Weed Management Decisions for Field-Grown Flowers

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Weeds are one of the many factors a grower must take into account to grow any flower crop. Weed management becomes an integral part of each management decision before, during and after the crop is grown. Weed seeds are present in the soil (seedbank) at all sites. Also, at many locations, weed seeds can be transported into the field by wind from adjacent areas or with water from off-site. Water pumped from a well does not pose this concern. Thus, weeds will always be present to grow with the crop.

Weeds often suppress crop growth during the early season. In any direct seeded crop, weed competition can be very detrimental during the first 4 to 6 weeks of the crop. In transplanted crops, competition is lessened but can be enough to reduce flowering, or time and uniformity of flowering. When selective herbicides can not be used, most often weeds that emerge with the crop are in the seed line. If selective herbicides can be used it will reduce the amount of hand weeding and allow much of the weed control to be with mechanical cultivation. There are many decisions that must be made as to what type and methods of weed management that is to be employed to successfully grow a profitable crop.

<u>Preplant</u>

Most cultivation is considered to be for weed control. Even the practice of planting in rows has been to facilitate weed removal with equipment. With small seeded flower crops, the soil needs to be mixed to form a good seed bed for planting, however with transplants or with larger seeded crops, a seedbed can be prepared with non-till planting equipment. Thus, if there was an advantage for weed control with one planting method or the other, the equipment is available to plant crops without extensive cultivation. If there are other pest problems such as nematodes or soil pathogens, then preplant soil fumigation needs to be considered and the soil needs to be worked finely (without clods) to allow the fumigant (methyl bromide, chloropicrin or 1,3-D) to move throughout the soil. Soil moisture and preparation is critical for maximum control with fumigation. With fumigants such as methyl bromide, 1,3-D or chloropicrin the soil moisture should be low, but not bone dry (15 to 30%). This allows the fumigant to move through the soil to kill the different organisms. If pesticides such as metam sodium or dazonet are used, they need to be mixed or placed into the soil where the pest organism resides since they do move easily throughout the soil profile, except with water. This placement can be done with the movement of irrigation water or by mechanically placing it at different depths in the soil with blades, sweeps or rotary tillers. If the soil is wet, then sprinkler irrigation over the metam will be helpful to increase control. Dazomet needs to be irrigated lightly cultivate, a gas flamer is used or a contact herbicide can be used. This keeps the soil from being turned and new weed seed being brought to the surface. If the purpose is to try and reduce the soil seedbank, then repeated cultivation's can be used to germinate and eliminate new seedlings. This is a long-term process and must be combined with eliminating new weed seed from entering the seedbank by stopping all weeds from seeding. Herbicides such as diquat (Reward) or glyphosate (Roundup or others) can be used on young weeds before planting then planting can be done a few days later without further disturbing the soil.

After Planting

After planting there are several weed control options. These depend upon the type of plant material that is planted (seed, propagule or transplant). Direct-seeded plantings needs the cleanest and finest seed bed with no weeds or trash. If weeds are present at seeding, then they will generally have a competitive advantage over the crop. If seeds or propagates are planted, there is a period of time when the weeds may germinate and grow before the crop emerges. This period if timed properly allows for a weed control practice such as flaming or a contact herbicide without soil residual before the crop emerges. This will allow the crop to emerge weed free.

Once a crop is planted there is an opportunity to apply an herbicide before the weeds emerge (preemergence, post plant). There are many flower crops where there is no known selective preemergence herbicide available. Information that is helpful for different crops can be obtained from local farm advisors offices, pest control advisors or from chemical company representatives. A practice that can help individual growers with each of their crops is to develop a spreadsheet program using each crop and indicate the selectivity such as in Table 1. The same type of spreadsheet can be developed for the herbicides and weed species on a particular farm (Table 2).

Preemergence herbicides can be selective on both weeds and crops. Depending upon which herbicide is used, there are certain weeds that will be controlled or weeds that are missed or not controlled. If an herbicide is selective in a crop then there will be certain weeds not controlled. These weeds must then need to be controlled in a different manner. Often this is done with cultivation or hand weeding. In fact, even in a crop where there are lots of control options, there is probably no management system where some hand weeding will not be needed. Selective herbicides will not give season-long control of all weeds. If weeds escape the various control treatments, then they need to be removed so there is no new seed produced to enter the seed bank.

