G	1.0 + 1.0	50	40	35	52
Eptam 20 G	3.0 + 3.0	67	55	36	67
Untreated	--	0	0	13	0

*1st treatment: 3/4/98; 2nd treatment (for split applications): 6/22/98

Table 4. Post Attachment Control of Dodder in Alfalfa, Canvari 1999.

Treatment	Rate Lbs ai/A	% Dodder Control		Dodder length (in)	
		7/13	8/05	7/13	8/05
Untreated	--	0	0	18–34	7–14
Pursuit*	.047 + .047	83	92	1.7–4	0.7–1.7
Pursuit*	.063	82	62	1.7–3	5.5–8
Pursuit*	.094	94	79	0.4–1.8	1.7–4.7
Pursuit + Prowl	.094 + 4.0	98	88	0.25–0.5	2.7–5.7
Prowl	4.0	42	48	5.3–18	4.7–9.3
Pursuit + X-77	.094	92	81	0.5–1.5	3.3–5.3
Pursuit + COC	.094	93	81	0.5–1.5	2–3.3
Pursuit + Hasten	.094	93	78	0.5–0.8	3.3–7.3

* Hasten and UN 32 added at 1 quart and 2 quarts per acre, respectively.

Table 5. Comparison of Flaming and Herbicides for Weed and Weevil Control in Established Alfalfa, Orloff, 1998.

Treatment and Rate/A	Shepherd's Purse	Tansy Mustard	Kentucky Bluegrass	Weevil larvae/sweep
Flaming @ 11 gallons	51	59	37	38
Flaming @ 22 gallons	76	75	46	31
Sencor @ 0.5 lbs + Gramoxone @ 0.4 lbs	100	100	100	66
Untreated	7	17	0	68

Herbicide-resistance in *Echinochloa oryzoides* and *E. phyllopogon* in California Rice Fields

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Early watergrass (*Echinochloa oryzoides*) and late watergrass (*E. phyllopogon)* have become the most serious weeds in California *rice* since continuous flooding was used to suppress barnyardgrass *(E. crus-galli)*. Continuous use of a limited number of available graminicides and an increasing number of control failures led to the investigation of herbicide resistance in early watergrass and late watergrass. Greenhouse dose-response studies with POST applications of molinate (Ordram), thiobencarb (Bolero), fenoxaprop-ethyl (Whip), and bispyribac-sodium (Regiment) estimating GR_{50} (herbicide dose to inhibit growth by 50%) values suggested resistance to all herbicides in two late watergrass accessions, and to Ordram and Bolero in one early watergrass accession, when compared to susceptible late watergrass and early watergrass control accessions, respectively. No resistance was detected in dose-response studies with propanil. Minimum and maximum ratios (R/S) of the GR_{50} values of resistant to susceptible late watergrass plants (in two experiments involving two resistant accessions) were 7.8 and > 13.3 for Bolero, 2.2 and 4.3 for Ordram, 16.5 and 428.7 for Whip, and 2.0 and 12.0 for Regiment. Minimum and maximum early watergrass R/S ratios (average of two experiments) were 21.9 and 4.6 for Bolero and Ordram, respectively. Thus, early and late watergrass populations may have developed cross and/or multiple resistance. Cross-resistance occurs when a given weed biotype is resistant to different herbicides through a common mechanism, and usually refers to herbicides that share a common mechanism of action. Multiple resistance involves different herbicides and more than one resistance mechanism; this is usually the case of resistance to chemically unrelated herbicides with different mechanisms of action on the weed. A resistant late watergrass (one accession tested) and the susceptible control were killed by POST applications of glyphosate, glufosinate, and clomazone, and by a PRE application of pendimethalin. Thus, the repeated herbicide use patterns resulting from the restricted availability of grass herbicides, and the prevailing practice of continuous rice culture have led to the selection of early watergrass and late watergrass biotypes, with the capacity to survive treatment by different herbicides. Therefore, it is important that the control of these grasses be diversified by the full use of preventive, mechanical, and cultural practices aimed at eliminating the survival, seed production, and dispersal of plants that escape herbicide treatment. Herbicides will continue to be the key resource for weed control in rice, and the importance of avoiding the repeated use of herbicides with the same mode of action cannot be overemphasized. Alternating or mixing herbicides with different modes of action that are equally effective on the target weed should help delay the buildup of resistance. Decisions on alternative herbicides can become more difficult when resistance has already developed to more than one herbicide. In such cases non-chemical means of weed control, such as water management, must be optimized. Some of the fields with resistant watergrass appear in relative proximity, suggesting that dispersal of resistant seed may occur. It is important to prevent transporting resistant seed across fields with agricultural implements, particularly when equipment is shared among growers. It is advisable that the areas infested with herbicide resistant watergrass be harvested last, and the equipment cleaned before proceeding to a new location. Good weed control along irrigation canals is also very important. The possibility of having no tolerance for the presence of watergrass in certified rice seed should be explored. The availability of new herbicides, especially with different modes of action than the existing ones, will be essential to avoid the repeated use of the same chemicals, and thus to delay the buildup of herbicide resistance. Knowledge of herbicide modes of actions and patterns of herbicide resistance, through scouting and testing, will provide a rational basis for herbicide use. Propanil is an amide herbicide that inhibits electron transport at photosystem II, and can also inhibit RNA and protein synthesis, and affect plasmalemma function. Bolero and Ordram are thiocarbamate herbicides that affect lipid (very long-chain fatty acids) biosynthesis. Whip is an aryloxyphenoxy-propionate that inhibits Acetyl CoA carboxylase, and bispyribac is an ALS inhibitor like bensulfuron. Regiment is a new herbicide for which registration in rice is being pursued.

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Current and Future Grass Herbicides in Rice

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In the early 1990s, rice weed control in California was simple and heavily dependent on two primary products, molinate and bensulfuron-methyl (Table 1). Other grass materials included thiobencarb (Bolero, Abolish) and propanil in designated areas. By the end of the decade, the pattern of grass herbicide use grew more complex, driven in part by events affecting broadleaf materials. Widespread resistance to bensulfuron among several broadleaf and sedge species stimulated increased phenoxy herbicide use. Subsequently, drift onto cotton in the Sacramento Valley caused a dramatic reduction in use of MCPA and 2,4-D after 1997. Concurrently; thiobencarb and propanil use increased because they are effective on smallflower umbrellasedge.

Table 1. Percent of planted acreage treated with selected rice herbicides, 1993-98.

Year:	1993	1994	1995	1996	1997	1998
			% of planted acres			
phenoxies	23.6	26.9	32.5	54.0	57.7	16.2
bensulfuron	91.7	86.9	85.9	75.4	55.0	41.9
fenoxaprop	--	6.9	5.7	5.1	4.7	3.9
molinate	88.4	78.9	75.4	71.2	61.3	55.4
propanil	1.3	2.1	2.3	4.3	7.6	27.5
thiobencarb	14.9	18.9	27.3	31.7	43.9	38.7

Source: Department of Pesticide Regulation, Pesticide Use Reporting website.

Watergrass resistance to commonly used grass herbicides was first reported in California in 1996 and adds a new layer of complexity. Resistance to commonly-used herbicides was confirmed in approximately forty fields from 1996-98, with the probability of many more. Concurrent with identification of resistant grass biotypes, water soluble formulations of propanil, which have lower drift potential, came on the market. Because propanil controls several broadleaf and sedge weeds in addition to *Echinochloa* species, the rice industry has vigorously supported expanded usage. To manage drift until testing can elucidate the drift risk, most propanil applications have been restricted to ground rigs. Propanil is estimated to have been used on 35.7% of the planted acreage in 1999 (County spray permits, W. Steinke, personal communication). Fenoxyprop use began in 1994 and has been consistently used on approximately 5% of the acres, primarily as a cleanup material for watergrass and sprangletop.

As we begin the 2000 growing season, grass weed control in California rice faces several challenges. Primary among them are the twin spectres of resistance and access to effective materials. Following is a brief discussion of the status of current and candidate products for grass weed control in California rice.

Registered herbicides for grass control in California rice

Molinate. Marketed by Zeneca as Ordram 15G and 8EC, molinate has been a mainstay for *Echinochloa* spp. control for over thirty years. It has a narrow spectrum, good selectivity and can be applied early post plant into the water, preplant incorporated or water run with the first flood. When used correctly, molinate is generally the most consistent watergrass herbicide and performs well on grass seedlings up to the four leaf stage. Molinate has very little residual. Recently, molinate resistant biotypes of watergrass were found in the Sacramento Valley. In addition, for the last several years, molinate has been subjected to a data request relative to Proposition 65. Recent research has demonstrated that molinate in test animals (rats) is metabolized differently than in human males and appears to disprove the evidence that it is a reproductive toxicant. While its usage has declined in response to resistance and use of other products, molinate remains a highly important herbicide in California rice production.

Thiobencarb. Marketed by Valent USA as Bolero 10G and by United Agri Products as Abolish 8E, thiobencarb provides control of *Echinochloa* spp, *Leptichloa fascicularis* and *Cyperus difformis*. Its broader spectrum is the primary reason thiobencarb use has increased. Post plant granule applications should be made before the grass reaches the two leaf stage but after the rice has reached the 1.5 leaf stage. Because the window for rice safety is very narrow, earlier timing may lead to injury and later timing to unacceptable control. The liquid formulation can be applied preflood surface and immediately flooded or post plant on drained fields to slightly larger weeds than with the granule. Thiobencarb is the product of choice when sprangletop and/or umbrellasedge are problems. It provides up to thirty days residual control. In certain low CEC soils along the eastern edge of the Sacramento Valley, a toxic de-chlorinated degradation product of thiobencarb has caused widespread damage following use of thiobencarb. This problem, known as 'delayed phytotoxicity syndrome' (DPS), has been identified in at least 56 fields. Specific causes or management procedures have not been entirely identified and thiobencarb use has been discontinued in many of these fields, leaving some of these growers without adequate alternatives. As with molinate, some resistant biotypes of thiobencarb have been identified.

Propanil. Marketed as SuperWham CA by RiceCo through UAP, and Stam 80 EDF by Rhom and Haas, both are water soluble formulations with lower drift hazard than the oil-based formulations. Propanil is primarily a watergrass herbicide which has found popularity as a broadleaf and sedge material. It is active on several species and is helpful in those fields where grass and broadleaf herbicide resistance has developed. Propanil is versatile and relatively selective to the rice, and can be mixed with a number of products to improve efficacy and broaden the spectrum. One promising combination is Duet, a mix of propanil and bensulfuron. Propanil is heavily regulated to prevent offsite movement. Three aerial use zones have been designated which are far from sensitive crops, primarily prunes. However, most propanil is restricted to ground application. No-propanil buffer zones of two mile radius are used throughout the Sacramento Valley to protect prunes, grapes, cotton and other sensitive crops. This results in many growers not having access to propanil. In addition, daily acreage limits of 1500 ac/

county have been established to reduce atmospheric loading. This results in application delays during peak periods. Current UC research appears to support smaller buffer zones and larger daily limits and proposals to ammend the regulations will be made by the Propanil Task Force for 2000. This would provide much greater access to the products and help with timliness of application to improve efficacy. Changes in aerial application zones are not likely although the industry clearly would like to increase this component to decrease reliance on ground rigs which are hard to use in rice fields.

Fenoxaprop. Marketed as Whip 1 EC by Aventis, fenoxyprop is effective for postemergent control of watergrass and sprangletop. Whip is applied from the one tiller stage to panicle initiation. Rates are adjusted according to timing. Whip will control grasses over a wide range of growth stages but has a narrow range of selectivity. Non-uniform application can cause crop injury and result in lower control. This product is useful for cleanup of weed escapes and is especially important for sprangletop control. Some resistant watergrass biotypes have been identified.

Table 2. Site of action of registered grass herbicides for rice and weed susceptibility.

		Weed Susceptibility[1]						
Herbicide	**Site of action**	**ECHCG, ECHPH, ECHOR**	**LEFFA**	**CYPDI**	**SCPMU**	**SAGMO**	**AMMCO, AMMAU**	**ALSPA**
molinate	VLCFA[2]	C	N	N	N	N	N	N
thiobencarb	VLCFA	C	C	C	N	N	N	N
propanil	Photosys-tem II	C	N	C	C	P	P	P
fenoxaprop	ACCase	C	C	N	N	N	N	N

[1] 'C' - >90% control; 'P' – partial control at label rate; 'N' - < 50% control at label rate

[2] Very long chain fatty acid inhibitor

Herbicides under development for grass control in California rice

Cyhalofop butyl. Under development by Dow Agro Sciences, cyhalofop will be marketed as 'Clincher'. It is effective for post-emergent control of watergrass and sprangletop but has no broadleaf or sedge activity. It is an ACCase inhibitor like fenoxaprop but has greater selectivity so can be applied to smaller plants. An EC formulation with 2.6 lbs ai/gal and an oil based granule are being tested. In University of California trials in 1999, the granule worked well on watergrass when applied early, but gave better control of sprangletop when applied later. The liquid formulation gave good to very good control at all timings. This material has potential for combinations with molinate, propanil and others. A Sect. 3 label application went in to USEPA in December, 1999 and a Section 18 application was submitted to CalEPA in January, 2000, for use in areas where DPS is a problem and thiobencarb cannot be used safely.

Bispyribac-sodium. This experimental material is under development in the US by Valent USA as 'Regiment' for post-emergent control of barnyardgrass and watergrass and is moderately active on ricefield bulrush. It will suppress or give partial control of ducksalad, umbrellasedge, and arrowhead and is weak on sprangletop. Timing is anticipated to be from early post, 3 leaf stage of the rice (lsr) or later, to the tillering stage, at 10-18 g ai/A. Regiment is an ALS inhibitor and has a wide window of application. Earlier application timing permits lower rates. Regiment will usually cause some stunting of rice at higher rates and later application timings. Because it shares the same mode of action with bensulfuron, which has been used since 1989 in California, resistance management will be important when using Regiment. This product has potential for use in combinations with propanil, Abolish and Grandstand to broaden its spectrum and manage resistance. A Sect. 3 label application went into USEPA in July, 1999 and a Sect. 18 application went to CalEPA in January, 2000, for control of resistant weeds in propanil buffer zones.

Clomazone. Under development by FMC, 'Command' is being tested in 3 ME and 1.9 G formulations for watergrass and sprangletop control. In 1999 UC trials, both foliar and granular formulations were applied into standing water at 0.2 to 0.6 lb ai/A, at the 0.5 to 2 lsr. Granules applied early at the higher rate give the best results but increased injury compared to the micro-encapsulated formulation. Some crop injury in the form of leaf bleaching and delayed growth was noted in trials, but disappeared after 15 days. Command is a carotinoid biosynthesis inhibitor and represents a new form of chemistry not currently in use in California rice, so may be very useful for resistance management programs. The product was used in Texas in 1999 under a Sect. 18 exemption. Because it causes bleaching on sensitive plants, drift management will be a consideration for this product.

Glufosinate. 'Liberty' is a broad spectrum, non-selective product under development by Aventis for use on transgenic rice which will carry the name 'Liberty-Link.' The product is contact active and is currently used on Liberty-Link corn, soybean and canola. It provides excellent control of watergrass and sprangletop, good control of redstem and arrowhead and partial control of bulrush and sedge. Sequential applications and mixtures with propanil Grandstand and Shark improved control but increased crop injury. Coverage is very important so water level will have to be adjusted to expose plants. Water management protocols, and rate, timing and combinations need refining. Drift management, especially when planted near non-resistant rice, will be vital. Liberty resistance genes have been inserted into the public variety M-202, the most widely grown variety in California, and seed is under production. Aventis is actively pursuing development of this technology for California for possible commercial use in 2001. The California Rice Commission is developing policies to appropriately integrate this technology in California markets to satisfy the needs of its various customers some of whom have announced they will not purchase genetically modified rice or will require labeling.

Glyphosate. Well known as 'Roundup,' Monsanto is also developing transgenic rice which will be called 'Roundup Ready.' This technology is currently widely used in the US in corn, soybeans, cotton and other crops. Roundup is broadspectrum and has systemic activity, and has a similar weed control spectrum as glufosinate. Similarly, sequential applications and possibly combinations will be beneficial to improve control and broaden the spectrum. Water management to expose weeds and drift management will be important with this product. Monsanto is also using M-202 and is in early stages of development of the transgenic rice and are proceeding cautiously while the industry and markets decide what they want to do with this new technology.

Table 3. Mode of action of candidate grass herbicides for rice and weed susceptibility.

		Weed Susceptibility[1]						
Herbicide	**Site of action**	**ECHCG, ECHPH, ECHOR**	**LEFFA**	**CYPDI**	**SCPMU**	**SAGMO**	**AMMCO, AMMAU**	**ALSPA**
Cyhalofop	ACCase	C	C	N	N	N	N	N
bispyribac	ALS	C	N	N	P	P	N	N
Clomazone	Carotenoid biosynthesis	C	C	N	N	N	N	N
glufosinate	Glutamine synthase	C	C	P	P	C	C	--
glyphosate	EPSP synthase	C	C	P	P	C	C	--

[1] ‘C’ - >90% control; ‘P’ – partial control at label rate; ‘N’ - < 50% control at label rate

Summary

Several key issues and trends will shape the future of grass weed control in California rice. Drift management is one of the issues because many of the current and future products will be applied as liquids. Ground rig application will likely increase as the primary drift management tool, in response to widespread use of materials which have high biological activity and broad spectrum at low dosage rates and which are applied as liquids. The California rice industry has responded to the need for ground application by fabricating a fleet of rigs capable of operating in flooded fields. In the near future, expect to see innovations in application methods that will combine the speed of air application with the drift control of ground rigs. One such example is the Australian SQIIRT technology which meters material into the field via gravity from a moving platform (either ground or air) with drop nozzles. The system depends on migration of the concentrated product to achieve control, but reduces drift because the material is not put out under pressure.

Another key issue is the need to control resistance through rotation and combinations of modes of action, in addition to cultural practices. Alternative materials with differing modes of action must be available for this to be a reality. Several new products are on the horizon but not all are new chemistry so they, too will require stewardship to prevent resistance from developing. They may be best in combinations, which will likely make crop injury more prominent, and growers will need to be able to assess the risk, cost and benefit of these combinations. As new chemistry, including herbicide tolerant technologies, becomes available, resistance management programs should become more effective.

In future, we expect grass weed control to become more complex as more modes of action come on the market, combination and sequential application becomes the norm, and new technologies emerge. Growers will probably spend more for rice weed control, will assume more risk and will need to be more knowledgeable about the alternatives. The days of simple weed control are gone.

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WHAT'S NEW IN INDUSTRY

Lontrel* (Clopyralid): A New Post-Emergence Herbicide for Control of Certain Broadleaf Weeds in Turf, Field Grown Nursery Stock and Landscape Ornamentals

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Dow Agrosciences

The selective herbicide clopyralid, a non-phenoxy member of the pyridine family, is registered in California as TRANSLINE* for Range & Pasture, as STINGER* for crops, and now as LONTREL for turf and ornamentals. Each product is formulated as a 3-lb/gallon monoethanolamine salt, containing 40.9% clopyralid.

LONTREL is highly active applied post-emergence on a limited number of broadleaf species, with sharpest activity on weeds from the Asteraceae (Compositae), Fabaceae, Solanaceae and Polygonaceae. Lontrel is applied at rates from 0.1-0.25 lbs ai/A (0.25- 0.66 pints/A). In turf, LONTREL offers outstanding control of common broadleaf weeds such as clovers and dandelions, which compose 80% or more of the weed biomass in most lawns, parks and golf courses. Although primarily active via foliar absorption, LONTREL usually provides several weeks of soil residual to control susceptible weeds via root uptake.

LONTREL has shown exceptional safety on mixed turf species even during high summer temperatures or when the turf is young. Diverse species such as St Augustinegrass, hybrid bermudagrass and kikuyugrass appear tolerant to LONTREL even above maximum label rates. LONTREL is labeled for all common cool and warm-season turf species, including tall fescue, perennial ryegrass, and even dichondra.

Several shrubs, trees and groundcovers have shown tolerance to directed or over-the-top treatment with LONTREL. This allows LONTREL to be used selectively as a “rescue treatment” when susceptible broadleaf weeds such as sowthistle, groundsel or marestail infest tolerant landscape or nursery ornamentals such as oleander, junipers, azalea, ice plant, ivy, and many species of trees. Certain field grown woody nursery stock is labeled for treatment either basal directed or in some cases broadcast overtop with LONTREL. Certain crops such as grapes and cotton that are highly sensitive to phenoxy drift, have shown tolerance to LONTREL at simulated drift rates.

LONTREL has a Caution label, and offers Worker Protection language, with a re-entry interval of 12 hours.

* Trademark of Dow AgroSciences

Imazapyr, A New Tool for Forest Site Preparation in California: A Two-Year Program Report for a Multilocation Study of Imazapyr Rate, Application Timing and Conifer Planting Timing Across Varying Precipitation Regimes

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Introduction

Imazapyr is a newly registered herbicide in California used primarily for forest vegetation management, control of noxious weeds on forestry sites and wildland areas, and certain right-of-way, industrial and non-crop uses. For forestry sites, imazapyr is available in a water soluble liquid formulation containing four pounds acid equivalent (ae) per gallon (Arsenal® Applicators Concentrate) or as an emulsifiable concentrate containing two pounds ae per gallon (Chopper®). Stalker®, also an emulsifiable concentrate formulation, is registered for industrial, right-of-way, and non-crop uses in California. Imazapyr is in the imidazolinone herbicide family, structurally similar to herbicides used in food crop production. Imazapyr is absorbed through foliage, root and stem tissues and translocates quickly in the apoplasm (xylem) and symplasm (phloem) with accumulation in meristematic regions (Shaner 1988). Imazapyr is an uncompetitive inhibitor of acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS) (EC 4.1.3.18), an enzyme mediating the first and rate limiting reaction leading to the synthesis of branched chain amino acids valine, leucine and isoleucine (Shaner et al. 1984, Anderson and Hibberd 1985). This enzyme is not found in humans, birds, fish, insects and other animals, accounting in part for imazapyr's low toxicity (Ahrens 1994).

Imazapyr is in animal toxicity category IV, the lowest toxicity category. Oral and dermal LD_{50} values are greater than 5,000 mg/kg. Imazapyr does not cause skin irritation, skin sensitization, or eye irritation. Imazapyr is classed in carcenogenicity group E, with no evidence of carcenogenic effects, the safest rating. Imazapyr is not teratogenic or mutagenic. Imazapyr has limited vertical movement in soil due to sorbption by clay and organic colloids and moderate water solubility (11,272 mg/l), with residues detected only within 15 cm of the soil surface (Mangels 1991). The field half-life of imazapyr ranges from 25-142 days in published studies, depending on soil type and environmental conditions. Microbial degradation is the principal means of imazapyr dissipation in soil. In water, rapid photodegradation occurs, with a 2-3 day half-life in shallow ponds. Imazapyr is a non-volatile herbicide.

Although field testing for forest vegetation management was just initiated in 1996 (Fredrickson and DiTomaso 1997), Arsenal and Chopper are the most widely used forestry herbicides in the Southern United States, particularly for loblolly pine (*Pinus taeda*) management. Applications may be made pre- or post-emergence for herbaceous weed control, but weed control is most effective with early post-emergence timing. Pre-plant herbaceous weed control applications provide the best conifer selectivity but require higher use rates to ensure adequate duration of weed control. For woody plant control, including hardwood brush and trees, optimum application timing is generally late in the growing season (mid-July through September) (Minogue, 1985). Conifer tolerance is also best late in the growing season, so over-the-top conifer release applications are normally planned for this period. Non-selective applications such as directed spray and site preparation may be accomplished prior to the late season by use of higher herbicide rate, tank mixtures, and applications with the emulsifiable concentrate formulation Chopper® in oil emulsion carrier which appears to improve foliar absorption (Minogue, et al. 1996, Minogue, et al. 1997). The optimum timing for cut stem, cut stump, and basal stem treatment is also during the late-season period but applications throughout the year are effective, except for a brief period in the early spring during strong sapflow.

Forests in California offer a great diversity in environmental conditions; elevation, rainfall, soils, crop tree species and associated plant communities. Rainfall and soil organic matter are expected to strongly influence microbial degradation rates and thus imazapyr persistence and herbicide rate response. This research was initiated on sites with contrasting environments to explore imazapyr rate and application timing effects for shrub, tree-forming hardwood, and herbaceous weed control in site preparation applications. Conifer tolerance was determined for early and late planting dates for Douglas-fir (*Pseudotsuga menziesii*), Ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), Redwood (*Sequoia sempervirens*), red fir (*Abies magnifica*), and white fir (*Abies concolor*). This report presents second-year results from this five-year study. First-year findings were published by DiTomaso and others, 1999.

Methods

A similar study design was established at three locations in Northern California (Table 1) to examine imazapyr rate and timing as main plots (Table 2). Treatments were assigned in a completely randomized design or randomized complete block design (Dana location, blocked on slope position) with 3 or, in the case of the McCloud location, 6 replications of main treatments. Main plots were split into four quadrant subplots to test conifer crop species and planting date effects.

Table 1. Environmental parameters and crop tree species for three study locations in Northern California.

Study Location	Cooperator	Rainfall (inches/yr)	Elevation (feet)	Crop Tree Species
Smith River	Simpson	120	300	Douglas- fir, Redwood
McCloud	Sierra Pacific	45	6000	Douglas-fir, Ponderosa pine, Red fir, White fir
Dana	Sierra Pacific	25	4000	Douglas-fir, Ponderosa pine, Sugar Pine

Herbicides were applied to 36x50 ft main plots using a CO_2 pressurized backpack research sprayer with a 12 ft, hand-held boom fitted with eight 8002 nozzles delivering 16 gallons per acre total spray volume at 25 psi. Imazapyr was tested using the Chopper formulation in 25% (vol:vol) Hasten® esterified seed oil carrier at 0.125, 0.25, 0.5, and 1.0 lb ae/acre (8, 16, 32, and 64 oz Chopper product per acre). At the Dana location, Arsenal AC was also applied at the late application timing using water carrier with 1% R-11 surfactant at 0.125, 0.25, and 0.5 lb ae/A (4, 8, and 16 oz Arsenal AC product per acre). At the Smith River and Dana locations, two application timings, targeted for May and August, were also tested in main plots. Herbicide treatments were compared to an untreated control, one for each application timing. Early versus late planting timing and crop tree species were tested in quadrant subplots within each of the rate and timing main plots, with random assignment of split plot treatments.

Arborescent hardwood rootstocks were assessed for species and live height in a 28x42 ft hardwood measurement subplot prior to treatment and at 1 and 2 years after treatment (YAT). Percent cover for groups; grass, sedge, forb, *Rubus*, vine, legume, fern, shrub, tree, weed free and debris was assessed in two 14x21ft quadrant subplots in each main plot prior to treatment and at 1 and 2 YAY. Dominant vegetation, having 5% or more of total cover, was assessed for percentage cover by individual species in the two quadrants at these same times.

Fifteen individuals of each crop tree species were planted into 14x21 quadrants. Seedlings were measured for total height in inches and groundline diameter in mm following planting and during the first and second dormant season following treatment. During the first and second growing season, following elongation of the spring flush, seedlings were assessed for phytotoxic symptoms using the condition following codes: 0=no damage, 1=chlorosis of foliage, 2=necrosis of foliage, 3=abnormal apical leader, 4=fasciculation in elongating shoots, 5=leader dieback, 6=mortality. Seedlings are assigned the code indicating the worst damage, ie the highest number.

Table 2. Herbicide treatments tested.

Main Plots

Product	Imazapyr Rate (lb ae/A)	Product Vol. (fluid ounces)	Carrier	Application Timing
Chopper	0.125	8	25% Hasten	May
Chopper	0.25	16	25% Hasten	May
Chopper	0.50	32	25% Hasten	May
Chopper	1.0	64	25% Hasten	May
Untreated Check	0	0		May
Chopper	.125	8	25% Hasten	3rd week August
Chopper	0.25	16	25% Hasten	3rd week August
Chopper	0.50	32	25% Hasten	3rd week August
Chopper	1.0	64	25% Hasten	3rd week August
Untreated Check	0	0		3rd week August
Arsenal AC	0.125	4	1% R-11	3rd week August
Arsenal AC	0.25	8	1% R-11	3rd week August
Arsenal AC	0.50	16	1% R-11	3rd week August

Application Date	Smith River	McCloud	Dana
May target	May 26, 1997	August 1, 1997	May 20, 1997
August target	July 30, 1997		July 31, 1997

Split Plots - For the planted crop tree species given for each location in Table 1

Planting Date	Smith River	McCloud	Dana
Early	December 8, 1997	October 29, 1997	October 25, 1997
Late	February 12, 1998	June 16, 1998	March 20, 1998

Results And Discussion

Vegetation

The Smith River study was installed in a two-year-old redwood and Douglas-fir plantation and had established vegetation when herbicides were applied (Table 3). The McCloud location was intensively prepared with machinery and was essentially bare ground when treatments were applied. The Dana study was also established in an existing one-year-old Ponderosa pine and Douglas-fir plantation, and thus had herbaceous vegetation, shrubs, and some tree species at the time of treatment.

Table 3. Associated woody and herbaceous vegetation at the three study locations.

Location	Woody Species	Herbaceous Species
Smith River, CA Del Norte Co.	Blue blossom (*Ceanothus thyrsiflorus*) Huckleberry (*Vaccinium spp*.) Coyotebush (*Baccharis pilularis*) Red alder (*Alnus rubra*) Blackberries and raspberries (*Rubus spp*.)	Fireweed (*Erechtites sp*.) Silver hairgrass (*Aira caryophyllea*) Blue wildrye (*Elymus glauca*) Japanese cudweed (*Gnaphalium japonicum*) Jubatagrass (*Cortaderia jubata*)
McCloud, CA Siskiyou Co.	Greenleaf manzanita (*Arctostaphylos patula*) Whiteleaf manzanita (*Arctostaphylos viscada*) Chinquapin (*Chrysolepis* sp.) Snowberry (*Symphoricarpos albus*) Bittercherry (*Prunus emarginata*)	Sedge (*Carex* spp.)
Dana, CA Shasta Co.	Squaw carpet (*Ceanothus prostratus*) Black oak (*Quercus kelloggii*) Greenleaf manzanita (*Arctostaphylos patula*) White fir (*Abies concolor*) Snowberry (*Symphoricapos albus*)	Sedge (*Carex* spp.) *Apocynum cannabinum* *Amelanchier alnifolia* *Cirsium vulgare* *Gayophytum sp*.

Effect of application date

In considering application date effects, one must recognize that differences between the two dates are due in part to treatment effects but are also influenced temporal differences; simply, different plants are present at May verses August assessment dates. Analysis of variance components showed significant application date effects only at the Smith River location (Table 4). At two years following treatment, sedge, forb, legume, and tree cover were greater for the May than August application. Tree cover would be least influenced by temporal differences, since these are perennial. Studies of application timing in other regions have demonstrated optimum tree forming hardwood control for applications late in the growing season. Cover for the weed free component was greater in August than May, but differences were not large.

Table 4. Percent cover 2 YAT for groups having a significant application date effect at the Smith River location.[1]

Date	Grass	Sedge	Forb	Legume	Tree	Weed Free
	(%)					
May	16 B	2.6 A	50 A	2.1 A	5.0 A	8 B
August	25 A	1.1 B	41 B	0.2 B	0.9 B	12 A
P>F [2]	.0065	.0012	.0122	.0001	.0074	.0012

[1]Within a column, means following by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=15 plots)
[2]The probability of a greater F statistic for application date source effects from analysis of variance components.

Effect of imazapyr rate

At the Smith River location application rate had a significant effect on percent cover of shrub, tree, and weed free components. Cover of woody plants decreased with increasing imazapyr rate and weed free cover increased with increasing rate as would be expected. Orthogonal contrasts were done to examine linear, quadratic, and cubic effects for rate response. Cover of these components showed significant linear effects for the response to rate (shrub P>F .0007, tree P>F .0382, weed free P>F .0011) with significant quadratic (P>F .0036) and cubic (P>F .0217) effects shown for shrub cover.

Table 5. Percent cover for groups having a significant application rate effect 2 YAT at the Smith River location.[1]

Imazapyr Rate (lb ae/A)	Shrub	Tree	Weed Free
	(%)		
0	5.7 A	7.4 A	6.3 B
0.125	2.3 B	3.0 AB	7.5 B
0.25	1.0 B	0.8 B	10.4 AB
0.5	1.2 B	3.3 AB	12.5 A
1.0	0.8 B	0.5 B	12.9 A
P>F[2]	.0004	.0789	.0081

[1]Within a column, means followed by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=6 plots)
[2]The probability of a greater F statistic for imazapyr rate source effects from analysis of variance components.

At the McCloud location significant rate effects were observed at 2 YAT for sedge, shrub, and weed free components (Table 6). Only small amounts of plant cover were present and differences in cover between application rates were not large, but cover for sedge and shrub components decreased with increasing rate whereas weed free cover increased with rate. Orthogonal contrasts showed highly significant linear rate effects for all three cover variables (P>F .0001).

Table 6. Percent cover for groups having a significant application rate effect 2 YAT at the McCloud location.[1]

Imazapyr Rate (lb ae/A)	Sedge	Shrub	Weed Free
		(%)	
0	1.3 A	2.2 A	96.6 C
0.125	1.0 AB	1.2 B	98.8 B
0.25	0.7 BC	0.9 BC	99.0 AB
0.5	0.4 C	0.8 BC	99.1 AB
1.0	0.4 C	0.6 C	99.3 A
P>F[2]	.0005	.0001	.0001

[1]Within a column, means followed by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=12 plots)
[2]The probability of a greater F statistic for imazapyr rate source effects from analysis of variance components.

Imazapyr rate had a significant effect only on shrub and weed free cover for the 2 YAT assessment at the Dana location (Table 7). Shrub cover decreased and weed free cover increased with increasing imazapyr rate in a linear fashion, as determined by orthogonal contrasts (shrub P>F .0003, weed free P>F .0094). For weed free cover only the 1.0 lb ae/A imazapyr rate was significantly greater than the check at this assessment.

Table 7. Percent cover for groups having a significant application rate effect 2 YAT at the Dana location.[1]

Imazapyr Rate (lb ae/A)	Shrub	Weed Free
	(%)	
0	10 A	69 B
0.125	5.6 AB	73 B
0.25	5.8 AB	74 B
0.5	1.8 B	72 B
1.0	1.0 B	82 A
P>F[2]	.0018	.0432

[1]Within a column, means followed by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=6 plots)
[2]The probability of a greater F statistic for imazapyr rate source effects from analysis of variance components.

Conifer tolerance and seedling growth

At the Smith river study location there were no significant effects of imazapyr rate or application timing on redwood and Douglas-fir crop tree height at 1 YAT, groundline diameter at 1 YAT, survival at 2 YAT, and all various seedling condition codes 2 YAT. Second dormant season height and diameter data have been only recently collected and data entry is in progress. To further examine possible injury effects on planted crop trees orthogonal contrasts for Chopper treatment versus the untreated check showed no effect on survival 2 YAT (Douglas-fir P>F .7823, redwood P>F .4839) or percentage of seedlings showing no symptoms at the 2 YAT assessment (Douglas-fir P>F .7977, redwood P>F .7192). At this study location 885 seedlings were assessed for each crop tree species. A few of the Douglas-fir seedlings treated with 1.0 lb ae/A, 25% more than the maximum labeled rate, showed evidence of imazapyr symptoms. Interestingly, two-year-old redwood seedlings oversprayed during study establishment showed severe injury, but most had resumed normal growth in the second growing season.

At the McCloud location there were significant imazapyr rate effects 2 YAT only for ponderosa pine (Table 8). Imazapyr treatment did not have a significant effect on seedling survival, but seedling height was less than the untreated check with 1.0 lb ae (twice the maximum labeled rate) and groundline diameter was less than the check for the 0.5 and 1.0 lb rates. This location has little weed cover and thus the effect herbicide absorption by associated plants has little impact on rate response in conifer tolerance.

At the Dana study location no significant Chopper or Arsenal rate effects were observed for Ponderosa pine, Douglas-fir, or sugar pine height, groundline diameter, or seedling survival at the assessments two years after treatment. Seedling phytotoxic symptom codes collected during the second growing season following treatment indicated no significant Chopper or Arsenal rate effects, except for Ponderosa pine (Table 9). A comparison of the mean percentage of trees showing no symptoms (or mortality) for

Table 8. Ponderosa pine seedling height, groundline diameter, and survival as effected by imazapyr rate at the McCloud study location in the second dormant season following planting.[1]

Imazapyr Rate (lb ae/A)	Total Height (inches)	Groundline Diameter (mm)	Survival (%)
0	12.5 AB	11.4 A	93
0.125	13.1 A	11.9 A	94
0.25	12.2 AB	11.2 A	93
0.5	11.6 BC	9.6 B	94
1.0	10.7 C	8.5 B	88
P>F [2]	.0107	.0005	.9831

[1]Within a column, means followed by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=6 plots)

[2]The probability of a greater F statistic for imazapyr rate source effects from analysis of variance components.

Chopper and Arsenal application dates and rates indicate no differences from the check except for the 0.5 lb Arsenal treatment in August and the 1.0 lb Chopper rate applied in May and August. These results indicate that Chopper rates should not exceed 0.5 lb ae/A to ensure tolerance to planted Ponderosa pine on dry sites.

Table 9. Percentage of Ponderosa pine seedlings showing no symptoms 2 YAT at the Dana location.[1]

Imazapyr Rate (lb ae/A)	Chopper May	Chopper August	Arsenal AC August
	(%)		
0	84 A	89 A	
0.125	84 A	87 A	88 A
0.25	98 A	93 A	85 A
0.5	83 A	74 AB	61 BC
1.0	54 BC	49 C	

[1]For all means in this comparison, those followed by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=3 plots of 15 seedlings)
[2]The probability of a greater F statistic for imazapyr rate source effects from analysis of variance components.

Effect of planting date

Significant planting date effects were evident for all crop tree species planted at the McCloud study location; Douglas-fir. Ponderosa pine, red fir, and white fir. Seedling survival and growth was better for the October planting than June for all species except white fir. Large difference in seedling survival were noted for Douglas-fir, red fir, and white fir between the two planting dates.

Table 10. Comparison of October, 1997 and June, 1999 planting dates on crop tree seedling height, groundline diameter (GLD), and survival during the second dormant season following treatment at the McCloud study location.[1]

Planting	Ponderosa Pine			Douglas-fir			Red fir			White fir		
	Height (in)	GLD (mm)	Surv. (%)	Height (in)	GLD (mm)	Surv. (%)	Height (in)	GLD (mm)	Surv (%)	Height (in)	GLD (mm)	Surv. (%)
October	13 A	12 A	99 A	n.s.	8 A	73 A	9 A	n.s.	76 A	8 B	6 B	67 B
June	11 B	9 B	86 B	n.s.	7 B	46 B	7 B	n.s.	43 B	9 A	7 A	80 A
P>F[2]	.0008	.0001	.0011		.0183	.0001	.0001		.0001	.0118	.0250	.0056

[1]Within a column, means followed by the same letter are not significantly different using Duncan's New Multiple Range Comparison at alpha=0.05. (n=6 plots)
[2]The probability of a greater F statistic for imazapyr rate source effects from analysis of variance components.

Conclusions

Imazapyr persistence is largely determined by rates of microbial degradation. The study locations contrast sites with varying rainfall, soil organic matter, elevation, and associated vegetation. At the Smith River location the persistence of herbaceous weed control was short, a few months, in contrast to the McCloud and Dana locations where lower rainfall and a shorter growing season provided slower microbial degradation and herbaceous weed control for two or more years. Imazapyr is known for broad spectrum control of woody shrubs and trees, including some species difficult to control with other herbicides such as tanoak, blueblossom, black oak, and bigleaf maple. Site preparation applications to control established brush, following harvest or in forest site rehabilitation, will provide long-term control of competing brush.

Conifer tolerance for planted Douglas-fir, redwood, red fir, white fir, and sugar pine was very good with Chopper and Arsenal site preparation applications, even with rates in excess of label recommendations (1 lb ae/A). This study demonstrated concerns for the use of imazapyr rates greater than 0.5 lb ae/A for site preparation in advance of planting Ponderosa pine in dry sites or at high altitude.

This work adds to a growing body of research information which will enable site-specific recommendations to best meet the needs of vegetation managers. Additional measurements and analyses are planned to garnish species control information and crop growth response in the coming years.

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Weed Management Areas in California

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Introduction

County-level Weed Management Areas(WMA), and other weed-specific coordination groups have brought invasive plant prevention and control to a more local level and have increased the sophistication and effectiveness of invasive species management in California. Between 1997 and 1999 the number WMAs has risen from 7 to 33, comprised of 47 individual counties.

A Weed Management Area (WMA) is a local organization that brings together landowners and managers (private, city, county, state, and federal) in a county, multi-county, or other geographical area for the purpose of coordinating and combining action and expertise in combating common invasive weed species. It is intended to be at the grassroots level where participants in the group are actually the people who are directly controlling weeds or doing education work with those who do.

For current information on Weed Management Areas, in general, and for each local WMA see the California WMA website:

http://www.cdfa.ca.gov/wma

A WMA may be voluntarily governed by a chairperson or a steering committee. To date, groups in California have been initiated by either the leadership of the County Agricultural Commissioner's Office or a Federal Agency employee. WMA's are unique because they attempt to address agricultural (regulatory) weeds and "wildland" weeds under one local umbrella of organization WMA's have printed weed I.D./control brochures, organized weed education events, written and obtained grants, coordinated demonstration plots, instituted joint eradication and mapping projects, as well as, many other creative and effective outreach and weed management projects.

Often WMA groups form to address management concerns (Suppression) for the crisis weeds in their area.

As the group gains momentum and members it can address an adaptive management model of regional weed control activities:

- Planning (strategic plan, MOU, management plan)
- Prevention - Education(at all levels), Regulations

- Detection - Finding, Reporting, Mapping (GPS,GIS)
- Suppression - Fire Model, Integrated Pest Management
- Re-vegetation - Forage crops, natives - depends on objectives
- Monitoring - Then back to planning for the next season

History

Traditional agricultural weed control and the Pest Prevention System have been implemented by the California Department of Food & Agriculture, County Ag Departments, US Department of Agriculture, and private individuals for the past century. With the inception of the modern environmental movement, groups such as the California Native Plant Society, California Exotic Pest Plant Council, the Nature Conservancy and others began to promote the focus of invasive weeds in wildlands. The first attempt at a weed management area was the Greater Yellowstone WMA which brought together three different states in to a collaborative effort which was deemed a great success. This led to dissemination of the coordinated weed control model to federal employees throughout the nation. California had 5 early adopters by early 1997. By mid 1999, 40 new counties had joined in by forming 33 WMAs. The future of these groups relies on finding stable funding sources and partnerships between WMAs to share information and resources.

Who Participates

- County - Ag Department, Roadways, Parks, Fire abatement
- State Agencies- CDFA, Parks, Fish & Game, Forestry & Fire, CalTrans, UC Cooperative Extension, Etc.
- Federal Agencies- BLM, Forest Service, NRCS, Park Service, Military
- Growers, Cattlemen, RCDs, Forest Industry, Landowners, Volunteers, Native Plant Society, Pest Control Operators, Open Spaces, Water Districts, Cities, Railroads, Utilities, Nurserymen

Benefits

There are four levels of benefits that can be progressively attained as the inputs of time and money are increased.

- Enhanced Cooperation & Sharing
- Weed Education & Awareness, Symposia
- On the Ground Demonstrations - Tests Plots, Workshops, Mapping
- More Weeds Killed through Cooperative Projects (Holy Grail)

Examples of Projects

County Fair Display, Brochures & Posters, Shared Personnel War-on-Weeds Conference, Treatment Test Plot, Grant Applications, Adopt-a-highway for Weed Control, Newspaper Articles, Field Days/ Workshops, Shared Equipment, Boards of Supervisor Tours, Weed ID Book, Report-a-weed contests, Student Weed Mapping, Speakers Bureau

Summary and Conclusion

In conclusion, Weed Management Areas are the result of local organization and initiative to further coordinate and elevate the activities to control, prevent, eradicate, and contain noxious and invasive weeds at the county level in California. They have established a track record of success primarily based on dynamic leadership and a number of funding programs within the state.

There is a growing momentum to solve resource based conflicts and address planning with coordinated local efforts which involve multiple stakeholders and agencies. WMAs can be viewed in this context although coordinated weed control is usually a win-win effort.