Precision planting and cultivation can make a major difference in the ease of weed management. Setting up equipment so distances are exact such as row width, using guide markers for bed formation, and direction of cultivation can make close cultivation a reality. Since the crop rows are exactly the same distance apart, then cultivator tools such as disks, knives, shovels, duckfeet or even hooded spraying can be close to the crop row, without significant damage to the crop.

Post emergence herbicides

In most flower crops, selective post emergence herbicides are not available. There are exceptions however. For example, in Gypsophila or Limonium the preemergence herbicides Ronstar or Goal can control some broadleaf weeds post emergence and still remain in the soil to control additional weeds as they emerge. There are also herbicides that will selectively control most grass weeds in broadleaf crops. The herbicides sethoxydim and fluazifop do not control annual bluegrass (a common field weed) but clethiodim will control it. (see Table 2). These should be used when the weeds and crops are young for the least amount of crop damage from competition or from the herbicide. Weed susceptibility to post emergence herbicides in flower crops are shown in Table 2. There are no selective post emergence herbicides to control broadleaf weeds in most crops after the weeds are beyond the seedling stage. In these crops, hand weeding becomes a greater part of the total weed control program.

Weeds should be removed throughout the growing season to keep them from seeding. If this practice is routinely practiced then there will be a long-term reduction in the seedbank and a reduction in the number of weeds. A practice that is critical for weed management is to control weeds at the end of the cropping season. All to often I have seen fields where it appears that cutting has been completed and weeds are tall and going to seed. These fields should be cultivated or the weeds need to be removed to reduce weeds in following crops. This same practice can be suggested for the field edges as well since the seeds easily are farmed back into the cropping area of the field.

Planning a weed control program for the whole farm as well as each crop can decrease the weed populations over time and reduce the need for extensive weeding costs. The costs for additional weed control are higher in the first years of a program, but will decrease with the years. There are farmers in the San Joaquin valley that have almost quit using herbicides as well as many other weed control practices. Their weeding costs are a minimal part of the overall crop management budget.

Knowing what weeds are to be expected in a particular field can allow plans for control programs that can match the crop and program to reduce control costs. There is no way to eliminate all weed control needs. Only by putting all the potential methods together with all the other crop management needs, can a manageable program be established.

Table 1. Examples of Preemergence Herbicide Registration for California Flower Crops

		Preemergence herbicides										
Crop	**Barricade**	**DCPA**	**Devrinol**	**Dimension**	**Gallery**	**Goal**	**Linuron**	**Pendulun**	**Pennant**	**Ronstar**	**Surflan**	**Treflan**
Achillea				F					F			F
Alstromeria												
Anemone												
Anthirrhinum									F			F
Asparagus												
Aster		F	F									F
Astillbe									F			
Aven (Geum)									F			F
Banksia										F		
Calluna vulgaris	F				F					F		
Callistephus chenisus												
Campanula												
Carnation									F	F		F
Caesalpina												
Columbine									F			
Chrysanthemum		F										F
Dafffodil				F								F
Dahlia												F
Delphinium									F			
Erica quadrangularis												
Erica vagens					F							
Gaillardia		F							F			F
Gladiolus	F	F							F			F
Gypsophila		F				F				F		F
Helianthus												F
Helichtysum		F										
Hemerocallis							F		F			
Hosta		F							F			
Hyacinthus					F				F			F
Iris (Dutch)	F	F			F		F		F			F
Liatris spicata												
Limonium perezii					F					F		
Limonium sinuatum										F		
Limonium tartaricum										F		
Narcissus	F		F	F			F	F	F		F	F
Peony												
Protea										F		
Star of Bethlehem									F			
Tulip				F	F				F			F
Zinnia									F			F

F = field planted ornamentals

Table 2. Weed Susceptibility to herbicides that may be used in some flower crops.