Developing and Implementing a Weed Management Area: The Plumas-Sierra Counties Experience

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The Plumas-Sierra Noxious WEEDS Management Group (P.S. WEEDS) is the second Weed Management Area (WMA) that I have worked on starting. The first, the Lassen County SWAT Team, had more humble beginnings mainly because we were unaware that we were starting a WMA, or at the time what a WMA was for that matter. We simply thought it would be a good idea if the county Ag Department's biologist, the U.C. Cooperative Extension's farm advisor, the botanist from the Bureau of Land Management (BLM), and a few others sat down and communicated and coordinated their noxious weed control activities. At that time, the focus was on yellow starthistle and developing some sort of inventory — we didn't think that we had very much yellow starthistle but that was because we had not completed an inventory yet — another lesson learned; and we also wanted to do some public education via the local newspaper. We weren't even looking for money back then mainly because we didn't know that there was any available for our purposes. It was a slow start, but the momentum and the group grew, we started applying for grants, and became very successful.

The P.S. WEEDS group had a more typical beginning of the WMAs that have formed since. We knew what we were doing now, or so we thought. I learned a lot from our first big meeting. The first thing that I learned was that the last thing anyone wants is another meeting to go to. Not much I could do to remedy that. Another thing that I learned was that this was a very diverse group of people, some with histories linked together, and that everyone didn't walk into that conference room that first day liking each other to start out. We had the County Agricultural Commissioner, the U.C.C.E. Farm Advisor, Caltrans, Natural Resources Conservation Service (NRCS), three of the four National Forests representatives, BLM, California Native Plant Society, private timber companies, county road departments, and others I'm sure I'm forgetting. There is a lot to be gained from diversity if you have a common working ground and I can think of none better than noxious weeds. We made noxious weeds our agenda, our only agenda, and have had only positive outcomes from our differing backgrounds ever since. I realize however, that people are more difficult to manage than weeds, which is why I stick with the weeds.

Have you ever realized that not everyone else in the world is as excited about killing weeds as you are? This is why we need public education on noxious weeds issues. Different pamphlets, brochures, and field identification guides have been published through WMAs in an attempt to get the word out about weeds. P.S. WEEDS has hosted a noxious weed tour through both our counties, formed a speakers bureau to address noxious weeds issues, held a two-day noxious weed seminar, gathered noxious weed reference materials which were donated to two libraries in our counties, put together a huge pavilion display on noxious weeds for our county fair, published "Control of Yellow Starthistle in Plumas and Sierra Counties" an informational brochure on identification and control, published "Learn To Recognize These Noxious Weeds" coloring book for children, had several newspaper articles printed, will be hosting a Land Management Field Day this June, and are presently working on a regional noxious weed brochure with other northeastern California WMAs to be given to recreationists and tourists traveling through our area. We have accomplished a lot with each of our partners contributing just a little.

Once you have your group formed, a Memorandum of Understanding (MOU) signed, and some small projects under your belt, then the real networking and partnering begins. I think big but start small. A biology professor from our local community college called and was looking for some heavy mil plastic bags to be donated as he was having his students during lab pull yellow starthistle on campus. I started making the calls through our partners and in no time had a box of bags from the county road department. Our present weed control crew has its labor funded by the California Department of Food and Agriculture (CDFA), spray equipment, supervision and training provided by the County Agricultural Commissioner, herbicides provided by all of the above plus local Resource Conservation Districts, and the pick-up truck and fuel is supplied by the Natural Resources Conservation District. We are presently working with the California Department of Fish and Game on a perennial pepperweed control project at their Hallelujah Junction Wildlife Area. The more projects we take on the more involved our many partners become and the outcome is more than any one partner could ever accomplish by themselves.

And then there's the money — the part you've been waiting to hear about. P.S. WEEDS put in one grant application last year with the National Fish and Wildlife Foundation (NFWF) and was funded to have a person this season map and inventory our noxious weeds sites using a Global Positioning Satellite (GPS) unit. Since last year we have applied for NRCS grants, RCD grants, and five more NFWF grants. There is also project funding available through AB 1168 to be distributed by CDFA that we will be applying for. All of these monies mean more weed control work and public education for your area.

I believe that WMAs are a win-win situation for all of those involved. If you haven't already joined a local WMA I encourage you to do so. They can use your expertise and involvement. I have found them to be very action oriented groups and the most dynamic meetings I have ever attended. And you never know, your local WMA may be funding your next weed control or research project.

Non-Target Effects of Glyphosate on Soil Microbes

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Introduction

Glyphosate is among the most popular herbicides registered for forest use in California. Noted for its broad effectiveness on competing vegetation, mild effect on conifers, rapid inactivation in soil, and low mammalian toxicity (DiTomaso 1997), glyphosate is an integral component of conifer release programs and has led to improvements in the growth of intensively managed forests (Powers and Reynolds 1999). Benefits of herbicide use must be viewed cautiously, however. Public concerns about environmental risks makes their forestry use controversial. Policy makers and forest managers thus need scientific documentation of the ecological effects of herbicides that go beyond the toxicological requirements met during product registration. In particular, our knowledge of the effect of glyphosate on non-target organisms in forest ecosystems is incomplete.

Soil microorganisms are an ideal community to evaluate non-target effects because they are affected both directly and indirectly by glyphosate. Direct, toxic effects result from inhibition of amino acid synthesis via the shikimic acid pathway (Grossbard and Atkinson 1985). Microorganisms and higher plants are the only organisms known to utilize this pathway, and thus are intolerant of glyphosate. All others lifeforms, including mammalian and avian species, lack the shikimic acid pathway and are unaffected by glyphosate (for example: LD_{50} for rats > 5000 mg/kg). Indirect effects of glyphosate may also be a driving force influencing the microbial community. Long-term control of understory vegetation can reduce soil organic matter and nitrogen content (Busse et al. 1996), both vital resources for microbial activity. Vegetation control can also regulate microbial activity by modifying microclimate, soil temperature, and soil moisture (Shainsky and Radosevich 1986). The choice of soil microorganisms as model organisms is further warranted by their ecological role. Soil microorganisms are responsible for essential processes in forests: decomposing organic matter, cycling nutrients, degrading toxic materials, and contributing to disease occurrence and suppression. Our objective was to determine whether soil microbial communities are adversely impacted by the non-target effects of glyphosate. This paper summarizes our preliminary findings. Complete details will be presented in a later paper (Busse et al., in preparation). Mention of any trade product does not imply Forest Service endorsement.

Experimental Approach

Direct and indirect responses of soil organisms to glyphosate were tested at three “Garden of Eden” study sites (Powers and Ferrell 1996). Briefly, the Garden of Eden study is a classic comparison of vegetation control, insect control, and fertilization across a range California’s Westside ponderosa pine plantations. For our purposes, a subset of treatments was compared: (1) 9 years (minimum) of understory vegetation control using repeated glyphosate applications, (2) no vegetation control. Three sites were selected among common soil types to provide a gradient of low (Elkhorn), medium (Whitmore) and high (Feather Falls) site productivity, and treatments were replicated three times per site. Understory-control plots have been maintained weed free since plantation establishment, whereas control plots were densely covered (> 70%) with shrubs at Whitmore and Feather Falls (Powers and Reynolds 1999) and moderately covered with shrubs (~ 25%) at Elkhorn by the 9-11th growing season.

Direct effects of glyphosate. Soil from the upper surface horizon (0-15 cm depth) was collected randomly from control plots at each site and used in the following studies.

(1) *Toxicity in soil-free media.* Bacterial and fungal communities were extracted from soil using physiologically-buffered saline and grown on both liquid and solid media containing increasing concentrations of glyphosate as its commercial formulation, Roundup, at 0, 0.5, 1, and 10 times the recommended spray-solution concentration (50 mM). Measurements of short-term, toxic responses were made, including bacterial and fungal viability, bacterial growth rate, and functional diversity of bacteria.

(2) *Toxicity in soil.* Glyphosate was added to soil samples at 0, 5, 50, 500, and 5000 mg/kg. Subsamples were taken 1, 3, 7, and 30 days after glyphosate incorporation and tested for total microbial biomass, bacterial biomass, fungal biomass, and bacterial diversity using the C-utilization method and phospholipid fatty-acid signatures. Microbial activity was estimated by CO_2 release during the initial 9-day period following glyphosate incorporation.

Indirect effects of glyphosate. Seasonal changes in microbial community size and function were compared for the vegetation-removal and control treatments at the Garden of Eden sites using soil samples collected from the surface 0-15 cm during the 1998 growing season. Spring, summer, and fall samples were analyzed for microbial biomass, total bacteria, fungal hyphal length, bacterial diversity, respiration, and mineralizable nitrogen.

Findings

Glyphosate was lethal to bacteria and fungi when added to soil-free media. At the recommended sprayer concentration of 50 mM, glyphosate reduced bacterial viability 1000-fold (from 10^7 to 10^4 cells/g soil) on solid media, and completely eliminated fungal growth. Increasing glyphosate to 500 mM stopped all bacterial growth. Bacterial growth rate in liquid media also declined following additions of glyphosate (Figure 1). Results were consistent for all Garden of Eden sites, confirming that glyphosate is directly and indiscriminantly toxic to bacteria and fungi when added to soil-free media.

Contrary to the toxic response in soil-free media, glyphosate stimulated microbial growth and activity when added directly to soil. Microbial respiration, a standard measure of activity, increased with increasing levels of glyphosate (Figure 2). The response was minor at 5 and 50 mg/ha, the estimated concentration range in the upper horizon of mineral soil following field application, and greatest at highest application rate. Again, the results were consistent for all sites. Increases in total and viable bacteria were found at the highest rate of glyphosate addition, with *Psuedomonas*, *Arthrobacter*, *Xanthomonas*, and *Bacillus* spp. increasing in population dominance. Fungal population size remained relatively unchanged regardless of glyphosate application rate.

How can glyphosate kill microorganisms in soil-free media, yet stimulate growth when added directly to soil? This riddle is answered by recognizing herbicide chemistry and mobility in soil. Glyphosate is a polar compound that binds rapidly with soil colloids (clay, organic matter, aluminum and iron oxides), precluding uptake by microbial cells or roots. In effect, glyphosate is unavailable for biological activity once in contact with soil. By comparison, glyphosate remains active and unbound in soil-free media and can penetrate cellular membranes, disrupt protein synthesis, and ultimately kill microorganisms. This alone explains the differences we observed between soil and soil-free media. However, it does not clarify why microbial activity increased following glyphosate additions to the Garden of Eden soils (see Figure 2). Again, this observation can be attributed to herbicide chemistry. Glyphosate is a simple amino acid ($C_3H_8NO_5P$), capable of supplying energy (carbon) and nutrients (nitrogen, phosphorus) for microbial growth when bound to soil particles. Follow-up experiments have identified carbon as the major limiting factor for microorganisms in these soils, and implicate a beneficial role of glyphosate as an available energy source for microorganisms.

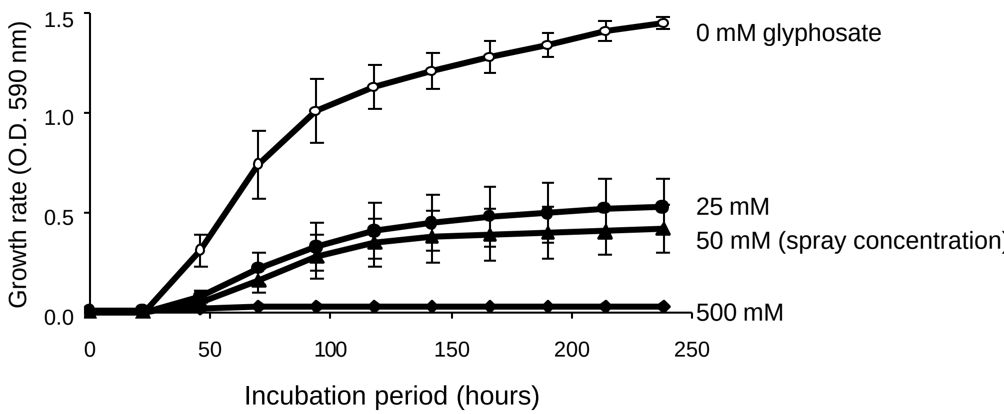

Figure 1. Inhibition of bacterial growth in culture media containing increasing concentrations of glyphosate. Bacteria were extracted from the Whitmore soil and their growth rate was determined by optical density using the average well-color development on Biolog plates. Similar results were found for Elkhorn and Feather Falls soils. Bars indicate one standard error of the mean.

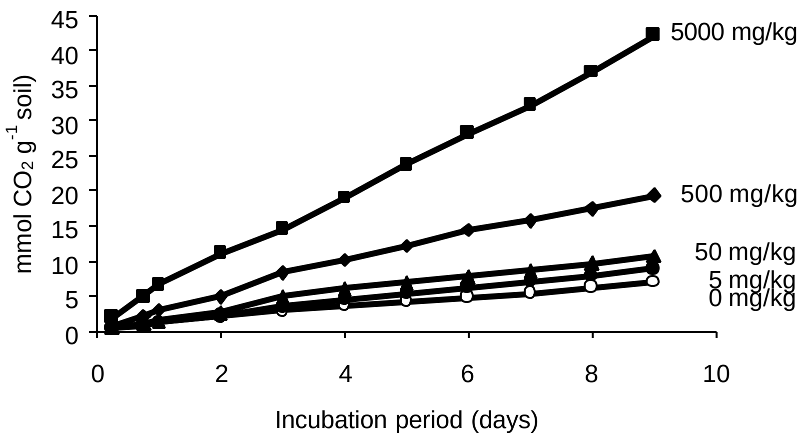

Figure 2. Stimulation of microbial respiration following addition of glyphosate to Whitmore soil. Between 5 and 50 mg/kg is the estimated concentration of glyphosate in soil following field application.

Glyphosate use, and weed control practices in general, prompt an additional ecological question regarding non-target organisms: does removal of understory vegetation and its associated functions modify the soil microbial community? We hypothesized that eliminating understory vegetation for a minimum of 9 years would affect microbial characteristics by reducing organic carbon input from roots and litter and modifying soil temperature and moisture. When monitored throughout the 1998 growing season, however, no differences in soil biological properties were found between glyphosate and control plots. All measures of microbial community size, diversity, and function were statistically equivalent between treatments. Further, no differences in soil carbon content or moisture availability were found between treatments.

Conclusion

Glyphosate had an inconsequential toxic affect on microorganisms from several ponderosa pine plantation soils. Microbial community size and activity were unaltered at the range of concentrations in soil anticipated following application. In fact, application of 100-times the normal soil concentration stimulated microbial activity and bacterial numbers by supplying supplemental energy for growth. Glyphosate toxicity was found in soil-free media, although the absence of glyphosate-adsorptive material (such as organic matter, iron and aluminum oxides, clay) in culture media is misrepresentative of soil conditions and should be considered an artifact. These findings agree with results from agricultural studies that show glyphosate does not have a toxic effect when added to soil due to its strong adsorption to soil colloids (e.g. Wardle and Parkinson 1992). Are these preliminary findings applicable to other forest types or soils? We suggest that the answer is yes. Lack of glyphosate toxicity to non-target microorganisms can be expected based on results from numerous studies plus recognition of glyphosate as a non-mobile and inactive compound in soil. Field results also indicated an inconsequential indirect effect of continuous understory vegetation control on microbial characteristics during the 1998 growing season at the Garden of Eden sites. Microbial communities were insensitive to 9 years of vegetation control, even though dramatic changes in shrub cover, tree growth, and tree nutrition were found (Powers and Ferrell 1996; Powers and Reynolds 1999).

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Vegetation Control, Fertilization and Oversowing Nitrogen-Fixing Winter Annual Legumes to Improve the Growth of Conifers

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I. Preface

I grow conifer forests on 425 acres in the Umpqua valley of Oregon. Our dominant species is Douglas-fir, but we have in recent years planted diverse species within our stands as a step toward increased forest health and productivity. Our most numerous species in addition to Douglas-fir are:

Hybrid larch (larix eurolepsis)

Grand fir (abies grandis)

Ponderosa pine (pinus ponderosa)

Coast redwood (sequoia sempervirens)

The forests are grown in an intensive silviculture regime including site preparation, vegetation control, fertilization and pre-commercial thinning.

This talk will discuss the sequence of steps which we take in establishing our regenerated forest stands. The results are rewarding. On sites with a site index of about 105 ft. (50 yr. basis), our stands are growing with an effective site index of 140 to 150, an increase of two site classes.

II. Site Preparation and Pre-plant Vegetation Control

Our forests begin as clear land, but without other measures brush and grasses would soon present severe competition to the young trees. The principal brush species are Scotch broom, Salal, and various rubus species. The brush and the grasses present not only moisture competition, but also competition for nutrients and mycorrhizal populations.

Pre-plant chemical site preparation consists of Accord, Arsenal, Escort and Oust applied in appropriate amounts in the late summer. A major function of the Oust is to prevent the germination of Scotch broom and other germinants.

After any residual vegetation has browned, slash is piled and burned. On very steep slopes, broadcast burning is used, though this is becoming more difficult to accomplish. On slopes of less than 20%, a winged sub-soiler is used to reduce the clay hardpans inherent in our soils.

III. Planting and Post-Planting Fertilization

Following the planting operations, the new stock is fertilized with about 40 grams of a slow release fertilizer formulated to be compatible with the needs of the trees and the status of the soils. The fertilizer contains all the macro and micro elements in balanced amounts. Most of the stock has been grown in containers and has a small amount of fertilizer in the plug, but we do not regard this as sufficient to maximize the first years growth.

By the end of the first year, we expect to achieve a height growth in excess of 75% of the initial height, and a diameter growth of about 150%, i.e. the final height will be about 175% of the initial height and the final diameter will be about 250% of the initial diameter. The volume at the end of the first year will thus be in excess of 1000% of the initial volume. We have achieved these values on a consistent basis, with a mortality of less than 2%.

On some sites, we experience a flush of thistles during the end of the first year. If the thistle seems numerous enough to inhibit stand growth, we apply transline in the very early spring.

In short, we regard the robustness of the stand at the end of the first year to be of critical importance to the future of the forests development. We want the trees vigorous and the ground clean.

IV. 2nd and 3rd Year

At the start of the second year, we increase the amount of slow release fertilizer (applied by hand on the surface around the trees) to about 180 grams. The Oust is fall-flown again, to suppress germinants of Scotch broom and other species. The use of Transline the following spring is dependent on the thistle load. If we have controlled the thistle well the first year, we will generally not need to re-control the second year.

At the start of the third year, we apply a faster acting balanced fertilizer to the trees at the rate of about 375 grams per tree. This is the last year for general vegetation control, which usually takes place in the spring as Oust or a combination of Oust and Transline. Any scotch broom or brush escapes are treated with a backpack basal spray. By the end of the third year, the trees are free to grow.

V. 4th Year Forward. Making the Transition to a Forest Stand

The forest soil at the end of the third year has now lost a portion of the organic matter present at the time of harvest. We now have a window of opportunity between the end of the third year and the closure of the stand (achieved by the end of the 7th or 8th year) to restore organic matter, since organic matter will again begin a long-term decline after stand closure.

Organic matter status is of great importance to the storage of moisture and nutrients for the developing forests. This has been recognized in the research literature but not very well emphasized to foresters.

Since we want to add the organic matter, we must grow some ground cover. Ideally, the ground cover would grow only during the cool season of the year and would become dormant in summer so that it did not reduce soil moisture. It should be fairly dense, so that Scotch broom and other brush germinants are excluded. If it could add nitrogen fixation to the system, so much the better. Logic led us to consider winter-annual clovers, and in our case subterranean clover ("sub-clover"). Let us look at some of the characteristics of sub-clover:

1. Sub-clover grows from the first rains in the fall until warm weather in May. Then it matures and dies, extracting no moisture from the soil profile during the summer. It leaves a seedbed which emerges with the fall or winter rains.

2. Sub-clover fixes about 100 lbs of nitrogen per acre. This is organic nitrogen and releases slowly. The nitrogen is distributed throughout the top 3-4 inches of soil.

3. Sub-clover processes inorganic sulfur into organic sulfur complexes which are stable, leach very slowly and are available to the conifers.

4. Germinating sub-clover forms a very dense mat, which is very effective in excluding weak germinants such as Scotch broom.

5. The clover will continue to reseed annually in the new forest stand until the stand closure is quite tight.

6. The seed is protected by a hard coat which allows some seed to survive for several decades.

7. The species is tolerant of acid soils. It does not need the addition of lime to grow well.

In order to grow a good sub-clover stand, it is necessary to supply molybdenum along with the seed and to inoculate the seed with an appropriate inoculant. This process is very conventional for livestock pasture growers.

The enhanced nitrogen status of the soils does encourage wild grasses to grow in along side the clover. By the time the grasses arrive, however, the trees dominate the site and have roots much deeper than the grasses.

The result of this strategy is the rapid development of the organic matter in the new forest soil. The nitrogen level is sufficient to minimize the necessity of adding nitrogen to the fertilizer blends which are applied to the forest.

We expect to pre-commercially thin these stands at 10 to 12 years. New openings as the result of thinning will undoubtedly encourage a resurgence of clover growth.

We take tissue samples from our forest trees and to fertilize them by air when the tissue analyses show that nutrient supplementation is advisable. We believe that this will be on a cycle of 4 to 5 years.

I have attached a tissue analysis below of the stands growing under the conditions which I described above. The trees are on site index 105 soils, growing at an effective site index of 140. These results show a good nutritional status, except that potash, zinc and molybdenum are below our target values. That has just been corrected with a supplemental aerial application.

VI. Final Comments

We have an open door policy on our procedures and results. We have many visits each year from professionals, academics and small woodland owners. If you wish to visit us and see the results yourself, you will be welcome.

Fenn Tissue Analysis

%S	Al	B	%Ca	Cu	Fe	%K	%Mg	Mn	Mo	%N	Na	%P	Zn
.116	393	35.9	.487	3.5	42	.645	.127	130	.048	1.71	12.7	.121	10.4

History, Mechanisms, and Strategies for Prevention and Management of Herbicide Resistant Weeds[1]

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Herbicide resistance is the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering. Resistance may occur in plants by random and infrequent mutations; no evidence has been presented to demonstrate herbicide-induced mutation. Through selection, where the herbicide is the selection pressure, susceptible plants are killed while herbicide resistant plants survive to reproduce without competition from susceptible plants. If the herbicide is continually used, resistant plants successfully reproduce and become dominant in the population. Thus, the appearance of herbicide resistance in the population is an example of rapid weed evolution.