		Preemergence herbicides							**Post emergence herbicides**						
	isoxaben	linuron	metam sodium	oryzalin	oxadiazon	oxyfluorfen	pendimethalin	trifluralin	clethodim	diquat	fluazifop	glyphosate	paraquat	sethoxydim	sulfosate
Annual Grasses															
annual bluegrass	N	C	C	C	C	P	C	C	C	C	N	C	C	N	C
annual ryegrass	N	C	C	C	P	N	C	C	C	P	C	C	C	C	C
barnyardgrass	N	C	C	C	C	P	C	C	C	C	C	C	C	C	C
crabgrass	N	C	C	C	C	P	C	C	C	C	C	C	C	C	C
wild oat	N	C	C	P	N	N	P	P	C	P	C	C	P	C	C
Annual broadleaves															
brass buttons	C	C	C	P	C	C	P	P	N	C	N	C	C	N	C
bur clover	C	C	P	N	C	C	N	N	N	C	N	C	C	N	C
chickweed	C	C	C	C	N	N	C	C	N	C	N	C	C	N	C
corn spurry	C	C	C	C	C	C	C	C	N	C	N	P	C	N	P
filaree	C	C	C	C	C	C	C	C	N	P	N	P	P	N	P
hairy fleabane	P	P	C	N	P	P	N	N	N	P	N	P	P	N	P
horseweed	P	P	C	N	P	P	N	N	N	P	N	C	P	N	C
knotweed	c	C	P	C	C	C	C	C	N	C	N	P	C	N	P
little mallow	C	P	P	P	C	C	P	P	N	P	N	C	P	N	C
mustard	N	C	C	N	C	C	N	N	N	C	N	C	C	N	C
purslane	C	C	C	C	C	C	C	C	N	C	N	C	C	N	C
red maids	C	C	C	C	C	C	C	C	N	C	N	C	C	N	C
stinging nettle	C	C	C	C	C	C	C	C	N	C	N	C	C	N	C
wild radish	N	C	P	N	C	C	N	N	N	P	N	C	C	N	C

C = controlled, P = partially controlled, N = not controlled

Comprehensive Management Programs for Turf

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Ornamental turf is often expected to be uniform and relatively weed free around commercial establishments. It is part of a look that says this property is well cared for and that people are paying attention to quality and details. This may be expressed as a desire for good "curb appeal" – a good first impression of the business or property. It may be part of a message that says "this company seems to care about the place where their employees work", or "this development seems to care about the place where the tenants live". Corporations in particular may want uniformity, security, control and hierarchy to be expressed in the landscape. They may want the landscape to tie the buildings together into a corporate presence. They may want the spaces that people walk through and look into to seem controlled. Perhaps they want some entrances to be "presented" as more important or differently than others.

When people are paying for a landscape service they expect the results of the service to match or exceed their expectations. Concepts such as sustainability, reducing green waste, using well adapted plants, and integrated pest management may not be important to the customer. However incorporating these concepts is important for the landscape management company because they reduce costs and make the management of the landscape more predictable and labor efficient. Many companies want to have a "good story" to tell visitors and employees. Help the customer make sound landscape management practices part of their story/identity. Try to explain the fertility program, e.g. what you are testing for, why fertilizing is done at certain times of the year, how you are trying to make efficient use of nitrogen fertilizer by grasscycling and why irrigation system upgrades save water and help reduce greenhouse gasses. Perhaps edging in the spring is a bad idea if crabgrass keeps growing in the edges. If the turf has had a history of getting weedy and then being dug up and replaced, point out to the customer that it does not have to be this way.

Weed Control Process

Do some Internet research about the weed or herbicide. I always check out http://axp.ipm.ucdavis.edu/, http://www.pace-ptri.com/ and http://gcsaa.expoventure.com/usercgi/texis/webinator/search. I also use Google and enter the weed and/or herbicide name and Elmore OR Cudney.

- Understand what the customer wants, their expectations about the service provider and their budget.
- Analyze the turf.
- Make a 90 day and yearly plan. Execute it. Be sure the money, labor and equipment resources are available for the key crabgrass/spurge preemergent window in late January/early February and, if *Poa annua* is a concern, in late August/early September. Be sure cool season turf receives fall and late fall (late November/early December) nitrogen fertility. Thoroughly check irrigation systems in February.

Identify the weeds.

One of the best ways to identify weeds is to use the Internet. A very good site is the UC IPM site: http://axp.ipm.ucdavis.edu/PMG/weeds_common.html. This site also lists books and other written references that can be used in the field.

The weeds that seem to cause the most customer concerns are crabgrass, kikuyugrass and bermudagrass in tall fescue - probably because they often don't get controlled. However any weed that disrupts turf uniformity may be a concern, especially if the weeds don't go away once pointed out. Also one weed near an entrance may cause more concern than a hundred weeds in turf behind a parking lot.

The weeds must be susceptible to herbicides you plan to use. Some broadleaf weeds are often difficult to control, e.g. *Oxalis*, spurge, knotweed, Canada thistle, yarrow, English daisy, black medic, and many other clover family weeds. Speedwells (*Veronica*) and pineapple weed are almost impossible to control unless the turf is vigorous. Annuals are usually difficult to control once they start to set seed.

- oxalis can only be systemically controlled with Turflon (triclopyr).
- nutsedge can only be systemically controlled with Manage. MSMA can be used to burn off the tops.
- grassy weeds are difficult or impossible to control, although crabgrass can be controlled preemergently.
- Do not let new turf get infested by bermudagrass or kikuyugrass. Crew must be trained to pick out invading plants as soon as they appear.

Many weeds that may be actively growing e.g. black medic or bur clover, false dandelions, and many thistles have small hairs that repel herbicides, and form thick cuticles during dry summer weather. Herbicides do not penetrate a thick cuticle well. Weeds that undergo frequent water stress are particularly hard to control for this reason.

Evaluate the need for preemergent herbicide

Crabgrass and spurge are major targets. Identify areas prone to crabgrass and spurge:

- crabgrass skeletons visible on lawn.
- thin, full sun areas.
- heat sinks (sidewalk, curb).

Target these areas for preemergent application.

Postemergence Crabgrass control

The most important part of crabgrass control is a good turf canopy. Crabgrass requires direct sunlight to grow. It will not grow well in the shade of a turfgrass canopy.

If crabgrass has emerged it must be controlled with postemergent applications (Acclaim or MSMA plus Dimension). The best time to control crabgrass is while it is still small in April or May. During this time the crabgrass is easy to control and the turf is still growing fast and will fill in. Customers usually don't notice the crabgrass until July. At this time the crabgrass is large and hard to control and the turf is growing slow and may not fill in. Dimension will keep crabgrass from coming back in these areas.

MSMA can be applied at high volume (2 to 4 gallons per 1000 SF) with a power sprayer. It is slightly more effective than Acclaim.

Prodiamine (Barricade) and pendimethalin have some postemergent control on very young crabgrass that has not tillered. This postemergent control is inconsistent.

Bermudagrass control in Tall Fescue turf

Repeat application of Turflon every four to six weeks will suppress bermudagrass.

Chemical programs must be combined with good cultural practices and often aeration/overseeding in the early fall. Remember that the bermudagrass is only suppressed not killed. If bermudagrass invasion is extensive, renovation is required.

Bermudagrass invasion of tall fescue is a common problem in California and Nevada. The extent of invasion is increased by:

- watering practices that allow the cool season grass to become stressed.
- mowing shorter than 2½ inches.
- other factors which slow down the growth of the desirable cool season turf, such as poor rooting, disease, or insect damage.

Bermudagrass will usually invade unless management practices are optimized for the cool season turfgrasses — tall fescue, bluegrass and ryegrass. Bermudagrass is much more drought tolerant than cool season grasses. If a lawn does not receive adequate water, bermudagrass will be favored. Bermudagrass is also more tolerant of short mowing heights. If mowing height is relatively low Bermudagrass again will be favored.

To judge adequate watering, look for areas of the turf that are thin and clumpy. This is a sign of poorly watered turf. As water becomes less available only the most vigorous and deeply rooted grass plants survive. During the fall and winter, when water is available, and vigorous growth resumes, the surviving grass plants become large clumps because there is little competition from surrounding plants.

Warm season grasses such as Bermudagrass grow well during the hot summer weather while cool season grass grows better during the spring and fall. One effect of poor water availability is an increase in temperature of the turf. When turfgrasses have plenty of water there is an evaporative cooling effect.

Kikuyugrass control in Tall Fescue turf

Control programs are similar to those for bermudagrass, since both are warm season invaders into cool season turf. There are three basic choices to make

1. Implement a kikuyugrass control program – Apply a mix of Turflon and MSMA herbicides 3 times at 6 week intervals starting in early May to stunt the kikuyugrass. Overseed with tall fescue after each herbicide treatment and again in the fall. Tall Fescue seed can be raked into Kikuyugrass without vertical mowing. Do not use preemergent herbicide if you are going to overseed.
2. Manage the kikuyugrass as the desirable turf – this requires verticutting 3 times per year in May, June and August. Kikuyugrass forms a yellowish-green, medium to coarse textured, aggressive, low growing turf that is difficult to mow and very prone

to thatching. Fertility must be low. After edging apply Primo growth regulator to slow the regrowth. Primo will also improve kikuyugrass appearance by making a tighter somewhat darker turf.