History

Herbicide resistance was first reported in 1957 (Hilton 1957, Switzer 1957). In California, common groundsel (*Senecio vulgaris*) was the first reported herbicide resistant weed species (Holt 1988). It was shown to be resistant to herbicides in the triazine chemical class. Since that time, plants of 61 species (42 dicots and 19 monocots) have evolved resistance to the triazine herbicides. Herbicide resistance in plants did not evolve as early as insecticide or fungicide resistance due to fundamental life cycle and genetic differences between plants, insects, and fungi. The delayed appearance of resistant weeds relative to insects and fungi is generally attributed to slower generation time of plants, incomplete selection pressure of most herbicides, soil seed reserve, and plasticity of weedy plants, all of which keep susceptible individuals in a population and thus delay evolution of resistance (Holt 1992). The appearance of herbicide resistance in plants is currently increasing at an exponential rate (Figure 1), mirroring the trends previously seen with insecticide and fungicide resistance. Besides triazine resistance, there are biotypes of over 150 weed species expressing resistance to 14 other herbicide classes. The most common mechanism of action or target site of herbicides, the chemical class, and the number of species with biotypes resistant to each herbicide class are summarized in Table 1.

In California, herbicide resistance currently is most widespread in aquatic weeds in rice production (Table 2). Many of these weed species have been selected for resistance to the sulfonylurea herbicide bensulfuron (Anonymous 1993). In addition, there has been one report of

[1] Adapted from Division of Agriculture and Natural Resources website publication: Herbicide resistance: the problem and management strategies. Timothy S. Prather, Joseph M. DiTomaso, and Jodie S. Holt. 2000.

triazine resistance as well as two reports of sulfonylurea resistance in a non-crop area. A roadside survey conducted in 1995 and 1996 found that resistance to sulfonylurea herbicides was common in Russian thistle (*Salsola tragus*). Most recently, a rigid ryegrass (*Lolium rigidum*) biotype exhibited resistance to glyphosate in a northern California orchard (Heap 1999; Dave Bayer, pers. comm.). Despite these examples, there are fewer reports of resistance in California to date than in other regions of the United States (Table 1). However, current and pending registrations in California primarily involve herbicides that act on amino acid synthesis (Accent, Pursuit, Shade-Out, and Upbeet). Use of herbicides in this group has selected resistance in many weed species. Since these herbicides lead to rapid selection for resistant weeds, the number of cases in California has increased and this trend is expected to continue. In addition, a number of genetically engineered crops that are resistant to specific herbicides will soon be available in California such as Roundup Ready cotton and corn. Sole reliance on the specific herbicide used in these resistant crop varieties will increase the selection pressure for resistance to that herbicide. Herbicide-resistant crops will not be an end-all solution to weed problems and they will lose their effectiveness for weed management if used continuously.

Mechanisms

Evolution and natural selection are the processes that have led to the plant species found around the world today. Many plants, particularly weeds, contain a tremendous amount of genetic variation that allows them to survive under a variety of environmental conditions. Most herbicides act on a single specific site of action. This site of action is usually under the control of a single gene, or at most a few genes. With a single gene mutation, even minor changes in gene expression can confer resistance by modifying the site where the herbicide has its toxic effect (site of action). The evolution of a resistant population of a species is brought about through selection pressure imposed by that herbicide or class of herbicides. When a herbicide exerts selection pressure on a population, plants possessing the resistance trait have a distinct advantage. Unlike the susceptible plants in this population, resistant individuals will survive and reproduce. Continuous herbicide exposure maintains the selection pressure, thereby rapidly increasing the number of resistant plants.

Some weeds have traits that promote the evolution of resistance. High seed production with most seed germinating within a year can accelerate the evolution of resistance. This occurs because susceptible plants are removed rapidly from the population by the herbicide, thus increasing the proportion of individuals possessing the trait that confers resistance. High seed production coupled with genetic variation increases the probability of resistance evolution. Perennial weeds, particularly those with vegetative reproductive tissues, are less likely to evolve resistance compared to weeds with an annual life cycle that produce abundant seeds since there is less genetic diversity in the population and less reliance on seed production, which would perpetuate resistance.

In the absence of herbicide treatment, weeds with resistance to the triazine herbicides are not as fit as susceptible plants of the same species. This is due to a reduction in the efficiency of photosynthesis in resistant plants caused by an alteration in a specific photosynthetic protein that is also the herbicide binding site, which confers resistance. Since resistant plants are less fit, they reproduce at lower rates and, consequently, represent a smaller fraction of the number of individuals within a population. In contrast, some resistance traits do not incur the same fitness cost and, thus, often represent a larger fraction of individuals within a population. The frequency of the resistance trait within the population is an important factor in the rate of selection for resistance among weed species. For example, resistance to triazines took 10 years of continual use to evolve. Unlike the triazines, the sulfonylurea herbicides (inhibitors of ALS, acetolactate synthase) have no fitness cost associated with the resistance trait. Resistance to these herbicides took only 4 years to evolve. For weed species with resistance to sulfonylurea herbicides, it has been estimated that the initial proportion of resistant plants in a population is approximately one-in-a-million individuals. Thus, if a weed population has a density of 10 plants per m^{-2}, one resistant individual would be expected for every 10 hectares (24.7 acres) of infestation. Without multiple control strategies, the resistant individual likely will survive to produce resistant seed.

There are several factors such as herbicide characteristics, plant characteristics, weed control practices, and production practices that increase the probability of selection for herbicide resistance. Herbicide factors that contribute to the potential for resistance include long soil residual activity, single target site and specific mode of action, and high effective kill of a wide range of weed species. Herbicides with prolonged soil residual activity have a longer time to select for the resistance trait since they will kill most susceptible plants that germinate over a growing season. Herbicides with a single target site controlled by few genes are more likely to encounter plants with mutations for resistance than are herbicides with several modes of action. High effective kill rapidly depletes susceptible genes from the population, resulting in a rapid increase in resistance from few initial plants.

Although the most common mechanism of herbicide resistance in weeds is an alteration at the site of action, resistance can also result from an enhanced ability of the plant to metabolize and detoxify the herbicide (Holt et al. 1993). This latter mechanism, however, is not yet widespread in the United States. Like target site changes, selection for enhanced metabolism can also occur with repeated application of the same herbicide or with herbicides that are affected by the same detoxification enzymes. For example, enhanced metabolism is thought to confer resistance to picolinic acid herbicides in yellow starthistle in eastern Washington. Weed biotypes with enhanced metabolism have a much lower level of resistance compared to weeds expressing resistance through site of action changes. Selection for weeds with enhanced metabolism is more rapid when a herbicide is used continuously at lower than recommended rates. This allows a gradual increase in the population of weed biotypes with an increased ability to metabolize the compound.

The most likely way to cause evolution of resistant weed populations is by exerting selection pressure on weeds with the same herbicides over several generations. Using long soil residual herbicides, the same herbicide continuously, or rotating among herbicides that target the same site exert selection pressure for resistance over several generations.

Continuous planting of the same crop in each growing season reduces options for rotating to herbicides with a different target site. For example, crop rotation in California rice is difficult, so rice is planted continuously. The herbicide bensulfuron (Londax, an ALS-inhibiting herbicide) was registered in rice in California in 1989. It was highly effective on most rice weeds. There were few alternative control techniques used in rice so Londax was used extensively for several years (Anonymous 1993). Resistance evolved quickly and now there are at least four weed species (Table 2) resistant to Londax.

The limited number of registered herbicides in many minor crops restricts the ability to rotate among compounds with different sites of action. This often leads to continuous use of one or a few herbicides and increases the probability of herbicide resistance evolving among the weed populations present in those fields. However, resistance has not become a problem in California's minor crop production areas. This is probably because of the extensive use of hand labor, cultivation and frequent rotation among a number of crops that have herbicides registered with different target sites. While hand labor and cultivation continue as effective methods to avoid resistance, herbicide rotation that has accompanied crop rotation may become ineffective since herbicides that target branched chain amino acid synthesis (sulfonylureas [ALS inhibitors] and imidazolinones [AHAS inhibitors]) are being registered for several of California's minor crops, including tomatoes and sugar beet. In addition, cotton, corn and alfalfa all have ALS-inhibiting and AHAS-inhibiting herbicides registered. The risk of weeds evolving resistance to these herbicides will increase if ALS-herbicides are used continuously in several crops within a rotation, since there will be continued selection pressure exerted on branch chain amino acid synthesis. Exclusive use of herbicides for weed control can rapidly select for resistance when other control practices such as tillage or hand hoeing are not used to control herbicide resistant weeds. In general, non-chemical methods will not select between susceptible and resistant plants and should be used whenever possible. Resistance also evolves more quickly in lower value solid-seeded crops grown on large acreage since cultivation and hand-weeding of these crops may not be feasible. Farmers with crops grown over large areas tend to rely heavily on herbicides for weed control. These large acreages contain a greater number of individual weeds that may contain a resistance trait.

Strategies for Prevention and Management

Any management action that reduces the selection pressure for resistance will reduce the rate of resistance evolution. A number of papers have outlined various strategies that can be used to reduce the potential selection for herbicide resistant and to management herbicide resistant weed populations (Crites 1990, Shaner et al. 1992, Mallory-Smith et al. 1993, Retzinger and Mallory-Smith 1997). Crop rotation is one of the best tools to prevent resistance. Rotating to another crop allows the use of both chemical and non-chemical methods of control. Manipulation of planting time, crop competitiveness, cultivation techniques, hand weeding and herbicides with different target sites are all possible in a crop rotation system. Farmers and Pest Control Advisors (PCAs) in California use many of the methods listed above to control weeds. These characteristics of California agricultural production are probably the reason that few weed species have evolved herbicide resistance. As highly effective herbicides with the same target site become registered in California in multiple crops of a rotation, the risk of resistance evolution increases. Herbicides with different chemistries and trade names, but with the same target site, can reduce the effectiveness of herbicide rotation. Some common crop rotations include cotton, corn, tomato, sugarbeet and alfalfa. All these crops now have herbicides registered for use that target the same site (ALS). Weed species will evolve resistance rapidly without rotation of herbicides with different target sites.

The use of herbicide resistant crops is a new technology with increasingly widespread adoption. In many cases, growers will rely more heavily on a single herbicide in these cropping systems. Such a strategy will likely select for weed biotypes resistant to that herbicide or mode of action. Tank mixing, rotating herbicides, rotating from herbicide resistant to non-herbicide resistant crop varieties, as well as integrating non-chemical control options within the weed management program will reduce the potential for weed biotypes evolving a resistant trait.

The use of short-residual herbicides also reduces selection pressure for herbicide resistance. In addition, tank-mixing herbicides with different modes of action (Table 1) can inhibit evolution of resistance, but combinations should be used that broaden the spectrum of weeds controlled as well as control the weed species of major concern. If two herbicides have nearly the same weed control spectrum, it would be better to rotate between them rather than tank-mix the two compounds. It is unlikely, but theoretically possible, to select for resistance to two herbicides simultaneously.

While weeds have traits that enhance the possibility for evolution of resistance, they also have traits that reduce the chance of resistance evolving. Weed species with seeds that remain dormant in the soil for several years will maintain a population of susceptible plants within the seedbank. Maintaining susceptible plants in the population can dilute the resistance trait. If there is a fitness cost to resistance, such as in the case of triazine resistance, then removing the herbicide at some point in the crop rotation cycle allows for competition between the resistant and susceptible plants, further diluting the gene pool for the resistance trait.

Besides crop rotation, the use of certified seed, equipment sanitation, and cultivation and/or hand-weeding all impede resistance evolution. A resistance problem is usually not detected until land managers or farmers observe about 30% weed control failure for a particular species. If these resistant weed patches can be identified early before their populations increase, management practices can be employed to prevent their spread. If weed escapes appear in patterns, such as distinct strips, or if several species normally controlled by the herbicide are present in these skips, then the problem is probably associated with a calibration or application error. However, patches represented by only one escaped species showing no distinctive pattern may indicate a herbicide resistant population. Suspicious areas should be brought to the attention of a Farm Advisor or Extension Specialist, especially if weed populations reoccur in subsequent years following use of the same herbicide.

California weed management will change significantly with the introduction of new herbicides and the advent of herbicide resistant crops. If we maintain a selection pressure through continued use of these new tools, the new tools will soon be rendered ineffective. Adopting proactive management strategies to prevent herbicide resistance conserves important weed control tools. If resistance management strategies are ignored there is the potential that IPM systems may lose flexibility to deal with weed problems.

Table 1. Herbicides, their mode of action, and herbicide classes registered for use in California. Resistance has evolved in most groups and are listed as weeds worldwide, in the United States, and in California. Chemical families marked with the same shading pattern have been shown to result in cross-resistance among weed species.

Mode of action	Trade name(s)	Common name	Chemical class	Number of resistant weed species: World-wide	United States	Cali-fornia
Photosynthesis inhibitor; electron diversion at photosystem I	Reward, Diquat Gramoxone, Cyclone, Starfire	Diquat Paraquat	Bipyridyliums	25	2	0
Photosynthesis inhibitors at photosystem II	Aatrex and others Bladex Pramitol Caparol and others Princep	Atrazine Cyanazine Prometon Prometryn Simazine	Triazines	61	17	1
Photosynthesis inhibitors at photosystem II	Velpar, Pronone Sencor, Lexone	Hexazinone Metribuzin	Triazinones	3	1	1
Photosynthesis inhibitors at photosystem II; same site as triazines but different binding behavior	Stam, Stampede, Propanil	Propanil	Amide	2	1	0
Photosynthesis inhibitor at photosystem II; same site as triazines but different binding behavior	Basagran, Lescogran	Bentazon	Benzothiadiazole	0	0	0
Photosynthesis inhibitors at photosystem II; same site as triazines but different binding behavior	Betanex, Betamix Betanal, Betamix, Spin-Aid	Desmedipham Phenmedipham	Phenyl-carbamates	0	0	0
Photosynthesis inhibitors at photosystem II; same site as triazines but different binding behavior	Pyramin Tough	Pyrazon Pyridate	Pyridazinones	0	0	0
Photosynthesis inhibitors at photosystem II; same site as triazines but different binding behavior	Hyvar	Bromacil	Uracil	1	1	0
Photosynthesis inhibitors at photosystem II; same site as triazines but different binding behavior	Karmex, Direx and others Lorox Spike	Diuron Linuron Tebuthiuron	Ureas	15	3	0
Photosynthesis inhibitors at photosystem II; same site as triazines but different binding behavior	Buctril, Moxy	Bromoxynil	Nitriles	1	1	0
Branched chain amino acid synthesis inhibitors at acetolactate synthase (ALS); also called acetohydroxyacid synthase (AHAS)	Arsenal, Stalker, Chopper Pursuit	Imazapyr Imazethapyr	Imidazolinones	18	13	0
Branched chain amino acid synthesis inhibitors at acetolactate synthase (ALS); also called acetohydroxyacid synthase (AHAS)	Londax Telar, Glean Manage, Permit Accent Shade-Out, Matrix Oust Upbeet	Bensulfuron Chlorsulfuron Halosulfuron Nicosulfuron Rimsulfuron Sulfometuron Triflusulfuron	Sulfonylureas	47	15	6

Branched chain amino acid synthesis inhibitors at acetolactate synthase (ALS); also called acetohydroxyacid synthase (AHAS)	Firstrate	Cloransulam	Triazolopyrimidine	2	2	0
Branched chain amino acid synthesis inhibitors at acetolactate synthase (ALS); also called acetohydroxyacid synthase (AHAS)	Staple	Pyrithiobac	Pyrimidinyloxyben-zoates	1	0	0
Aromatic amino acid inhibitor at EPSP synthase	Roundup, Accord, Rodeo, Touchdown	Glyphosate	Glycine	2	1	1
Glutamine synthesis inhibitor	Finale, Liberty, Rely	Glufosinate	Phosphinic acid	0	0	0
Bleaching; inhibitor of carotenoid synthesis at phytoene desaturase (PDS)	Predict, Solicam, Zorial	Norflurazon	Pyridazinone	0	0	0
Bleaching; inhibitor of carotenoid synthesis at phytoene desaturase (PDS)	Sonar	Fluridone	Unclassified herbicide	0	0	0
Lipid synthesis inhibitors at acetyl CoA carboxylase (ACCase)	Hoelon Whip, Acclaim Fusilade	Diclofop Fenoxaprop Fluazifop	Aryloxy phenoxy proprionate	21	8	1
Lipid synthesis inhibitors at acetyl CoA carboxylase (ACCase)	Prism, Select Poast, Vantage	Clethodim Sethoxydim	Cyclohexanedione	6	2	0
Lipid synthesis inhibitors; not ACCase	Lasso, Partner Dual	Alachlor Metolachlor	Chloroacetamide	3	0	0
Lipid synthesis inhibitors; not ACCase	Sutan Ro-Neet Eptam, Eradicane Ordram Tillam Bolero	Butylate Cycloate EPTC Molinate Pebulate Thiobencarb	Thiocarbamates	3	2	1
Lipid synthesis inhibition; not ACCase	Prefar, Betasan	Bensulide	Acetamide	0	0	0
Fatty acid synthesis inhibitor	Nortron, Prograss	Ethofumesate	Benzofuran	1	1	0
Growth regulators; synthetic auxins (action similar to indoleacetic acid)	Banvel, Vanquish, Clarity	Dicamba	Benzoic acids	3	1	0
Growth regulators; synthetic auxins (action similar to indoleacetic acid)	Several Several Several	2,4-D MCPA Mecoprop (MCPP)	Phenoxy carboxylic acids	15	3	0
Growth regulators; synthetic auxins (action similar to indoleacetic acid)	Transline, Stinger, Lontrel Garlon, Remedy, Pathfinder, Grandstand, Turflon	Clopyralid Triclopyr	Picolinic acids	1	1	0
Mitotic disruptors; microtubule assembly inhibitors	Balan Sonalan, Curbit Surflan Prowl, Pendulum Barricade, Endurance, Factor Treflan	Benefin Ethalfluralin Oryzalin Pendimethalin Prodiamine Trifluralin	Dinitroanilines	9	5	1
Mitotic disruptors; microtubule assembly inhibitors	Dimension Visor	Dithiopyr Thiazopyr	Pyridazine	1	0	0
Mitotic disruptor; microtubule assembly inhibitors; different site than dinitroanilines	Kerb	Pronamide	Benzamide	1	1	0

Cell division inhibitor; site unknown	Devrinol	Napropamide	Acetamide	0	0	0
Cell wall synthesis inhibitor	Gallery	Isoxaben	Benzamide	0	0	0
Cell wall (cellulose) synthesis inhibitor	Casoron, Norosac	Dichlobenil	Nitrile	0	0	0
Membrane disruptors	DMSA and others Several	DSMA MSMA	Organic arsenicals	1	1	0
Rapid membrane destruction; site unknown	Scythe	Pelargonic acid	Unclassified herbicide	0	0	0
Free radical generator; inhibitor of protoporphrinogen oxidase (PPO)	Goal	Oxyfluorfen	Diphenyl ether	0	0	0
Free radical generator; inhibitor of protoporphrinogen oxidase (PPO)	Ronstar	Oxadiazon	Oxadiazole	0	0	0
Free radical generator; inhibitor of protoporphrinogen oxidase (PPO)	Milestone	Azafenidin	Triazolone	0	0	0
Unknown	Avenge	Difenzoquat	Pyrazolium salt	1	1	1
Unknown	Metam, Vapam	Metham	Dithiocarbamate	0	0	0
Unknown	Aquathol, Hydrothal, and others	Endothall	Disodium salt of methanearsonate	0	0	0
Unknown	Several Barespot Monobor-Chlorate	Copper sulfate and chelate Sodium chlorate and metaborate	Inorganics	0	0	0

Table 2. Herbicide resistant weeds in California.

Species	Common name	Area	Year reported	Chemical class (herbicide)
Senecio vulgaris	Common groundsel	Orchard, asparagus	1981	Triazine (atrazine)
Lolium perenne	Perennial ryegrass	Roadside, railway	1989	Sulfonylurea (sulfometuron)
Cyperus difformis	Smallflower umbrella sedge	Rice	1993	Sulfonylurea (bensulfuron)
Sagittaria montevidensis	California arrowhead	Rice	1993	Sulfonylurea (bensulfuron)
Salsola tragus	Russian thistle	Roadside	1994	Sulfonylurea (chlorsulfuron, sulfometuron)
Avena fatua	Wild oat	Barley, wheat	1996	Pyrazolium salt (difenzoquat)
Ammania auriculata	Redstem	Rice	1997	Sulfonylurea (bensulfuron)
Scirpus mucronatus	Ricefield bulrush	Rice	1997	Sulfonylurea (bensulfuron)
Echinochloa phyllopogon	Late watergrass	Rice	1998	Thiocarbamate (thiobencarb)
Echinochloa phyllopogon	Late watergrass	Rice	1998	Aryloxyphenoxy propionic acid (fenoxaprop)
Lolium rigidum	Rigid ryegrass	Orchard, roadsides	1998	Substituted amino acid (glyphosate)
Echinochloa crus-galli	Barnyardgrass	Cotton	1999	Dinitroaniline (trifluralin)

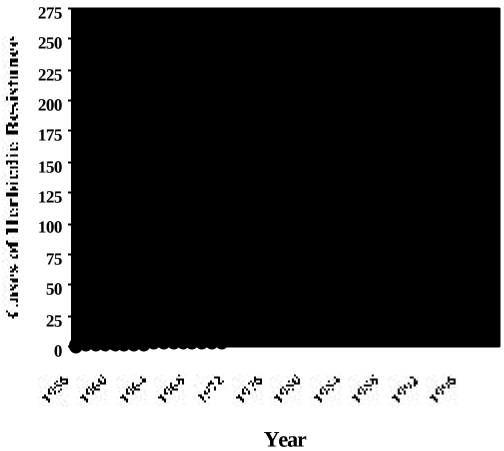

Figure 1. Chronological increase in herbicide resistance in weeds worldwide.

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Herbicide Resistant Crops: Implications for Agriculture

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An early demonstration of Buctril (bromoxynil) resistant cotton in the Western U.S. that place near Phoenix, Arizona in 1993 generated considerable interest by demonstrating the potential of genetic engineering to provide new weed control technologies to farmers. Agriculture stands on the threshold of an era of widespread availability of crop plants that have been genetically engineered to have herbicide resistance and insect tolerance as well as other agronomically desirable yield and quality traits. For example, the Weed Science Society of America recently listed eight transgenic crop species resistant to several herbicides that have been or will soon be commercialized (Table 1). Many other herbicide resistant transgenic crops are currently under development (e.g., Roundup Ready alfalfa, Roundup Ready lettuce, Roundup Ready rice, Roundup Ready wheat and imidazolinone resistant wheat).