3. Renovate the turf – Kill all existing grass and weeds and sod or seed with tall fescue. Aggressive fall fescue varieties compete best with Kikuyugrass. If you do renovate you will have keep invading kikuyugrass out. If it was there before it will come back.

Poa annua control in Tall Fescue turf

Poa annua invasion is usually from irrigation problems. Poa annua is a prolific seed producer and will successfully invade any gaps in the turf. Herbicide programs have not been very successful. Do not use phosphate fertilizers unless soil tests show a need.

The turf should be receiving a proper turf fertility program.

- Good weed control requires competition from the turf. Turf competitiveness is increased with nitrogen fertilizer.
- Clovers and black medic can be difficult to control weeds. Clovers are legumes and are encouraged by phosphate, potash, and sulfur fertilizers. They can be controlled somewhat with fertilizers high in nitrogen and low in phosphate. Established turf, especially cool season turf, usually does not require much phosphate and potash.

Turf fertility is improved by recycling the clippings produced by mowing. Clippings should be left on the lawn whenever possible. The clippings contain significant amounts of turf nutrients. If these nutrients are removed by removing the clippings, more nutrients will have to be added by fertilization. Nitrogen fertility requirements are reduced by about ¼ to ⅓ by returning clippings. Analyze mowing practices to ensure that clipping return is maximized.

Keeping turf constantly wet during warm weather can result in loss of nitrogen fertilizer to the air (denitrification). This is wasteful of fertilizer and contributes to "greenhouse" gas accumulation. The soil surface should be allowed to dry between irrigations. The following series of microbe mediated reactions change plant available nitrogen to unavailable atmospheric nitrogen. Nitrous oxide is a greenhouse gas.

NO_3^- ----> NO_2^- -----> NO gas ------> N_2O gas --------> N_2 gas
Nitrate-->Nitrite--->Nitric Oxide-->Nitrous Oxide-->Dinitrogen

The following conditions are conducive to nitrogen fertilizer loss through microbial denitrification.

- Absence of oxygen from wet soil and thatch
- Warm temperature
- Easily metabolized organic matter from clippings, senesced turf and root exudates
- Presence of nitrate or nitrite

General Turf Fertility Guidelines

We can make accurate measurements of nitrogen, molybdenum, sulfur, copper and iron and other elements, but these measurements usually fail to provide usable information. Iron for example can be plentiful both in the soil and inside the plant; but iron can still be unavailable to the new tissues and therefore deficient to the plants needs.

- Test the soil for proper calcium, magnesium, and potassium balance and for the presence of adequate phosphorous. When clippings are removed test the soil once a year.
- Nitrogen fertility needs are assessed by turf density, growth rate, color and knowledge of seasonal needs.
- Color judgments alone tend to lead to overuse of nitrogen fertilizer.

There is no accurate soil test to determine nitrogen fertilizer need for turfgrasses.

Grass will rapidly take up available nitrogen. Also, the nitrogen status of a turf can vary rapidly. Today it can have excess, next week a lack. A soil analysis showing abundant soil nitrogen under turf would tend to indicate one of three things:

- Fertilizer has just been applied.
- The turf is sick.
- The turf is experiencing climatic adversity such as drought or heavy overcast.

A healthy well-irrigated turf growing with adequate sunshine will generally take up nitrogen fertilizer so rapidly that nitrogen fertilizer will drop to low levels in the rootzone within a few days of its application.

An analysis of clippings for nitrogen may show a good level of nitrogen however that may have no use. During a time of vigorous growth the same turf may be under-supplied with nitrogen a few days after collecting the sample.

A low value of nitrogen in clippings has excellent predictive value of a deficiency. However, we could already see the paler color of the grass when we took the sample so the analysis tells us nothing new.

Indicators of need for increased nitrogen fertility

- Weeds germinating and becoming established. Clover family weeds are a particularly good indicator.
- Worn spots showing up or failing to heal.
- Clipping production low - not enough growth for replacement of wear.
- Bare soil visible from above.

Different turf types (species) have different yearly nitrogen requirements; also turf will need less nitrogen if it is growing in shade or poor soil.