Although the development of herbicide resistant crops (HRC) and insect tolerant crops are impressive scientific accomplishments, these agronomically important traits are the proverbial "tip of the iceberg". In the long-term, transgenic crop varieties may have improved tolerance to abiotic stresses such as salinity, temperature extremes, and water stress, as well as, improved yield and quality characteristics compared to current crop cultivars. Improved ratios of amino acids that allow more complete human utilization of foods, such as high lysine corn, and the production of molecules with human health benefits in food plants such as molecules that reduce blood cholesterol levels or help protect against cancer are examples of improved quality characteristics that may be developed. Crops used for livestock and dairy feed will also be modified for improved utilization by animals. Plants will also be used as industrial crops to produce pharmaceuticals or other valuable molecules. We may develop new food sources by genetically modifying plant species not traditionally used as food. There are probably other aspects of crop production and crop cultivars that will change in ways we can not foresee at this time.

It is relevant for the purposes of this discussion to briefly review how transgenic herbicide resistant crops are produced. The first step is to identify genes that confer resistance to a herbicide. In recent years, many genetically based examples of herbicide resistance have been found in weeds and herbicide resistance genes, many derived from soil microorganisms, have been introduced into crop plants using genetic engineering (Table 2). To date, useful genes that confer herbicide resistance have either produced an enzyme that detoxifies a herbicide before it can cause phytotoxic effects or have produced an enzyme with a modified herbicide binding site so that the enzyme can continue to function in the presence of the herbicide. Once a gene is identified, extensive research is required to determine the regions of the gene that confer resistance, to find suitable promoters that govern the expression of the herbicide resistance trait in the desired crop species, and to resynthesize the gene into a form that can be introduced into a plant cell. The new genetic trait must then be transferred into plant cells, typically using a "gene gun" or the *Agrobacterium* spp. transformation systems, and incorporated into a plant genome. Once incorporated into the genome, the promoter must function to express the gene so that the desired gene product (e.g., a detoxifying enzyme or an enzyme with a modified binding site) is produced in all plant tissues where it is needed to confer herbicide resistance.

Herbicide resistant (HR) transgenic cells must be selected from millions of non-herbicide resistant cells following successful gene transfer and whole plants must be regenerated from the HR cells. After molecular verification of gene presence and expression, various sexual and asexual propagation methods are used to obtain and increase the numbers of HR plants and seed. HR crops then undergo extensive greenhouse and field tests in which the HR trait is incorporated into agronomically successful crop cultivars and the performance of the resulting varieties is compared to the recurrent parents for yield and quality. Field testing also determines how the HR trait may change commercial weed control and farming practices in various regions, determines the commercial value of the HR trait, and determines how the HR trait may impact weed populations and other biological organisms. The impacts of changes in weed control and farming practices on physical components in agroecosystems such as soils (e.g., no-till or reduced tillage crop production to reduce soil erosion) are also studied. An ecological and biosafety analysis and review is also conducted and regulatory permits are obtained for large scale use. Proprietary and commercial arrangements are made to bring the HR trait to the market place and after introduction, there is continued monitoring of the HR trait and associated herbicide use for safety, efficacy and impacts on the environment.

Herbicide resistant crops were among the first genetically modified organisms (GMO) to reach the market place. This was because single gene traits are the easiest traits to transfer between genetically unrelated organisms in contrast to the difficulty of transferring multi-gene traits or making multiple genetic changes such as those involved in increasing the lysine content in corn. The fact that herbicide resistant crops were among the first GMO to be marketed has influenced the public debate regarding GMO. The benefits of HRC accrue to farmers and to the agrochemical and seed companies marketing GMO. Although HRC can change farming practices in both economically and biologically beneficial ways, HRC do not directly benefit the public. Because there is no direct benefit, a portion of the public (i.e., potential consumers of HRC) has objected to the introduction of GMO because they believe the benefits do not out weigh the risks associated with genetic engineering. This component of the public debate is exacerbated by a lack of scientific understanding, anti-technology sentiments and the complexity of the ethical issues involved. Commercial interests marketing GMO have opposed the labeling of GMO in part due to these sentiments and in part due to the lack of scientific evidence for risks that out weigh the benefits of genetic engineering. Public attitudes will likely change when there are compelling nutritional and human health benefits associated with the consumption of genetically modified foods. Coincidentally, the attitude of commercial interests with respect to the labeling of GMO may change when these nutritional and human health benefits have value in the market place.

Lotz et al. (1999) discussed the debate surrounding HRC in Europe and the results of a technology assessment conducted in the Netherlands that identified four main concerns regarding HRC. First, there is uncertainty about the long-term agronomic and ecological impacts of growing HRC on a large scale. Second, growing HRC means that weed management may continue to rely heavily on chemical weed control increasing the dependence of agriculture on herbicides. Third, the successful development and marketing of HRC and continued dependence on herbicides may retard the development of innovative nonchemical weed control methods.

Fourth, the environmental quality of some of the herbicides for which HRC are being developed is not considered sufficient by some to warrant development. In addition to these biological concerns, there are also concerns about the economic consequences of the development of HRC (Radosevich et al., 1997).

With the widespread commercialization of transgenic herbicide resistant crops imminent, it is relevant to consider the potential economic consequences of HRC. Will HRC reduce the cost of weed control or reduce economic losses caused by weed interference with crops? Clearly, for many farmers the potential reduction in hand weeding costs and reduction in yield losses due to weed interference make the use of HRC and associated herbicides economically attractive. However, total seed and weed control costs with HRC and associated herbicides can be more expensive than existing or older chemical control options so that, depending on weed populations in their fields, not all farmers will adopt new weed control technologies based on HRC. The development of HRC has had economic consequences beyond direct impacts on farmer's weed control strategies. The need for coherent crop seed production and marketing of HRC in conjunction with the associated herbicides has led to the consolidation of herbicide manufacturers and crop seed companies. Seed companies producing transgenic crop seed must manage the development of more varieties considering all of the possible combinations of regionally adapted varieties and potential insect and herbicide resistant traits. The situation becomes even more complex when the potential traits considered include nutritional and other quality enhancements. Will this increased complexity affect the improvement of basic agronomic traits in transgenic crop varieties? Competitive marketplace pressures due to the introduction of HRC has also resulted in consolidation and mergers between other chemical companies. The overall increase in economic concentration due to reduced numbers of independent seed companies, chemical manufactures, and other companies in the portion of the economy from which farmers purchase equipment and inputs may have long-term consequences on the cost of farming.

The use of HRC provides several advantages that may facilitate the development of more sustainable agricultural practices. As indicated above HRC may reduce the cost of weed control and may improve the control of previously difficult to control weeds by providing new chemical control options. HRC may contribute to integrated weed management by increasing the options for weed control available to farmers including crop rotation and non-chemical weed control methods. HRC often allow the replacement of preemergence herbicides with the use of postemergence herbicides that facilitate the goals of site-specific management because treatments can be imposed based on the emergence of weeds. HRC may promote systems for minimal tillage and mixed cropping by reducing the soil residual effects of preemergence herbicides. Finally, currently used herbicides may be replaced by more environmentally benign herbicides that are associated with HRC.

Herbicide resistant crops and new selective herbicides provide new postemergence weed control options that provide increased flexibility in designing weed management programs. For example, Roundup Ready (RR) Cotton, BXN Cotton, and Staple herbicide all allow cotton growers to control broadleaf weeds in seedling cotton during a time period when they were previously unable to topically apply postemergence herbicides. The improvements in weed control have reduced the costs of hand weeding morningglory and other weed species in cotton and reduced overall weed management costs. New herbicide technologies often allow easier or better control of previously difficult to control weeds without the disadvantages associated with other herbicides. For example, sequential Roundup Ultra applications in RR cotton often result in better control of purple and yellow nutsedge with less injury to cotton than sequential DSMA and MSMA applications. Similarly Roundup Ultra use in RR Corn provides a means to control Johnsongrass without the soil residual effects on rotational crops associated with the use of Accent (nicosulfuron) or Beacon (primisulfuron).

Herbicide resistant crops and new selective herbicides also increase the ability of farmers to use crop rotation and non-chemical weed control methods. HRC can increase the use of postemergence herbicides such as glyphosate (Roundup Ultra) and glufosinate (Liberty) that have little or no soil residual and reduce to use of soil applied herbicides with long soil residuals that restrict crop rotation. Examples include the use of Roundup for Johnsongrass control in Roundup Ready corn discussed above and the control of nutsedge spp in Roundup Ready cotton using Roundup rather than Zorial (norflurazon) which has a long soil residual and does not fit rotational practices in the Western U.S. Crop rotation leads to a diversification of weed control practices, both chemical and nonchemical, that limits the ability of weed species to become dominant in a field or develop herbicide resistance. The development of precision guidance systems for farm implements has removed many of the impediments to using close cultivation and in-row weeding techniques in row crops such as cotton. Electro-hydraulic guidance systems that actively steer implements such as cultivators using a sensing device to detect a furrow or crop row facilitate precision cultivation. Improved mechanical weed control also limits the development of dominant weeds and herbicide resistance because it is generally nonspecific.

Many studies have investigated various levels of herbicide inputs and cultivation for weed control in cotton and other crops. In general, both herbicide use and cultivation reduce crop yield losses caused by weed competition but acceptable control can not be obtained with cultivation alone. Poor weed control in the seed row is the major shortcoming of mechanical weed control. In cotton, topical applications of Staple herbicide or Roundup Ultra on RR cotton, or Buctril on BXN cotton followed by sequential post-directed applications now allow growers to chemically control weeds in the cotton seed row. These herbicides complement the use of cultivation with in-row weeders by giving growers the means to control weeds in the cotton seed row when the cotton is not large enough (i.e., generally less than 10 inches tall) to allow the use of in-row weeders. Electro-hydraulic guidance systems and precision cultivation allow close cultivation without crop damage early in the season and facilitate the use of in-row weeders by keeping the cultivator precisely aligned on the seed row. Guidance systems can also reduce the amount of herbicide used by reducing the width of the postemergence herbicide spray band. The combination of the herbicide sprays and precision guided cultivation with in-row weeding tools that are effective in removing broadleaf weed seedlings in the crop row can greatly reduce hand-weeding costs associated with annual morningglory species. Although in-row weeders are less effective on purple and yellow nutsedge, close cultivation does reduce nutsedge competition with cotton. In addition to the substantial saving associated with the elimination of hand weeding costs, the reduced operator fatigue and greater tractor speeds attained with precision guidance also increase productivity and reduce cultivation costs.

Although HRC can improve weed management practices they do not change grower practices with respect to herbicide application. HRC still require the use of spray rigs or tractor mounted sprayers for ground applications and airplanes for aerial herbicide applications.

Growers must still worry about the calibration and maintenance of spray equipment and the details of herbicide applications such as the selection of nozzle type and size, pressure, spray volume and adjuvant selection. In contrast, transgenic *bacillus thuringiensis* (Bt) Corn or Bt Cotton produce an insect toxin and thus eliminate the need for some insecticide applications. This obviously reduces application and insecticide costs and has desirable secondary effects such as improved management and utilization of beneficial insects in integrated pest management programs for these crops. HRC merely represent another mechanism for providing selective chemical tools to growers and as such supplement the more traditional chemical screening and herbicide discovery efforts of the agrochemical industry. For example, Staple herbicide was developed for selective weed control in cotton by Dupont using traditional methods at about the same time that Buctril and Roundup resistant cotton varieties were developed by Calgene and Monsanto, respectively, allowing the use of the associated herbicides in cotton.

In many of the examples discussed above, HRC are associated with an increase in the use of postemergence herbicides at the expense of preemergence herbicides. This change in herbicide use patterns facilitates the goals of site-specific management where weed control treatments are imposed based on the emergence of weeds. The use of global positioning systems coupled with geographical information systems to map the location of weeds by species in a field may allow the application of selective herbicides only where they are required and may allow the application of different herbicides depending on the weed species present. The development of computer based optical recognition systems would further encourage the use of site-specific management with postemergence herbicides. Such systems have the potential to reduce the overall use of herbicides. HRC have also been associated with the increased use of no-till, minimal tillage, and mixed cropping production systems. The adoption of no-till and reduced tillage practices in corn and cotton have reduced preemergence herbicide use, soil erosion, and the off-site movement of preemergence herbicides. HRC have made possible some forms of no-till production such as ultra narrow row cotton where cultivation is not possible and topical postemergence herbicides must be relied upon for weed control. By reducing reliance on preemergence herbicides, HRC have also made possible mixed cropping systems where the residual effects of preemergence herbicides would inhibit the growth of some crop components. In mixed cropping systems where one crop component is grown for only a portion of the season (i.e., legumes for nitrogen fixation), the herbicide associated with the HRC provides a means to selectively kill a component of the crop mixture. Lastly, some currently used herbicides may be replaced by HRC and associated herbicides that are more environmentally benign chemicals as judged by persistence in the environment and effects on other biological organisms.

There are disadvantages associated with the development and use of HRC. The successful introduction of resistance to a few herbicides into major crops (e.g., corn, soybeans, cotton, wheat, and rice) and widespread HRC adoption by farmers will decrease the potential market for new herbicides and may decrease the market share of existing herbicide products. For example, the successful marketing of Roundup Ready soybeans in the Midwestern U.S. significantly reduced Pursuit sales in the soybean market. The consolidation of agrochemical companies, in part due to the costs of developing and marketing GMO, reduces the number of companies that can develop new herbicide chemistry. If fewer herbicides are developed and marketed in the major commodities, there may be fewer herbicides available to be registered for use in minor crops. The same economics drive both the development of HRC and new herbicides, thus many minor crops will not be genetically engineered to be herbicide resistant unless technological advances reduce the cost of developing HRC. The success of HRC with respect to cost and weed control efficacy may promote continued reliance on chemical weed control and increase the use of herbicides for crop production. Thus, the success of HRC may reduce the economic incentives for the development of non-chemical weed control methods that are needed to reduce and manage the occurrence of herbicide resistant weeds.

The greatest risk posed by the widespread adoption of herbicide resistant crops and associated herbicides is the increased risk of developing herbicide resistant weed populations. Requirements for the development of resistance are that heritable (i.e., genetic) variation for the herbicide resistance trait exists and that natural selection acts upon the weed population. The degree of selection imposed by herbicide use depends on the efficacy of herbicide (i.e., effectiveness of weed control), the frequency of herbicide use, and the duration of the herbicide effect. The widespread use of HRC can greatly increase the frequency of use of a particular herbicide (e.g., Roundup Ready crops). In addition, if normal crop selectivity and HRC result in the use of the same chemistry or herbicide in several crops in a rotation, the frequency of use further increases. If a chemistry or herbicide has both postemergence and preemergence herbicide activities the duration of the herbicide selection pressure also increases. These phenomenon alone and especially together (e.g., imidazolinone use in IMI-corn, bean, and alfalfa rotations) increase the risk of developing herbicide resistant weeds. Some weed species may acquire herbicide resistance through introgression or gene flow between species. Introgression has occurred between HR canola and associated *Brassica* weeds in Canada and the possibility for introgression between pigweed species for ALS inhibitor resistance has been demonstrated. In addition to the development of herbicide resistant weeds, the repeated use and reliance on a few herbicides in the absence of other control methods as has occurred in no-till cotton and corn will cause a change over time in the weed species present in fields. Weed species naturally tolerant to the herbicides used will predominate at the expense of herbicide susceptible species. Thus, in the long-term, weed species shifts, herbicide resistant crop plant volunteers, and herbicide resistant weed species may increase the difficulty of weed management despite the development of HRC.

Management to avoid weed population shifts and the development of herbicide resistant weeds or to manage existing herbicide resistant and naturally tolerant weeds involves avoiding total reliance on a single herbicide or class of herbicide chemistry. Management strategies include manipulating herbicide rate where appropriate, alternating herbicides with different target sites, and using herbicide mixtures (i.e., using different mechanisms of action simultaneously). Integrated plant management (IPM) practices are also important in minimizing the use of chemicals and reducing herbicide selection pressure. In contrast to chemical weed control, mechanical weed control is generally non-selective (i.e., does not discriminate between plant species or genotypes within a species) because all species contacted by steel are killed. Other IPM practices useful in avoiding the development of herbicide resistant weeds include limiting seed dispersal of suspected small resistant populations (i.e., eradication) and rotating crops and associated cultural practices and herbicides. In the short-term, the economic and biological success of HRC may suppress the development of innovative non-chemical weed control methods that may be critical to the long-term success of HRC.

In summary, most occurrences of herbicide tolerant and resistant weeds have proven to be manageable using integrated plant management practices. Thus, in the short-term, the advantages associated with HRC appear to out weight the risks of developing herbicide resistant weeds in many crop production systems. However, questions remain about the long-term effects of HRC when they are used on a large scale. How will HRC affect total herbicide use? How will HRC affect weed flora and the control of volunteer crop plant problems? How will the diversity of weed control methods, both chemical and non-chemical, in major and minor acreage crops be affected by the wide spread adoption of HRC? What effects will incorporating multiple herbicide resistance into a single cultivar have? Continuous monitoring and cooperation between industry, government, academic scientists and other members of the public will be required to realize the full potential of transgenic crops in general and herbicide resistant crops specifically. The long-term benefits of HRC will depend on the wise use of chemical technologies within the context of integrated plant management practices.

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Table 1. Commercialized transgenic crops with herbicide resistance listed by the Weed Science Society of America in 1998.[a]

Transgenic Crop	Herbicide Tolerance	Trademark/Company	Estimated Year & Place Commercialized
Canola (*Brassica napus*)	bromoxynil	BXN Canola - Rhone-Poulenc[b]	Europe (1995)
		Liberty Link Canola - AgrEvo	Canada (1995) Europe (1995)
	glyphosate	Roundup Ready Rape - Monsanto	Canada (1997) Europe (1998)
Clover (*Trifolum repens*)	bromoxynil	CSIRO & New Wales Agriculture	Australia (2001)
Corn (*Zea mays*)	glufosinate	Liberty Link Corn - AgrEvo	USA (1997)
	Glyphosate	Roundup Ready Corn, Monsanto & DeKALB Genetics	USA (1997) Canada (1998)
	imidazolinones	IMI Corn - American Cyanamid, Pioneer, Ciba Seeds, Asgrow, Northrup King	Australia (1998-99) USA (1997)
	sethoxydim	SR Corn - BASF/DeKalb Genetics	USA (1997) Brazil (1997)
Rice (Oryza sativa)	glufosinate	Liberty Link Rice - AgrEvo	USA (2000-01) Asia (2000-01)
Soybean (*Glycine max*)	glufosinate	Liberty Link Soybean - AgrEvo	USA (1998) Brazil (1998-99)
	glyphosate	Roundup Ready Soybean, Monsanto & Asgrow Seeds	USA (1997) Brazil (1997) Argentina (1997)
	sulfonylureas	STS Soybeans - DuPont	USA (1993)
Sugar Beets (*Beta vulgaris*)	glufosinate	Liberty Link Sugar Beet - AgrEvo	Europe (1999-00)
	glyphosate	Roundup Ready Sugar Beet, Monsanto	Europe (1997-98)
Tobacco (*Nicotiana tabacum*)	bromoxynil	BXN Tobacco - Rhone-Poulenc	Europe (1997-98)
Upland Cotton (*Gossypium hirsutum*)	bromoxynil	BXN Cotton - Rhone-Poulenc	USA (1997)
	glufosinate	Liberty Link Cotton - AgrEvo	USA (2000)
	glyphosate	Roundup Ready Cotton-Monsanto	USA (1997)
	sulfonylureas	19-51a Cotton - DuPont	USA (1997)

[a]Adapted from: Weed Science Society of America. 1998. Herbicide Handbook-Supplement to the 7[th] ed. Edited by Kriton K. Hatzios. 102 pages.
[b]Rhone-Poulenc and AgrEvo merged in 1999 to form Aventis.

Table 2. Gene based examples of herbicide resistance in crops and weeds.

Herbicide	Novel gene product	Mechanism
triazines (e.g., prometryn, atrazine)	Chloroplast D1 protein	mutated target
substituted ureas (e.g., diuron)	Chloroplast D1 protein	mutated target
sulfonylureas (e.g. chlorsulfuron)	acetolactase synthase	mutated target
imidazolinones (e.g., imazapyr)	acetolactase synthase	mutated target
pyrimidyl thiobenzoates (e.g., pyrithiobac)	acetolactase synthase	mutated target
aryloxyphenoxypropanoates (e.g., diclofop)	Acetyl coenzyme A carboxylase	mutated target
cyclohexanediones (e.g., sethoxydim)	Acetyl coenzyme A carboxylase	mutated target
glyphosate (e.g. Roundup, Touchdown)	EPSPS (5-enolpyruvylshikimate--3-phosphate synthase)	over expression
glyphosate (e.g. Roundup, Touchdown)	EPSPS (5-enolpyruvylshikimate--3-phosphate synthase)	mutated target
glyphosate (e.g. Roundup, Touchdown)	glyphosate oxidoreductase	detoxification
bromoxynil (e.g., Buctril)	nitrilase	detoxification
2,4-D	monooxygenase	detoxification
glufosinate (e.g., Liberty)	N-acetyl transferase	detoxification

GMOs: California Regulatory Issues

Tobi Jones, Ph.D.
California Department of Pesticide Regulation

State Policies on Biotechnology
- Formulated in mid-1980's
- Examined Federal Coordinated Framework
- Used existing state laws

Microbial Pesticides
- Ice Minus (AGS) was early test of procedures (1987)
- DPR uses advisory committee to discuss
- Registering engineered BT drew no attention (1994)

Transgenic Plants
- Pest protected plants
- Herbicide tolerant plants
- Other traits: quality, nutrition, health enhancements, fine chemicals
- CDFA, USDA permits may apply before commercialization

Plant Pesticides
- DPR currently not requiring registration
- Awaiting final federal rule, clarification on labeling, data requirements
- State continues to evaluate roles, issues
- FIFRA 25(b) exemptions need close attention

Herbicide Tolerant Plants
- DPR uses same principle as EPA:
  - Regulate herbicide, not plant
- Appropriate tolerances and labels needed
- Worker protection measures may apply
- DPR watching federal approaches to herbicide resistance closely

California Issues
- Concerns of organic farmers: contamination of organic crops by GMO pollen
- Potential legislation/initiative to require food labeling
- Receptiveness of export market to GMOs

The Food Quality Protection Act of 1996
Progress Update

Ron E. Hampton
The IR-4 Project, Western Region
University of California, Davis

Important Websites
- www.epa.gov/pesticides (with links to TRAC, FQPA, and OPs)
- www.epa.gov/REDs
- www.ars.usda.gov/opmp
- www.cook.rutgers.edu/~ir4

FQPA Review
When setting pesticide tolerances under FQPA, the EPA now considers:
- The new safety standard - 'reasonable certainty of no harm'
- Exposure from all routes - oral, dermal and inhalation
- Cumulative effects of exposure to pesticides with a common mechanism of toxicity
- Potential increased sensitivity of children to pesticides

FQPA Review
The EPA must reassess all tolerances established before 8/3/96 within 10 years (33% to be completed by 8/99).
The EPA must develop a screening program for potential 'endocrine disruptors'.