Turf that has not received much fertility in the past may need extra fertilizer to have good color. This is especially true when iron is used for color enhancement. Iron is only effective on turf that has active growth from regular fertilizer applications.

Athletic fields have a much higher nitrogen requirement. Wear tolerance comes from quantity of top growth and top growth is stimulated by nitrogen.

- Sometimes the soil can "tie up" nitrogen fertilizer[1]. This usually occurs in new areas where the topsoil has been removed or the soil has been mixed up so the topsoil is not on top or has been diluted. Over a period of several years the turf will make new topsoil. Aeration often helps speed up this process.
- A dull mower will make large brown wounds on the cut ends. This makes the turf look less green

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[1] One theory is that Bacteria dominate the microflora of these soils (http://www.soilfoodweb.com/lo1.html). Turf roots exude simple sugars to supports microbes in the root zone and bacteria are more competitive than fungi when the dominant energy source (food) in simple sugars. Bacteria have a C:N ratio of about 5:1 compared to the C:N ratio of 30:1. Over time fungi become established. Fungi consume bacteria and release nitrogen that becomes available to the turf.

Comprehensive Weed Management Program for Landscapes

Dave Hanson Environmental Industries

Objective: Review the Decision Making Process and Variables Involved in Selecting the Appropriate Weed Management Options

Decision Tree for Landscape Weed Management

Historical Thought Process

- Identify the weed/weeds
- Develop strategy based on plant species, time of year, irrigation, selectivity
  - Pre vs. Post vs. Manual
- Soil type
  - adsorption / potential for leaching / movement
- Application Equipment

**Today's Landscapes are Far More Diverse and Complex:
Many More Site-Specific Variables than in the Past**

Consider Some of the Variables from Landscape Perspective

- New vs. Renovated Landscape
- Slope vs. Flat Grade
- With Turf vs. Only Trees, Shrubs, Ground Cover
- Irrigated vs. Non Irrigated Landscape
- Mulched vs. Non Mulched Landscape
- Chemical vs. Non Chemical Options
- Potential for Staining

New vs. Old or Renovated Landscapes

- Wide Variation in Weed Species
  - Grass vs. Broadleaf species
  - Annuals vs. Perennials

Slope vs. Flat Grade

- Potential Difficulties with Application
- Possible Offsite Movement
- Creation of Special Problems

With Turf vs. Only Trees, Shrubs, Ground Cover

- Major Impact on Product Selection Control
- May also Affect Control Strategy

Irrigated vs. Non Irrigated Landscape

- Affects pattern of Weed Growth
- Can affect activation/degradation herbicide
- Potential impact on timing of application

Mulched vs. Non Mulched Landscape

- Mulch can help prevent weed outbreaks
- Mulch can impact herbicide activity
- Weeds do grow on Mulch

Chemical vs. Non Chemical Options

- Environmentally sensitive sites
- Regulatory exclusion

Potential for Staining

- Affects product selection
- Affects application technique

Bottom Line = Weed Management in Today's Landscapes Demands:

- More Customized Approach to Individual Sites
- More Frequent Evaluation of Variables

Comprehensive Weed Management in Landscapes is a Continuing Process

- Most Products Work Provided:

- Correct Weed Spectrum
- Proper Application Rate
- Optimum Activation
- Matching Highest Level of Herbicide Activity with Peak Germination of Target Weeds

Effect Of White Clover (*Trifolium repens*) Living Mulch On The Growth Of Tomato Plants (*Lycopersicon esculentum*) And Associated Weeds.

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Introduction

Living mulch effectively reduce soil erosion, fix atmospheric N in amounts almost sufficient for the need of the subsequent crop, improve soil organic content, increase soil water holding capacity, and reduce weed competition and damage caused by certain pests (Abdul-Baki et al, 1993). A living mulch system is more complex than conventional, clean-tilled systems and is not suited to all situations. On the other hand, only in creating a more complex, diverse agro-ecosystem is there a potential for beneficial interactions. The loss of diversity greatly weakens the tight functional links between species that characterize natural systems. As diversity increases, so do opportunities for coexistence and beneficial interference between species that can enhance agro ecosystem sustainability. Diversity – especially that of below ground performs a variety of ecological services that have impacts to both on and off the farm, such as nutrient recycling. Living mulches have poten! tial as an alternative approach for weed control that could allow an important reduction in herbicide dependency. (Hutchinson and McGiffen, 2000). Short-term economic incentives have discouraged the inclusion of living mulches making long-term soil maintenance increasingly difficult (Grubinger and Minotti, 1990).