The Nine Science Policies of TRAC
The Tolerance Reassessment Advisory Committee (TRAC) helped the EPA identify 9 science policy issues that are key to the implementation of the FQPA and tolerance reassessment:
1) Applying the FQPA 10-Ffold safety factor
2) Dietary Exposure Assessment – Whether or how to use the "Monte Carlo" analyses
3) Exposure Assessment – Interpreting "No Residues Detected."
4) Dietary (Food) exposure estimates
5) Dietary (Drinking Water) exposure estimates
6) Assessing residential exposure
7) Aggregating exposure from all non-occupational sources
8) How to conduct a cumulative risk assessment of organophosphate and other Pesticides
9) Selection of appropriate toxicity endpoints for risk assessment of organophosphates

Status of Science Policy Papers
- EPA has issued 14 of 19 science policy papers addressing 8 of the 9 policy issues.
- An additional 7 papers on related topics have been issued (for a complete listing of documents, go to /pesticides/trac/science).
- The comment period for "Guidance for Performing Aggregate Exposure and Risk Assessment" has been extended to Feb '00 (use the link to FQPA).

FQPA Directives

Reducing risk from pesticides under FQPA

- Aggressive reregistration and tolerance reassessment schedule
- Expedite reviews of new, safer 'reduced risk' chemistries

Prioritization of Tolerance Reassessment

- Group 1 (228 pesticides/5546 tolerances) includes OPs, carbamates and B_2 carcinogens
- Group 2 (93 pesticides/1928 tolerances) include registrations prior to 1984
- Group 3 (148 pesticides/2247 tolerances) includes post-1984 pesticides

Tolerance Reassessment Status

3290 tolerances were reassessed by 30 July 1999 -
this achievement surpassed the goal of 33% within 3 years
(for a complete listing, go to /oppfead1/fqpa/toleran.htm)

Herbicide Reregistration Eligibility Decisions (REDs)

- Public comment for Alachlor, Dichlobenil, Propachlor, Triclopyr and DCPA REDs closed in '99
- Pebulate and EPTC REDs have been issued - open to public comment (www.epa.gov/reds)
- 60-day public participation period on Bensulide risk management was completed (8/99)
- Vernolate was voluntarily canceled
- Atrazine is on deck for 2000 (manufacturing of Cyanazine was phased out 12/31/99).

Risk Mitigation in Reregistration Eligibility Decisions (REDs)

Mitigation	#REDs
Canceled, deleted or declared not eligible	21
Restricted to use only by certifies applicator	14
Limited the amount, frequency or timing	32
Greater PPE or REI restrictions	13
Ground or surface water safeguards	19
Spray drift labeling	17

Risk Mitigation in EPTC (Eptam) RED

- Requires additional PPE (i.e., double layering or clothing and respirator) and engineering controls (i.e., enclosed cab).
- Prohibits certain application for homeowner use and reduced maximum rate from 15 to 5 lbs product per acre (due to its residential use, the 10X safety factor will be retained for all risk assessments).
- Requires registrant to identify threatened or endangered species adjacent to treated areas.

FQPA Directives

Reducing risk from pesticides under FQPA

- Aggressive reregistration and tolerance reassessment schedule
- Expedite reviews of new, safer 'reduced risk' chemistries

New Active Ingredients Registered Under FQPA

- 48 new reduced-risk conventional pesticides and biopesticides (62%)

New Uses Registered Under FQPA

- 774 new uses for reduced-risk conventional pesticides and biopesticides (78%)

What can you do?

- Be informed - visit the EPA and USDA websites
- Get involved - contact the EPA Chemical Review Manager (CRM) for your pesticide
- If you do not know the CRM for your pesticide, contact Pat Cimino at cimino.pat@epa.gov for assistance
- Provide real-world use patterns (e.g., rate, PHI, number of applications) to the CRM
- If you work with an at-risk pesticide on a minor crop, contact the IR-4 Project (732-932-9575 or 530-752-7633):
  - to conduct risk mitigation studies to modify the current use pattern and reduce exposure or,
  - to request residue trials for safer, alternative pesticides

Biotechnology - The Big Picture

Tobi Jones, Ph.D.
California Department of Pesticide Regulation

Biotechnology: The Early Days
- Early 1970's: Emergence of recombinant DNA technology
- 1978: NIH guidelines prohibit environmental release of rDNA organisms without approval
- 1983: UC Berkeley field test of Ice Minus approved
- 1983-1987: Lawsuits/environmental analysis delay field test
- 1983-1984: Congressional hearings on government preparedness

Coordinated Framework for the Regulation of Biotechnology
- 1984: White House appoints committee under Office of Science and Technology Policy
- Framework published in 1986
- Outlines agency roles, responsibilities
- Framework still used today by federal agencies

Coordinated Framework Principles
- Techniques of biotechnology are not inherently risky
- Regulate products, not process
- Use existing laws
- National Academy of Sciences agreed on risk issues

Federal Regulatory Oversight - USDA
- Jurisdiction: Plant pests, plants, veterinary biologics
- Laws: Federal Plant Pest Act
- Activity: Permits or notification, non-regulated status determination

Federal Regulatory Oversight – FDA
- Jurisdiction: Food, feed, food additives, veterinary drugs, human drugs, medical devices
- Laws: Federal Food Drug and Cosmetic Act
- Activity: Novel foods policy; consultation; food additive petition; labeling as needed

Federal Regulatory Oversight - EPA
- Jurisdiction: Microbial and plant pesticides, new uses of existing pesticides, novel microorganisms
- Laws: Federal Insecticide Fungicide, and Rodenticide Act; Federal Food, Drug and Cosmetic Act; Toxic Substances Control Act
- Activity: Registration or exemption (FIFRA); tolerance/exemption (FFDCA); reporting/exemption/field tests (TSCA)

Plant Pesticides

- EPA proposed rules in 1994
- Covers *genes and gene products* to protect plants against pests
- Plants are not subject of regulation
- Definition is broad; proposed rule contains FIFRA 25(b) exemptions

Herbicide Tolerant Plants

- EPA regulating the herbicide, not the plant
- Not subject to plant pesticide rule
- May require new tolerances, label

POSTERS

Cooperative Weed Management Areas

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Weed Management Areas (WMAs) are local organizations that bring together landowners and managers (private, city, county, State, and Federal) in a county, multi-county, or other geographical area for the purpose of coordinating and combining action and expertise in combating common invasive weed species. The WMA functions under the authority of a mutually developed memorandum of understanding (MOU) and is subject to statutory and regulatory weed control requirements. A WMA may be voluntarily governed by a chairperson or a steering committee. To date, groups in California have been initiated by either the leadership of the County Agricultural Commissioner's Office or a Federal Agency employee. WMAs are unique because they attempt to address agricultural (regulatory) weeds and "wildland" weeds under one local umbrella of organization. It is hoped that participation will extend from all agencies and private organizations. WMAs have; printed weed I.D./control brochures, organized weed education events, written and obtained grants, coordinated demonstrations plots, instituted joint eradication and mapping projects as well as many other creative and effective outreach and weed management projects.

For further information about WMAs in general, see the California WMA website at http://www.cdfa.ca.gov/wma *or contact Steve Schoenig at the California Department of Food and Agriculture,* sschoenig@cdfa.ca.gov

Cooperative Sierra Yellow Starthistle Mapping and Assessment Project

Steve Schoenig[1], Aaron Queheillalt[1], Larry Shields[2]
1) IPC, CDFA. Sacramento California, 2) Office of Roadsides, Caltrans

The California Department of Food & Agriculture (CDFA) and CALTRANS are teaming together to fund and lead a project to coordinate a multi-agency mapping of yellow starthistle (YST) at mid-elevations on the central and south-western Sierra. The project will also map YST on State highway right-of-ways in the central-western Sierra. One of the main products of this activity will be a report that will identify areas of high and low priority for stopping the spread of YST.

Yellow starthistle is estimated by the CDFA to cover over 12 million acres in California and is completely beyond total statewide eradication. Such a project would cost billions of dollars and engage tens of thousands of people for many years. Currently, the major activity devoted towards YST is focused on reducing infestation levels in areas where YST is very abundant. However, YST is still moving into non-infested watersheds. There are large areas, including private land and public forests and parks, that can still be protected from the presence of YST in whole watersheds and valleys. In areas like the mid-elevation western Sierra slope, control efforts should focus on prevention of further spread and on local eradication. Agencies and private landowners need better information on where to prioritize this type of control and eradication so that they are making the most effective use of their budgets.

CDFA and CALTRANS, with support from the County Agricultural Commissioners, members of the California Interagency Noxious Weed Coordinating Committee, and local Weed Management Areas, propose mapping of YST by a few hundred resource management professionals, qualified amateurs, and landowners. Mapping will be carried out at a fairly high level of resolution and put into a Geographic Information System. Primary areas of focus will include public lands and roadway easements. A secondary focus will be on the mapping of YST on private land.

Weed Free Forage and Mulch in California

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Hay, raw feeds, and straw can contain germinable weed seeds if grown in fields where weeds are allowed to produces seeds, or rhizomes. These weeds can be spread into new areas by domesticated animals and mulches used for erosion control. Verifying that animal feed and mulch is weed free before it is used in an area can prevent the spread of weeds. Prevention programs are much simpler and cheaper than detection, control, or eradication programs for weeds that are already established.

After the final approval of the Sierra Nevada Framework, lands under the jurisdiction of the Forest Service will close to those not using Certified Weed Free Forage; and it is expected that Bureau of Land Management, and National Park Service will follow suit. The closure has a three-year timeline: the first season (tentatively 2000) there will be implementation of a certification and education about what the closure means for land users. The second year, enforcement will be limited to warnings to those not in compliance. The third year, total enforcement will occur.

The California Agricultural Commissioners and Sealers Association (CACASA) formed a Weed Free Forage Committee California to develop and implement a weed free certification program which will comply with Weed Free Forage requirements on Federal Lands in the Sierra Nevada. Materials included in this program are: hay, grains, straw, and mulch. The committee has to date adopted procedures for certifying forage as “weed-free”. They are currently working on documentation procedures. Finalizing the certification program should happen at the Spring Conference of the California Agricultural Commissioners.

Montana started its Noxious Seed Free Forage Program in 1972. Since then, the idea has spread, and now almost all the Western States have or are working on Weed Free Forage certification programs. Several states also have closures to non-certified forage applied on Federal lands. Colorado has additionally closed lands managed by its Department of Wildlife to non-certified forage.

For more information contact Karl Bishop (510) 283-6365 or Joanna Clines (559) 294-4938.

Preventing the Purple Plague from Taking over California's Wetlands

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The California Department of Food and Agriculture (CDFA) was recently awarded a grant by the CALFED Bay-Delta Program to conduct a purple loosestrife prevention, detection, and control program. Purple loosestrife is a showy ornamental that has escaped home gardens and nurseries and moved extensively throughout the wetlands of the United States causing immense ecological destruction. Loosestrife is listed by the CDFA as a "B" rated noxious weed and as a "species with potential to spread explosively" by the California Exotic Pest Plant Council. Based on historic records, the distribution of purple loosestrife is currently in multiple, mostly small and scattered populations, in the Sacramento-San Joaquin Delta system and nearby hydrological units. However, infestations of purple loosestrife often follow a pattern of establishment, maintenance at low numbers, and then dramatic population increase when conditions are optimal.

Purple loosestrife, which spreads primarily by copious production of seed the size of ground-pepper, threatens to become established and forms dense stands that crowd out native wetland vegetation and associated wildlife, thus threatening the overall biodiversity of aquatic, wetland, and riparian areas. The complex interface between farm land and water in the Bay-Delta estuary also provides rich and varied habitat for wildlife, particularly waterfowl. The displacement of valued flora and fauna and the diminishment of critical fish and wildlife habitats by purple loosestrife infestations has been well documented throughout the United States.

Primary program objectives will be to conduct: (1) a broad education and training campaign, (2) extensive surveying and mapping, (3) a collaborative assessment meeting of cooperators to develop site specific adaptive management plans, resulting in (4) comprehensive local management, control, and eradication efforts, and (5) monitoring. The geographical focus will be on the Sacramento-San Joaquin Delta watershed where there are a number of threatened and declining species due to a multitude of environmental stressors. The project will be an extensive collaborative effort with: CDFA Integrated Pest Control Branch District Biologists, County Agricultural Commissioners, local Weed Management Areas, CA Department of Boating and Waterways, the CA Department of Fish and Game, CA Parks and Recreation, U.S. Fish and Wildlife Service, USDA-ARS Resource Conservation Districts, and local watershed groups, amongst others.

For more information please contact Carri Benefield, Purple loosestrife Project Coordinator, (916) 654-0768, cbenefield@cdfa.ca.gov.

Annual Morningglory (*Ipomea* Spp.) Control In Cotton

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Tulare, Madera, Tulare, Madera Counties

Abstract

Annual morningglories (*Ipomea* spp) are difficult to control with existing cultural and herbicide programs in cotton. The objectives of these studies in 1997 and 1999 were to evaluate: increasing rates of Staple, tank mixes of Staple with UN-32, tank mixes of Staple with MSMA, increasing rates of Valor, tank mixes of Valor with Roundup Ultra, and tank mixes of Valor with MSMA. In 1997 all rates of Staple + Agridex gave partial control of emerged annual morningglory in Acala cotton. The addition of 5 gallons of UN-32 fertilizer to Staple increased control in all rates of Staple. UN-32 fertilizer alone gave some control. Cotton injury was slight for 14 days following treatments. The addition of UN-32 to Bladex gave better control of annual morningglory than the Bladex + Agridex, however cotton injury increased. In 1999 Valor + Agridex gave excellent control of emerged annual morningglory, however cotton injury was severe almost killing most plants. The tank mixes of Valor + MSMA and Valor + Roundup Ultra also gave excellent control of annual morningglory and purple nutsedge. The addition of Roundup Ultra, the tank mixes of Roundup Ultra with Bladex and Goal also gave excellent control of annual morningglory and black nightshade.

Introduction

Ivyleaf morningglory (*Ipomea hederacea*) and tall morningglory (*Ipomea purpurea*) are the predominant species in the San Joaquin Valley. Annual morningglories *(Ipomea* Spp.) climb over cotton plants, interfere with defoliation, harvest, and are difficult to control with current herbicide programs. Roundup Ready cotton is limited by its early herbicide timing and cotton injury on later timings. The BXN cotton program is limited by rates. The current labeled rates in California is too low for effective control. Herbicide combination may be more effective.

Materials and Methods

In 1997, Acala Maxxa field near Visalia, California was divided into a randomized complete block design with four row plots and four replications. Cotton was 14” tall with 12 nodes. Seedling morningglory was in the cotyledon to small twining stage. Herbicides were applied in 20 gpa with a Hagie high cycle sprayer at 25 psi using 8002 flat fan nozzles at 2 mph. Treatments were applied June 6 and June 23, 1997. Air temperature and wind speed for the applications were at 75^{o}F and 0-3 mph. Ratings were taken at 7, 14, 21, and 28 days after treatment (DAT).

In 1999, Roundup Ready field near Tulare, California was divided into a randomized complete block design with six row plots and four replications. Cotton was 9" tall with 9 nodes. Seedling morningglory was in the 3-leaf stage to small twining stage. Herbicides were applied in 20 gpa with a Hagie high cycle sprayer at 20 psi using 2.5 flood jets nozzles at 2.4 mph. Treatments were applied June 24, 1999. Air temperature and wind speed for the applications were at 98^{o}F and 0-2 mph. Ratings were taken at 7, 14, and 21 days after treatment (DAT).

Results and Discussion

In 1997 at the conventional site, Staple + Agridex rates gave partial control of emerged annual morningglory. The split application did not affect weed control (Table 1). There was little cotton injury with Staple treatments (Table 2). Bladex + Agridex, Caparol + Agridex, and Goal + Latron gave good control of annual morningglory (Table 1). There was no injury at 28 days after treatment for any treatment. A second flush of annual morningglory came through all treatments following irrigation.

In 1997 all rates of Staple + Agridex gave partial control of emerged annual morningglory (Table 1). The addition of 5 gallons of UN-32 fertilizer to Staple increased control in all rates of Staple. UN-32 fertilizer alone gave some control (Table 1). Cotton injury was slight for 14 days following treatments. The addition of UN-32 to Bladex gave better control of annual morningglory than the Bladex + Agridex, however cotton injury increased (Table 2).

In 1999 Roundup Ready site Valor + Agridex rates gave excellent control of emerged annual morningglory, black nightshade, and purple nutsedge (Table 3, 4, & 5). The combination rates of Valor with MSMA and Roundup Ultra also gave excellent control of emerged annual morningglory, black nightshade, and purple nutsedge (Table 3, 4, & 5). All treatments with Valor had a high rate of cotton injury killing most of the plants (Table 6). Roundup Ultra, Roundup Ultra + Goal, and Roundup Ultra + Bladex gave good control of emerged annual morningglory and there was little cotton injury with those treatments (Table 6).

Table 1. Annual Morningglory Control in Maxxa Cotton- Tulare County 1997.

Treatment	Rate/A	14 DAT	21 DAT	28 DAT
Staple	.09 oz	55	51	43
Staple	.14 oz	51	44	23
Staple	.04 oz	43	38	40
B. Staple	.04 oz			
Staple	.06 oz	48	30	45
B. Staple	.06 oz			
Staple	.09 oz	53	44	70
B. Staple	.09 oz			
Staple + MSMA	.09 oz + 2 pt	58	66	84
Gramoxone	.8 pt	73	65	48
Gramoxone	1.2 pt	80	85	50
Gramoxone	1.6 pt	89	85	43
UN-32	5 gal	13	18	5
Bladex + UN-32	2.4 pt + 5 gal	56	45	60
Caparol + UN-32	3.2 pt + 5 gal	83	84	78
Staple + UN-32	.09 oz + 5 gal	58	51	50
Bladex	2.4 pt	83	79	55
Caparol	3.2 pt	86	74	65
Goal	4 pt	78	63	48
Bladex + Goal	2.4 pt + 2 pt	90	83	90
Untreated	-----	0	0	0

Table 2. Cotton Injury in Maxxa Cotton- Tulare County 1997.

Treatment	Rate/A	14 DAT	21 DAT	28 DAT
Staple	.09 oz	0	3	0
Staple	.14 oz	0	0	0
Staple	.04 oz	0	0	0
B. Staple	.04 oz			
Staple	.06 oz	0	0	0
B. Staple	.06 oz			
Staple	.09 oz	0	3	0
B. Staple	.09 oz			
Staple + MSMA	.09 oz + 2 pt	0	3	0
Gramoxone	.8 pt	16	23	63
Gramoxone	1.2 pt	15	30	58
Gramoxone	1.6 pt	23	36	71
UN-32	5 gal	8	0	0
Bladex + UN-32	2.4 pt + 5 gal	9	5	0
Caparol + UN-32	3.2 pt + 5 gal	14	6	0
Staple + UN-32	.09 oz + 5 gal	6	3	0
Bladex	2.4 pt	14	4	0
Caparol	3.2 pt	19	15	33
Goal	4 pt	14	10	0
Bladex + Goal	2.4 pt + 2 pt	15	10	5
Untreated	-----	0	0	0

Table 3. Annual Morningglory Control in Roundup Ready Cotton- Tulare County 1999.

Treatments	Rate/A	7 DAT	14 DAT	21 DAT
Roundup Ultra	2 pt	75	80	91
Roundup Ultra + Caparol	2 pt + 1.6 pt	81	80	88
Roundup Ultra + Bladex	2 pt + 1.2 pt	88	94	96
Roundup Ultra + Goal	2 pt + 2 pt	91	94	
Roundup Ultra + Dual Magnum	2 pt + 1 pt	79	75	79
Valor	.126 lb	100	100	100
Valor	.188 lb	100	100	100
Valor + MSMA	.126 lb + 2.6 pt	98	100	100
Valor + Roundup Ultra	.126 lb + 2 pt	100	100	100
Untreated	-----	0	0	0

Table 4. Black Nightshade Control in Roundup Ready Cotton- Tulare County 1999.

Treatments	Rate/A	7 DAT	14 DAT	21 DAT
Roundup Ultra	2 pt	79	86	93
Roundup Ultra + Caparol	2 pt + 1.6 pt	85	90	100
Roundup Ultra + Bladex	2 pt + 1.2 pt	79	88	100
Roundup Ultra + Goal	2 pt + 2 pt	86	93	93
Roundup Ultra + Dual Magnum	2 pt + 1 pt	79	91	100
Valor	.126 lb	80	93	99
Valor	.188 lb	90	98	100
Valor + MSMA	.126 lb + 2.6 pt	88	98	100
Valor + Roundup Ultra	.126 lb + 2 pt	75	95	99
Untreated	-----	0	0	0

Table 5. Purple Nutsedge Control in Roundup Ready Cotton- Tulare County 1999.

Treatments	Rate/A	7 DAT	14 DAT	21 DAT
Roundup Ultra	2 pt	37	70	100
Roundup Ultra + Caparol	2 pt + 1.6 pt	45	80	95
Roundup Ultra + Bladex	2 pt + 1.2 pt	45	50	75
Roundup Ultra + Goal	2 pt + 2 pt	82	83	100
Roundup Ultra + Dual Magnum	2 pt + 1 pt	45	75	100
Valor	.126 lb	78	83	89
Valor	.188 lb	80	85	92
Valor + MSMA	.126 lb + 2.6 pt	83	98	98
Valor + Roundup Ultra	.126 lb + 2 pt	85	90	96
Untreated	-----	0	0	0

Table 6. Cotton Injury in Roundup Ready Cotton- Tulare County 1999.

Treatments	Rate/A	7 DAT	14 DAT	21 DAT
Roundup Ultra	2 pt	0	0	0
Roundup Ultra + Caparol	2 pt + 1.6 pt	21	5	3
Roundup Ultra + Bladex	2 pt + 1.2 pt	36	29	25
Roundup Ultra + Goal	2 pt + 2 pt	28	11	3
Roundup Ultra + Dual Magnum	2 pt + 1 pt	8	3	3
Valor	.126 lb	83	90	90
Valor	.188 lb	85	90	90
Valor + MSMA	.126 lb + 2.6 pt	86	93	93
Valor + Roundup Ultra	.126 lb + 2 pt	81	91	91
Untreated	-----	0	0	0

Noxious Times Newsletter

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The Noxious Times is a quarterly newsletter sponsored by the California Interagency Noxious Weed Coordinating Committee (CINWCC). This publication provides agencies and local staff with relevant information on noxious weed control throughout California. By providing news, policy information, and program reports from specific agencies, the Noxious Times serves as a resource for those interested in sharing information and coordinating efforts against noxious weeds.

Look us up on the web at: www.cdfa.ca.gov/noxioustimes

Sign-up today, Add a friend! There are three ways to add a colleague or neighbor to the mailing list:

(1) Write to 1220 N Street, Room A-357, Sacramento CA 95814, (2) Requests by e-mail to www.cdfa.ca.gov/noxioustimes or (3) Calls to (916) 654-0768.

Table 6. Cotton Injury in Roundup Ready Cotton- Tulare County 1999.

Treatments	Rate/A	7 DAT	14 DAT	21 DAT
Roundup Ultra	2 pt	0	0	0
Roundup Ultra + Caparol	2 pt + 1.6 pt	21	5	3
Roundup Ultra + Bladex	2 pt + 1.2 pt	36	29	25
Roundup Ultra + Goal	2 pt + 2 pt	28	11	3
Roundup Ultra + Dual Magnum	2 pt + 1 pt	8	3	3
Valor	.126 lb	83	90	90
Valor	.188 lb	85	90	90
Valor + MSMA	.126 lb + 2.6 pt	86	93	93
Valor + Roundup Ultra	.126 lb + 2 pt	81	91	91
Untreated	-----	0	0	0

Noxious Times Newsletter

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Broadleaf Weed Control With BXN (Bromoxynil) Transgenic Tolerant Cotton

Ron Vargas[1], Steve Wright[2], Brian Marsh[3], Tomé Martin-Duvall[1], Mark Keeley[3]
[1] University of California Cooperative Extension, Madera County, [2] University of California Cooperative Extension, Tulare County, [3] University of California Cooperative Extension, Shafter Research and Extension Center, Kern County

Abstract: Broadleaf weeds including annual morningglory (*Ipomoea spp.*), black and hairy nightshade (*Solanum spp.*), lambsquarter (*Chenopodium album*), and pigweeds (*Amaranthus spp.*) are major weed pest of cotton in California. Chinese thornapple (*Datura furox),* though not as common, is becoming more prevalent. BXN transgenic tolerant cotton has been developed which allows over the top applications of bromoxynil (Buctril) throughout the season. Control of these and other broadleaf weed species has been excellent.

Buctril was applied to Stonville BXN 47 cotton in several trials over the top at the 2 to 4 leaf stage and post directed at various timings at rates of 0.5 to 1.0 lb ai/A during the 1997, 98 and 99 seasons. Buctril was also tank mixed with Bueno6 (MSMA), Staple (pyrithiobac sodium), Prism (clethodim), Poast (sethoxydim) and Fusilade (fluazifop-p-butyl). Trials were conducted in Madera, Fresno, and Kern counties.

In 1997, Buctril exhibited excellent control when applied alone over- the-top of 2 to 4 leaf cotton to seedling morningglory or followed by a post directed Buctril application at 90 to 96 percent control 35 days after the initial treatment(DAT). Staple followed by MSMA also provided excellent control. There was no adverse effect to cotton growth and development with any of the treatments tested.

In 1998, at 7 DAT, the Buctril treatments exhibited significantly greater control of morningglory than Staple at 68 percent compared to 40 and 48 percent. From 14 to 43 DAT, the Staple treatments exhibited significantly greater control at 80% compared to Buctril followed by MSMA at 45%. With no further treatments morningglory growth in all treatments completely over grew the cotton resulting in entire crop loss.

In 1999, Buctril + Bueno 6 provided the greatest control (87%) of morningglory at 7 DAT with the Buctril Staple tank mix providing 60% control. After cultivation and hand removal of morningglory Buctril and Bueno6 applied to morningglory with 2 or less true leaves again exhibited the greatest control at 100 percent at 7 DAT to 95 percent at 16 DAT. When applied to morningglory greater than 2 true leaves, control was reduced by 50 to 70%.

In other studies, at 21 DAT, all treatments except Bueno 6 alone exhibited excellent control of Chinese thornapple at 97 to 100 percent. At 14 DAT, Buctril (either alone or tank mixed) exhibited excellent control of black and hairy nightshade and lambsquarter at 95 to 100 percent. When tank mixed with any of the grass herbicides, the efficacy of Buctril on pigweed was severely reduced at 4 to 5 percent control.

End of the Era of Uniform Herbicide Applications?

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Introduction

Environmental improvements and reduced costs may be derived by reducing pesticide use through precision application of chemicals only to areas with pest infestations instead of treating entire fields at uniform rates. Methods of spatial statistics (geostatistics) are developed to describe variation, develop maps, and improve sampling of weed populations.

Material and Methods

Commercial fields with processing tomatoes were used for the research. The fields were located in Yolo county, California. In 1998 and 1999 weed densities were recorded by field sampling on a grid using a hand held data logger with a Differential Global Positioning System. Grid spacing was 150 ft (= 30 rows) across rows and 170 ft along the row. Weed seedling densities were monitored during the tomato season. Weed densities were counted in $0.25m^2$ quadrat at every grid point. Counts were recorded for individual weed species.

Geostatistical methods were used to quantify weed densities by using GS+ software. The geostatistical procedure is useful for obtaining weed infestation maps with reasonable sampling size. Semivariogram interpolation (kriging) was done for calculating weed densities between sampling points as a basis for selective spraying. The number of neighboring points used in kriging was chosen based on the results of the cross-validation. Contour maps were constructed showing the estimated barnyardgrass density. The percentage of the field with various densities of barnyardgrass was plotted against hypothetical threshold values to examine scenarios involving selective control. The locations of weed-free area in two consecutive years were compared to assess the accuracy of predicting weed infestation from previous years.

Results and Discussion

Barnyardgrass (*Echinochloa cruss-galli*) and black nightshade (*Solanum nigrum*) accounted for approximately 80 % of the total weed counts in both years 1998 and 1999. Original data did not follow a Gaussian distribution and were log-transformed. Semivariograms of transformed data were plotted. The least squares procedure was used to fit the model to sample variogram.

Within high density areas the plants were spatially related within 60 ft. At larger scale, the percentage of autocorrelation was about 85 %, indicating that, within the range of 450 ft, there was a 85 % variation in seedling density explained by the distance between points. The large scale variability might be due to field cultivations and harvesting procedures.

The area of field free of barnyardgrass plants reached 30 % in 1998 and 40 % in 1999. About 50 % of the field had less than 5 plants of barnyardgrass per square meter in both years. About 17 % of the field had no weeds in both subsequent years. If the simple selective application strategy with on-off nozzle function is implemented, a herbicide saving of up to 30 to 70 % could be achieved.

Conclusions

Weed species occur in a spatially aggregated pattern. More abundant species are less aggregated and their spatial pattern approach the random distribution. Less abundant weed species are highly aggregated.

The edges of the fields are more weedy than areas inside the field under conventional herbicide treatments.

Under the uniform herbicide application, weed clumps remain stable.

Geostatistical methods can be used to make weed maps.

Fields can be separated into areas with no weed infestation and areas with similar related weed densities.

The field weed maps provide data on the spatial pattern of weed infestation which, together with a weed treatment strategy, could be used to generate treatment maps.

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Throw Your Shears Away

Poems by David Haskell

The Sanchez Brothers

The younger brother had come for his paycheck.
Saturday was payday at the Sanchez Ranch.
That 80 acres of leased gravel and weeds.
It was this farming family's last chance.

The ranch was a hillside homestead,
with a slope that would tire a goat.
The old well was slow on the recharge,
and could barely keep the rain-birds afloat.

The older brother found an FHA loan,
To grow bell peppers for the fresh market.
But without the support of a growers co-op,
it was a decision he would come to regret.

He had to sort and pack his daily pick,
without cooling or chlorination.
And load the truck trailer with the hope,
it would survive a one-day destination.

But last week's pick had turned to mush,
Four hundred cartons of green stained glue.
And the LA market just dumped the load.
There was nothing else they could do.

To the younger brother, it was just an excuse,
another week without any pay.
Another breach of their kitchen contract.
Another season asking him why does he stay.

He anger flashed and he jumped his brother.
A rematch of many childhood fights.
Now fueled with an adult's frustration.
He was going to "kick his ass" all right.

Their bodies slammed the side of my pickup.
It rocked from their vengeance and rage.
And their father and I sat trapped inside,
by the despair that hung like a cage.

Still equally matched, they finally stopped,
To hurl threats and allegations.
And the youngest brother finally broke the ties.
To win the fight to become someone.

Throw Your Shears Away

A pruner needs a pair of sharp shears,
to make the cuts to shape a new life.
And a tall ladder made with seasoned wood,
and sturdy steps to bear the stretching and strife.

The family orchard needs pruning every season,
after the foliage have dropped from the trees.
And the branches and limbs show their true character,
that may be hidden by the beauty of the leaves.

Now the rains have started and the ground is soft,
so set your ladder with a firm hand.
And push those legs through the deceptive mud,
to the plow pan to make the best stand.

Cut out those shiny green suckers,
they'll only rub the other limbs wrong.
Like all parasitic relationships.
They only take and they don't belong.

Cut out the blight and the deadwood.
Keep your trees free from beetles and disease.
Cut out the deadwood hanging in your life.
Those prejudices will only block the breeze.

When you're pruned as high as the third step.
Give the ladder a shake with your weight.
It's good to test the strength of your values,
when a fall would not be a serious mistake.

Cut the new growth back to one leader,
to keep the limbs focused and strong.
Thin out the branches and fruit wood,
to awaken new buds when spring comes along.

When you finally see the tops of the other trees,
its time to stop and enjoy the view.
The climb up this ladder is a long one.
And the moments at the top are few.

Sometimes, the ladder can start to slip,
when you're ten feet off the ground.
And your heart climbs up into your throat.
You've got a second to look around.

Then, the old farmers words come to you,
"Throw your shears away", if you're going down.
"Throw away your ego and that pride.
They will only cut you when you hit the ground".

Reach out for a limb that could save you.
That extended arm now can bear the weight.
And lower yourself safety to the ground.
Its time to let the family decide your fate.

Bearings, Belts and Chains

"Bearings, belts and chains, that's all this combine is".
When I asked what he would do, if the machine was his.
"The wood is still good and she looks complete.
But she's still just an antique".
And the mechanic left us at the Agronomy lot,
where she sat parked, marked "out of stock".

She had a simple technology, born of necessity,
To feed a nation at war.
To harvest the crops and save the seed.
To build a new world, the US would lead.
And her partner in this noble endeavor,
was the farm advisor, to pull all the levelers.
To translate the University's R and D,
into plots and trials that the farmer could see.

Now today's ag economy is a global spinning wheel.
And information is the currency that drives these business deals.
But this wealth failed to reach the deficits ringing in the U.C. halls.
So the Regents decided the Internet could make those annoying farm calls.
They offered the advisors a "Golden Handshake" to mark them "out of stock".
Now many of them sit parked at the back of the Agronomy lot.

But Mother Nature is a fickle partner to do business with, indeed.
And years of experience are now lost when they retired this special breed.

The Lakay*

Maximo was a simple man.
He made a living working with the land.
But he had lived a full life.
You could see it in the lines in his hands.

He left his island nation with nothing.
The steam freighters came and carried them away.
And dropped the survivors in Hawaii,
to cut sugar cane for a dollar a day.

When he finally reached the Golden State.
The Depression was grinding men's souls.
He followed the pickers and "help wanted" signs,
and lined up behind the Okies from the Dust Bowl.

The brothers finally settled in Fremont,
leasing ground to start their own farm.
Then the Japanese bombed Pearl Harbor.
And war hysteria sounded the racial alarm.

When their neighbors were shipped off to "camp",
the brothers saved their farm from looters in town.
And they made enough money during the war years,
to buy their own piece of fertile valley ground.

Maximo was a quite man.
But when he spoke he had something to say.
"Too much water make the plants lazy.
They will just throw their blossoms away".

He was not an educated man,
but he understood nature's ways.
And the natural cycles of life and death,
and the seasons that can't be changed.

Water was his silent partner.
Together they brought the seeds to life.
And he raised generations of vegetable crops.
Along with five children and a wife.
Now its time for him to join the water,
to rest in the same earthen bed.
Let us lay him down in this furrow,
to find the peace that is reserved for the dead.

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* Lakay is a Tagalog word for "old man" said in respect.

Watsonville

Watsonville is the best fishin hole,
I know.

At Hansen's, the Amigos give Ruben a beer,
to tell them the story, they always love to hear.
How he caught a "Chevy" with the big John Deere.
Aye, I was discing the home ranch on 129.
When I saw this kabron, coming in his "low" ride.
So I made my next turn a little wide,
and I buried that disc deep in his side.
He fought hard, spun us both around.
He must have weighted at least three thousand pounds.

Bobby's bragging again down at the Trucker's Café.
About his last fishing trip to the Monterey Bay.
Well, I saw that bobbing orange antenna ball.
So I set the diesel engine stall.
I set the hook with a hard right swerve,
and my trailer drove the car up over the curb.
And the sound of folding metal was all I heard.
Now I was a little worried, to tell you the truth.
Until that driver popped up, out of the sunroof.

Down at the Junction, the engineers have always thought,
that Casey's fifty-footer was the largest ever caught.
They still talk about the trophy that he got.
He hooked that tired trucker one morning at five,
when the gates were stuck at Riverside Drive.
Gaffed with the coupler, behind the driving wheel.
Gutted him on the spot, peeling back the steel.
And the berries and cherries spilled out of that van,
like fruit cocktail from a forty-foot can.

I told you about the best fishin hole,
I know.
Beware, they might catch you there.

Milestone ™* (Azafenidin):
A New Pre-Emergent Herbicide for Citrus

Stephen S. Deitz and Hugo T. Ramirez
Sawtooth Ag Research and E. I. duPont de Nemours & Company, Inc.
**registration pending*

Introduction

Weed control in citrus usually consists of a winter-applied pre-emergent material and several applications of post-emergent materials throughout the spring and summer. Some weeds, such as common groundsel, *Senecio vulgaris* L., in the winter and prostrate spurge, *Euphorbia maculata* L., in the summer have shown tolerance to some pre-emergent materials. In addition, flax- leaved fleabane, *Conyza bonariensis* (L.) Cronq., has become a problem because some standard pre-emergent programs are ineffective and it is difficult to control with most post-emergent materials. Milestone 80 DF TM (Azafenidin) is a new pre-emergent herbicide developed by E. I. duPont de Nemours & Company, Inc. In two trials, Azafenidin (Milestone) was tested in two young citrus orchards to evaluate weed control spectrum, longevity and safety to young citrus.

Materials And Methods

Ivanhoe Site

The Ivanhoe site consisted of three-year-old citrus trees, planted in loam soil, recently grafted over to Late Powell Navel. Azafenidin was applied at 8, 12, and 16 oz ai/A. Norflurazon (Solicam DF) and Thiazopyr (Visor 2E) were the grower standards in this trial and applied at 64 oz ai and 64 fl. oz /A, respectively. Glyphosate (Roundup Ultra 4 SL) was added to each treatment at 1.0 lb. ai/A. Treatments were administered with a CO_2 backpack sprayer attached to a hand-held flat boom, housing six nozzles 20 inches apart. Treatments were mixed to volume and applied at 30 GPA and 30 psi. Each plot was 20 ft wide (1 swath on each side of a tree) and 40 ft. long. The trial was set up in a randomized complete block design, with four (4) replications. The application was made on January 16, 1999 and incorporated three days later with over 0.4 inches of rain.

At the time of application, several weed species were present, including: coastal fiddleneck, *Amsinckia intermedia* Fisch. & Mey; common mallow, *Malva neglecta* Wallr.; shepherdspurse, *Capsella bursa-pastoris* (L.) Medic.; annual bluegrass, *Poa annua* L.; red-stem filaree, *Erodium circutarium* (L.) L'Her. Ex Ait.; and flax- leaved fleabane, *Conyza bonariensis* (L.) Cronq. Post-emergent weed control was evaluated at 14 and 27 DAA (DAA= Days after Application), and then all plots were over-sprayed with Glyphosate in preparation of pre-emergent weed emergence data. Pre-emergent weed control was evaluated at 65, 95, and 120 DAA by noting species present and recording the number of each weed in each plot.

Elderwood Site

This trial was conducted in a four-year-old citrus orchard, (c.v. Thompson Improved), planted in clay loam soil. Azafenidin was applied at 8, 12 and 16 oz ai/A. For comparison, Simizine (Princep 90 WP) and Diuron (Karmex 80 DF) were applied as a tank-mixture at 25.6 + 25.6 oz ai/A and Thiazopyr was applied at 64 fl. oz/A. Treatments were applied with a CO_2 backpack sprayer attached to hand-held flat boom, housing six nozzles 20 inches apart. Treatments were mixed to volume and applied at 30 GPA and 30 psi. Each plot was 20 ft wide (1 swath on each side of a tree) and 28 ft. long. The trial was set up in a randomized complete block design, with four replications. The application was made on January 20, 1999, and incorporated two hours later with over 0.8 inches of rain.

At the time of application no emerged weeds were present. Weed control was evaluated at approximately 118, 160, and 191 DAA, by noting species present and recording the number of each weed in each plot. Plots were over sprayed with Glyphosate at 118 and 161 DAA to clean up the plots and reset untreated areas.

Results

Ivanhoe Site

Post-Emergent Weed Control

At 27 DAA, all rates of Azafenidin + Glyphosate showed 100% control of all weeds evaluated except for flaxleaved fleabane (98 to 100% control) (Table 1). These levels of control by Azafenidin were observed as early as 20 DAA. Glyphosate tank-mixed with non post-emergent herbicides, Norflurazon and Thiazopyr gave 100% control of fiddleneck, 98 to 100% control of annual bluegrass, 68 to 70% control of fleabane, 38 to 50% control of shepherdspurse, and less than 20% control of common mallow and red-stem filaree (Thiazopyr + Glyphosate showed 50% control of filaree) at 27 DAA.

Table 1: Post-Emergent Control (% Control) at 27 DAA.

Treatment	Shepherdspurse	Annual Bluegrass	Red-Stem Filaree	Common Mallow	Flax-leaved Fleabane
Azafenidin - 8 oz ai/A	100	100	100	100	98
Azafenidin - 12 oz ai/A	100	100	100	100	98
Azafenidin - 16 oz ai/A	100	100	100	100	99
Norflurazon - 64 oz ai/A	38	98	20	18	70
Thiazopyr - 64 fl. oz/A	50	100	50	18	68

Pre-Emergent Weed Control

By 95 DAA, the untreated averaged 213 fleabane and 28 mallow plants per plot (Table 2). Azafenidin applied at 8, 12, and 16 oz ai/A had 60, 59, and 12 fleabane per plot, respectively. The Norflurazon and Thiazopyr treatments averaged 21.3 and 18.6 fleabane plants per plot, respectively. No treatment of Azafenidin , Norflurazon, or Thiazopyr showed any mallow emergence at 95 DAA. The untreated also had 14 annual sowthistle, *Sonchus oleraceus* L., and 5 common chickweed, *Stellaria media* (L.) Vill., plants per plot. The 8 oz ai/A rate of Azafenidin had 3.8 sowthistle per plot, while all other treatments showed no annual sowthistle emergence. The lower two rates of Azafenidin had 1 to 2 chickweed per plot, while the highest rate of Azafenidin and Norflurazon had no chickweed emergence. The 8 oz ai/A rate of Azafenidin also showed 12 panicle willowweed, *Epilobium paniculatum* Nutt. Ex T. & G., plants per plot. Small populations (less than 0.5) were found in the 12 oz ai/A rate and Norflurazon plots. No panicle willowweed was found in the 16 oz ai/A rate of Azafenidin. The untreated was also void of panicle willowweed because of competition with other weeds. For comparison, the Thiazopyr treatment averaged 14.6 willowweed plants per plot. Summer annual weed emergence was observed at 95 DAA with 132 tumble pigweed, *Amaranthus albus* L., plants found per plot in the untreated (Table 2). All Azafenidin treatments showed no pigweed emergence except the lowest rate (1.3 pants per plot). Norflurazon averaged 26 pigweed plants per plot at 95 DAA, while no pigweed was observed in the Thiazopyr plots.

At 120 DAA, the untreated averaged 175 fleabane plants per plot (Table 3). Azafenidin applied at 8 and 12 oz ai/A had 141 and 115 fleabane per plot, while the 16 oz ai./A rate had 40 per plot. For comparison, Norflurazon and Thiazopyr had 33 and 21.6 fleabane plants per plot, respectively. The untreated also showed high pressure of mallow and sowthistle (63 per plot each). All treatments showed no mallow emergence, except Thiazopyr (1.6). The lowest Azafenidin rate, Norflurazon, and Thiazopyr showed sowthistle populations at 6.3, 1.8, and 1.6 plants per plot, respectively. The 12 to 16 oz ai/A rates of Azafenidin showed no sowthistle emergence. The untreated had 25 prostrate knotweed, *Polygonum aviculare* L., plants per plot at 120 DAA. The lower two rates of Azafenidin had some knotweed emergence (2.8 and 1.3 plants per plot), while the highest rate and Norflurazon showed no knotweed emergence. Azafenidin applied at 8, 12, and 16 oz ai/A had 7.8, 2.5 and 0.5 willowweed per plot, while Norflurazon averaged 1.3 per plot (Table 4). Thiazopyr continued to show weakness against willowweed with 15 plants emerged per plot.

Summer annuals emerged at 120 DAA included tumble pigweed and annual grasses (predominately junglerice, *Echinochloa colona* (L.) Link). The untreated averaged 200 pigweed and 34 grass plants per plot. Azafenidin applied at 8, 12, and 16 oz ai/A had 18, 3, and 0.8 pigweed plants per plot, respectively, while Norflurazon had 26 and Thiazopyr averaged 12. No grass had emerged in any treated plot by 120 DAA (Table 4). A total weed count at 120 DAA revealed that the untreated plots averaged 581 plants per plot. Azafenidin applied at 8, 12, and 16 oz ai/A had 185, 126, and 41 plants per plot, respectively, corresponding to 69, 79, and 93% control when compared to the untreated (Table 5). For comparison, Norflurazon and Thiazopyr averaged 64 and 59 plants per plot, respectively, corresponding to 89 and 90% weed reduction.

Table 2: Average Number of Weeds Plants per Plot at 95 DAA.							
Treatment	Flax-leaved Fleabane	Tumble Pigweed	Common Mallow	Prostrate Knotweed	Annual Sowthistle	Common Chickweed	Panicle Willowweed
Untreated	213	132	28	25	14	5	0
Azafenidin - 8 oz ai/A	60	1.3	0	3	3.8	1.5	13
Azafenidin - 12 oz ai/A	59	0	0	1.3	0	1.3	0.3
Azafenidin - 16 oz ai/A	12	0	0	0	0	0	0
Norflurazon - 64 oz ai/A	21	26.3	0	0	0	0	0.5
Thiazopyr - 64 fl. oz/A	19	0	0		0		14.5

Table 3: Average Number of Weeds Plants per Plot at 120 DAA.				
Treatment	Flaxleaved Fleabane	Tumble Pigweed	Annual Sowthistle	Common Mallow
Untreated	175	200	63	63
Azafenidin - 8 oz ai/A	141	18	6.3	0
Azafenidin - 12 oz ai/A	115	2.5	0	0
Azafenidin - 16 oz ai/A	40	0.8	0	0
Norflurazon - 64 oz ai/A	33	26.3	1.8	0
Thiazopyr - 64 fl. oz/A	22	12	1	1.6

Table 4: Average Number of Weeds Plants per Plot at 120 DAA.						
Treatment	Panicle Willowweed	Prostrate Knotweed	Junglerice	Common Lambsquarters	California Burclover	Prostrate Spurge
Untreated	0	25	34	18	5	0
Azafenidin - 8 oz ai/A	7.8	2.8	0	0.5	4.8	5
Azafenidin - 12 oz ai/A	2.5	1.3	0	0	0.5	5
Azafenidin - 16 oz ai/A	0.5	0	0	0	0	0
Norflurazon - 64 oz ai/A	1.3	0	0	0.5	2	0
Thiazopyr - 64 fl. oz/A	15		0			0

Table 5: Average Number of Weeds Plants per Plot at 120 DAA.	
Treatment	All Weed Species
Untreated	581
Azafenidin - 8 oz ai/A	185
Azafenidin - 12 oz ai/A	126
Azafenidin - 16 oz ai/A	41
Norflurazon - 64 oz ai/A	64
Thiazopyr - 64 fl. oz/A	59

Elderwood Site

Because the Elderwood site did not have a high pressure of winter annuals, the results discussion will focus on summer annual weed control. Summer annuals started to emerge by 118 DAA (Table 6). The untreated plots averaged 19 puncturevine, *Tribulus terrestris* L.; 2.3 witchgrass, *Panicum capillare* L.; 5.5 tumble pigweed, *Amaranthus albus* L.; 25 lovegrass, *Eragrostis cilianensis* (All.) E. Mosher; and 6 prostrate spotted spurge, *Euphorbia maculata* L, plants per plot. Puncturevine was the only summer annual observed in Azafenidin treatments at 118 DAA, though in low populations. Azafenidin applied at 8 oz ai/A had 0.3 puncturevine per plot, while the 12 and 16 oz ai/A rates showed no puncturevine. Simizine + Diuron had 9 puncturevine, 12 witchgrass, 2 tumble pigweed, and 3 lovegrass plants per plot. Thiazopyr showed little or no summer annuals except 2 pigweed per plot and a low population of prostrate spurge (less than one plant per plot).

By 161 DAA, the untreated showed 20 lovegrass and 40 junglerice plants per plot. Azafenidin applied at 8, 12, and 16 oz ai/A showed 7, 2, and 5 lovegrass per plot, respectively, and 10, 6, and 2 junglerice (Table 7). Simizine + Diuron averaged 3.0 lovegrass and 16 junglerice per plot, while Thiazopyr had no grass emerged at 161 DAA. The untreated also showed 15 to 16 pigweed and puncturevine per plot. Azafenidin applied at 8, 12, and 16 oz ai/A had 2, 0.3, and 0 pigweed and 2.5, 2.8, and 0.3 puncturevine per plot, respectively (Table 7). Simizine + Diuron showed no new pigweed emergence and an average of 11 puncturevine plants per plot. Thiazopyr had less than 1 plant per plot of either puncturevine or pigweed.

At 190 DAA, the grass population in the untreated averaged 10 lovegrass, 18 junglerice, and 11 feather fingergrass, *Chloris virgata* Swartz, plants per plot. Emergence in the untreated and Simizine + Diuron plots was hindered because of the residue of previous weeds through the season blocked sunlight to the soil. Azafenidin applied at 8, 12, and 16 showed 18, 9, and 6 junglerice per plot, respectively and 7, 5, and 5 lovegrass, with little or no fingergrass (Table 8). Simizine + Diuron averaged 13, 4.3, and 0.8 junglerice, lovegrass, and fingergrass, respectively per plot. Thiazopyr showed little grass emergence at 190 DAA with 1.5, 0.5 and 0 junglerice, lovegrass, and fingergrass per plot.

Broadleaf weeds present in the untreated at 190 DAA included an average of 13 pigweed and 9 puncturevine per plot. Azafenidin applied at 8, 12, and 16 oz ai/A showed 6, 2, and 0.5 pigweed per plot, respectively; and 4, 4, and 0.8 puncturevine per plot. Simizine + Diuron averaged 4 pigweed and 14 puncturevine per plot, while Thiazopyr had 8 pigweed and 4 puncturevine per plot at 190 DAA (Table 8).

Table 6: Average Number of Weed Plants per Plot at 118 DAA.					
	Little Lovegrass	Puncturevine	Witchgrass	Prostrate Spurge	Tumble Pigweed
Untreated	25	19	2.3	6	5.5
Azafenidin - 8 oz ai/A	0	0.3	0.6	0.1	0
Azafenidin - 12 oz ai/A	0	0	0	0	0
Azafenidin - 16 oz ai/A	0	0	0.3	0	0
Simizine + Diuron (25.6 + 25.6 oz ai/A)	2.5	8.8	12	0	2.3
Thiazopyr (Visor) - 16 oz ai/A	0	0.3	0.3	0.8	2.5

Table 7: Average Number of Weed Plants per Plot at 161 DAA.				
Treatment	Little Lovegrass	Junglerice	Tumble Pigweed	Puncturevine
Untreated	20	41.3	15.3	16.3
Azafenidin - 8 oz ai/A	7.3	10	2	2.5
Azafenidin - 12 oz ai/A	2.3	5.5	0.3	2.8
Azafenidin - 16 oz ai/A	5.3	2	0	0.3
Simizine + Diuron (25.6 + 25.6 oz ai/A)	3	15.5	0	10.8
Thiazopyr (Visor) - 16 oz ai/A	0	0	0.3	0.8

Table 8: Average Number of Weed Plants per Plot at 190 DAA.				
Treatment	Junglerice	Little Lovegrass	Feather Fingergrass	Tumble Pigweed
Untreated	17.5	10	11	12.8
Azafenidin - 8 oz ai/A	17.5	7.3	0.3	5.6
Azafenidin - 12 oz ai/A	8.8	5	0	2.3
Azafenidin - 16 oz ai/A	5.5	5	0	0.5
Simizine + Diuron (25.6 + 25.6 oz ai/A)	12.5	4.3	0.8	4.1
Thiazopyr (Visor) - 16 oz ai/A	1.5	0.5	0	8.3

Conclusions

Azafenidin provided excellent post-emergent activity (>98% control) at 27 DAA against all weeds tested at the Ivanhoe site when tank-mixed with Glyphosate. Azafenidin tank-mixed with Glyphosate (1 lb ai/A) showed a significant increase in post emergent control on common mallow, red-stem filaree, flaxleaved fleabane, and shepherdspurse when compared with Glyphosate tank-mixed with pre-emergent standards of Norflurazon or Thiazopyr.

Azafenidin applied at 8 to 16 oz ai/A showed excellent pre-emergent weed control on a broad spectrum of weeds. At the Ivanhoe site, all rates of Azafenidin showed nearly 100% control of the following weeds: common mallow, annual sowthistle, tumble pigweed, junglerice, and common lambsquarters, *Chenopodium album* L., at 120 DAA. The 16 oz ai/A of

Azafenidin rate showed nearly 100% control of California burclover, *Medicago polymorpha* L.; panicle willowweed and prostrate spurge. By 120 DAA, the 8 oz ai/A rate of Azafenidin did show weakness on panicle willowweed, California burclover, common chickweed and spurge. The lower two rates (8 and 12 oz ai/A) of Azafenidin showed 75% reduction of fleabane at 95 DAA, however, by 120 DAA, fleabane control broke for both rates. The 16 oz ai/A rate of Azafenidin showed fleabane control comparable to Norflurazon and Thiazopyr at 120 DAA. At the Elderwood site, all rates of Azafenidin showed excellent control of the following summer annuals at 118 DAA: lovegrass, puncturevine, witchgrass, tumble pigweed, and prostrate spurge.

Azafenidin gave long-term weed control. At the Elderwood site, all rates of Azafenidin gave excellent control of all summer annual weeds that had emerged in the untreated at 118 DAA. By 161 DAA, Azafenidin gave adequate grass control and excellent broad-leaf control. By 190 DAA, Azafenidin applied at 16 oz ai/A was still showing excellent pigweed and puncturevine control at the Elderwood site. Azafenidin showed significantly longer weed control than the grower standard of Simizine + Diuron. When compared to Norflurazon and Thiazopyr, Azafenidin tended to give longer control of broadleaves such as puncturevine and pigweed, but control broke down sooner on grass species such as junglerice and lovegrass.

Azafenidin was safe to citrus trees. No phytotoxicity was observed on the citrus trees in either trial at any evaluation date.

Post and Preemergence Weed Control in Tree Crops with V-53482

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V-53482, with the active ingredient flumioxazin, is being developed by Valent U.S.A. Corporation as a low use rate preemergence broadleaf herbicide for use in soybeans, peanuts, sunflowers, sugarcane, grapes, and almonds. V-53482 is also being developed for post directed applications in cotton and sugarcane. In conventional-tillage soybean and sunflower herbicide programs, V-53482 controls problem broadleaf weeds such as common ragweed, common lambsquarters, pigweeds, black nightshade, tall and common waterhemp, and prickly sida. In no-till and reduced-tillage programs, V-53482 aids rapid burndown and offers residual control (4 to 6 weeks) of broadleaf weeds.

In 1999, V-53482 was tested in tree and vine crops in CA for post and preemergence weed control. A trial was conducted in peaches to evaluate both post and preemergence activity. The trial was in the Reedley, CA area and was applied to the middles of one year old peaches. Each plot was 6.6 ft. X 30 ft. and each treatment was replicated 3 times. The materials were applied on 2/10/99 with a back pack sprayer that delivered 24 gpa at 43 psi. At application weeds present were: chickweed (3 to 8" wide), shepherdspurse (2 to 4 " tall), annual bluegrass (3 to 4 leaf and 1 to 1.5 " tall), common groundsel (2 to 3" tall), and henbit (2 to 3 " wide and 1.5 to 2 " tall). V-53482 was tested at 0.1, 0.19, 0.25 and 0.38 lb ai/A alone and in mixes with Roundup at 1.0 lb ai/A (all with Agridex at 1.0% v/v). V-53482 at 0.1 lb ai/A plus Roundup was also tested with AG 98, Silwet 77, and no adjuvant. Roundup was tested alone at 1.0 lb ai/A and Goal at 0.5 lb ai/A was tested w/ and w/o Roundup. Postemergence activity was rated at 7, 16 and 22 days after treatment (DAT). The 22 DAT evaluations are presented with this poster.

Preemergence control was evaluated later in the season by using the Valor 0.1, 0.19, 0.25, and 0.38 lb ai/A treatments that were in mixes with Roundup and Agridex. A Roundup alone treatment was used as the comparison for preemergence activity. The Goal + Roundup treatment was also evaluated even though the Goal rate used was for postemergence control. Weeds were "burned off" in these plots after the postemergence ratings so that the preemergences activity could be more easily evaluated. Preemergence evaluations were conducted at 63 and 112 DAT. The 112 DAT evluations are presented with this poster.

Postemergence results: V-53482 at 0.19, 0.25, and 0.38 lb ai/A w/o Roundup provided 100% postemergence control of chickweed and henbit. None of the V-53482 rates alone provided acceptable control of annual bluegrass (ABG), shepherdspurse, or common groundsel. When V-53482 was tank mixed with Roundup 100% control of these three weed species was achieved.

Preemergence results: V-53482 at all rates tested except the low rate of 0.1 lb ai/A provided good preemergence control of spotted spurge and prostrate pigweed with the highest rate of 0.38 lb ai/A being the most efficacious (98 and 100% control respectively). V-53482 provided only fair preemergence control of annual bluegrass. The two higher V-53482 rates provided about 70% ABG control while the 0.19 lb ai/A rate only provided 37% control.

High Temperature Solarization for Weed Control in Container Soil and Potting Mixes

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Summary

A "double-tent" solarization technique, which develops higher soil temperatures than solarization of open fields, was recently approved by the California Department of Food and Agriculture (CDFA) as a nematicidal treatment for containerized nursery production. The technique was tested for effect as an herbicidal treatment. Laboratory-derived thermal death dosages (temperature x time) for six weed species important in California [*Portulaca oleracea* (common purslane), *Amaranthus albus* (tumble pigweed), *Sonchus oleraceus* (annual sowthistle), *Sisymbrium irio* (London rocket), *Solanum nigrum* (black nightshade), and *Echinochloa crus-galli* (barnyardgrass)] were determined, as previously reported. In a field validation of the laboratory data, moist soil which was placed in black polyethylene (poly) planting bags containing seeds of the six test species was subjected to 24 hours of solarization after reaching a threshold temperature of 60 C (2 hours after initiation of the experiment). Other samples of weed seeds were incubated under ambient temperature (ca. 23 C). Samples were removed at 2, 4, 20, and 24 hours after reaching the 60 C threshold. They were then incubated at ca. 7 C for 12 weeks to ameliorate possible secondary dormancy effects. After the cold treatment, seeds were moistened and incubated at a temperature regimen of 16 hours at 30 C and 8 hours at 20 C, with exposure to a fluorescent grow-light during the 30 C cycle. Apart from the non-solarized control treatment, no weed seeds germinated at any of the sampling periods, in accordance with the laboratory thermal death data. The "double-tent" solarization technique may be useful to many growers of containerized plants in warmer areas of California.

Introduction

Maintaining soil and potting mixes free of weed infestation is essential for profitable nursery, greenhouse, and field production of high-value horticultural crops. In the case of nursery stock for farm planting, California law makes it mandatory that it be free of economically important nematodes (CCR Sections 3055-3055.6 and 3640). Producers of containerized nursery stock for transplanting in the San Joaquin Valley of California currently use different methods for obtaining pest-free planting substrate. Some purchase "virgin" soil or organic media from off-site locations, while others use various methods of chemical soil disinfestation, primarily methyl bromide. An alternative to methyl bromide is steam treatment, which necessitates expensive investments in steam generation equipment. We have developed a simple "double-tent" solarization method which provides soil temperatures in excess of 70 C (158 F) for pasteurizing soil or potting mixtures in warmer climatic areas (1). This technique was recently approved by the California Department of Food and Agriculture (CDFA) as a nematicidal treatment for containerized nursery plants (CDFA NIPM Item#12) as follows:

Solarization of soil until the temperature of all of the soil reaches a minimum of 158 F (70 C) that is maintained for at least 30 contiguous minutes. Soil must be either in polyethylene planting bags or in piles not more than 12 inches high. Soil in piles must be placed on a layer of polyethylene film, disinfested concrete pad, or other materials which will not allow reinfestation of soil, and covered by a sheet of clear polyethylene film. An additional layer of clear polyethylene film must be suspended over the first layer to create a still air chamber over the soil to be treated. Soil moisture content must be near field capacity. Soil temperature at the bottom center of the pile or bag must be monitored and recorded to ensure that the minimum temperature of 158 F (70 C) for 30 minutes is achieved. Following treatment, the soil and containers shall be protected from reinfestation by nematodes."

We previously reported on development of a thermal death database to predict efficacy of solarization for weed management in California (2). The database included the relatively high temperatures (50-70 C = 122-170 F) that would reached during the "double-tent" solarization technique. This paper describes a field validation experiment of "double-tent" solarization as an herbicidal treatment for container soil and potting mixes in the San Joaquin Valley.

Materials And Methods

Seed species and preparation. The six weed species used for experimentation were *Portulaca oleracea* (common purslane), *Amaranthus albus* (tumble pigweed), *Sonchus oleraceus* (annual sowthistle), *Sisymbrium irio* (London rocket), *Solanum nigrum* (black nightshade), and *Echinochloa crus-galli* (barnyardgrass). Seeds of each species were placed in nylon organdy bags and tied tightly with string. Each organdy sample bag contained 50 weed seeds mixed with approximately 11 g of field soil. One bag of each of the six weed species was then placed in the center of each black polyethylene (poly) nursery bag filled with field soil (soil mass ca. 18 x 15cm). Poly bags were watered thoroughly and allowed to drain overnight prior to initiation of the solarization treatment.

Solarization treatment. Five steel pallets (ca. 1.3 m x 1.3 m x 12 cm high) spaced 0.7 m apart were arranged in a north-south orientation in a field at the UC Kearney Agricultural Center (KAC). The soil beneath the pallets was covered by a sheet of black poly film. Four black poly bags, each containing bags of weed seeds of each experimental species were randomly distributed on each pallet. Soil temperature at the center of the soil mass in the poly bags was monitored with a Hobo® micrologger placed in a fifth bag on each pallet (replication). Air temperature and solar radiation data were monitored via CIMIS station #39 ('Parlier.A'; Fresno County) located at KAC ca. 300 m from the experimental site. Each pallet was covered with a sheet of transparent poly film which was stretched over the sleeves and anchored on all sides with soil in a shallow trench. Two metal hoops were placed over each plastic-covered pallet. A sheet of the transparent film was stretched over the hoops, creating a tent with ca. 23 cm space between the two plastic layers, and anchored on all sides as before. Five bags containing 100 seeds of each species were prepared as above and left in the laboratory at ambient temperature (ca. 23 C) to serve as controls.

Sample incubation. One poly bag of soil and weed seeds was removed from each pallet at four intervals (2, 4, 20, and 24 hours) after soil temperature in the center of the bags reached 60 C. Following removal from the pallets, poly bags were taken to the lab and left intact at room temperature for 48 hours. Organdy bags of weed seeds were then exhumed from the poly bags and placed in covered plastic crispers in an unlighted Revco® incubator at a temperature of ca. 7 C for 12 weeks to minimize the possibility of secondary dormancy. Bags of weed seeds were then removed, opened, the contents placed in a petri dish containing a disk of Whatman® #1 filter paper; then moistened with deionized water and placed in covered plastic crispers. The crispers were placed back in the incubator adjusted to a diurnal cycle of 16 hours at 30 C and 8 hours at 20 C, with exposure to a fluorescent grow-light during the 30 C cycle. Deionized water was added to petri dishes as needed to maintain moisture.

Germination data. Petri dishes were examined periodically and germinated seeds were counted and removed. Seeds were considered as germinated when the radicle had emerged and the plumule elongated to 3mm. Germination counts were done at intervals of 10, 12, 15, 20, 27, and 30 days after soil was placed in petri dishes and moistened.

Results And Discussion

Soil and air temperature and solar radiation accumulation. Experimental exposure of weed seeds to solarization began at 1300 hours on August 27, 1999 and ended at 1500 hours on August 28. Soil temperature at the beginning of the experiment was 32 C. The 60 C threshold temperature imposed for timing of weed seed heat dosage was reached at 1500 hours (two hours after treatment initiation); treatment continued for 24 hours after the temperature threshold was reached. Soil temperatures in black poly bags under the double-tented pallets reached maxima of 68 and 75 C on August 27 and 28, respectively; and a minimum of 16 C during the 24 hour period of treatment. During the treatment period, air temperature reached maxima of 38 C and 36 C; and a minimum of 17 C. Global radiation totaled 598 and 589 Langleys on August 27 and 28, respectively.

Weed seed samples incubated for 24 hours after the 60 C soil temperature threshold was achieved accumulated 10.1 hours above 50 C, 7.0 hours above 60 C, and 1.3 hours above 70 C, while samples incubated for 20 hours accumulated 10.1 hours above 50 C and 4.2 hours above 60 C. Samples incubated for two or four hours above the 60 C threshold also accumulated an additional one hour above 50 C.

Weed seed germination. After post-treatment incubation for 3 months in the cold and 4 weeks at plant growth temperatures, there was no germination in any of the seeds subjected to solarization. Weed seeds from the control treatment of all tested species germinated at levels of 11-42% of the original numbers.

Previous laboratory experiments with the same weed species used in this study showed that none could survive more than 20 minutes at 70 C, while the time of exposure at 60 C necessary to kill all seeds was 15 minutes (*E. crus-galli*, *S. erio*, and *S. oleraceus*), one hour (*A. albus*), two hours (*S. nigrum*), or three hours (*P. oleracea*). At 50 C, exposure times needed for 100% seed mortality ranged widely, from 4 hours (*S. oleracea*) to 113 hours (*A. albus*) (2). Results from the field validation experiment showed that even after the minimum dosage (one hour above 50 C, then two hours above 60 C), no seeds germinated from any of the species tested. These data agreed with the laboratory thermal death results. Although further field testing will be necessary to completely reconcile laboratory vs. field thermal inactivation data, it is clear that the solarization treatment tested can be useful as a low-cost alternative to methyl bromide or steam disinfestation for growers of containerized plants in the warmer areas of California.

References

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