Plants in association interfere with each other through environmental modification, allelopathy or competition. This is influenced by the environmental conditions, resource levels, growth characteristics of the interacting species and proximity factors such as density, species, proportion and spatial arrangement. The effect of intercropping tomato (*Lycopersicon esculentum*) and white clover (*Trifolium repens*) on tomato fruit yield, ground cover, weed suppression and tomato height measurements as an indication of interference were studied in test plots at California Polytechnic State University, San Luis Obispo. The experiment was conducted as a randomized complete block design with two treatments, three replications for the living mulch treatment and four replications for the pure stand treatment. The land for the experiment was prepared by conventional tillage, listed and shaped into raised beds 80 centimeters wide using a PTO-driven bed shaper.

Materials and methods

An experimental unit had four rows, with seven tomato plants in a row. Plant spacing was 35 cm between plants and 75 cm between rows. The living mulch seeds were broadcasted 06/20/00 at a rate of 30 pounds per acre. Tomatoes were transplanted on 07/20/00 and the fruit harvested between 10/10/00 and 10/25/00.

Results and discussion

There was no significant difference in the fruit yield obtained from the tomato pure stand and the intercropped treatment. The pure stand averaged 175 kg/ha as compared to the inter crop plots which averaged 152 kg/ha.

There was however a significant difference in weed cover between the two treatments. Weeds covered 58% of the ground surface in the pure stand nine weeks after transplanting the tomatoes, and only 21% in the intercrop system quadrant method. Using the transect method, it was 43.8% weed cover in the living mulch treatment and 25.8% in the intercrop system seven weeks after transplanting the tomatoes. In both treatments the most prevalent weeds were common mallow (*Malva neglecta*), redroot pigweed (*Amaranthus retroflexus*) and common purslane (*Portulaca aleracea*). Similar results were observed by Brandsaeter, 1998 whereby early in the season, there were no differences in weed biomass or numbers observed between a monocrop and a white cabbage living mulch treatment, but the weed biomass and numbers became significantly lower in the living mulch treatment late summer. In the same experiment, both subclover and white clover gave significantly more marke! table cabbage heads than monoculture due to less insect damage

Fig 1. Percentage groundcover seven weeks after transplant – transect method. Different letters mean significant differences exists between treatments $p<0.05$

Fig 2. Percentage ground cover nine weeks after transplant – quadrant method. Different letters mean significant differences exists between treatments $p<0.05$

Two weeks after transplanting the tomato, there was no significant difference in the tomato plant height between the two treatments, but this changed three and four weeks into the growing season. Crop-weed competition was more severe in the intercrop stand as evidenced by the stunted growth of the tomato plants. On average for the first two weeks, the tomato heights were 20.4cm and 30.2cm for the intercrop system and 26.4cm and 39.7cm for the monocrop system. The third and fourth weeks averages were 40.0cm and 44.6cm for the intercrop and 48.7cm and 53.0cm for the monocrop system respectively.

There was no significant difference in biomass harvested from a pure stand tomato plot (5.45 kg/plot) and an intercropped or living mulch stand (5.66 kg/plot). The lack of an effect on biomass by the treatments could be an indication that even with interference, there were still ample nutrients available, possibly including nitrogen fixed by rhizobia on the roots of the white clover.

Living mulch has shown considerable potential as a N source and a means of improving weed control in cropping systems. Simple models that can predict biomass production, N accumulation and supply, and water use for different planting windows would greatly assist growers in deciding the feasibility of including a living mulch in a given planting system. Successful mixed crop communities around the world offer fruitful ground for research on how avoidance of competition, or coexistence, plays an important ecological role in cropping systems.

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Resistance of Restored Central Valley Grassland Communities to Yellow Starthistle Invasion

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Introduction

Yellow starthistle (*Centaurea solstitialis*) is a highly invasive weed of Mediterranean origin which is spreading rapidly in California (Pitcairn et al. 1998). It displaces other vegetation and degrades the quality and economic utility of rangeland, public wild lands, roadsides, and recreational areas. This study explores the effectiveness of planting competitive native grassland species to reduce yellow starthistle populations and mitigate future weed invasions.

Potential benefits of restoring native grassland to reduce weed populations include:

1) Weed reduction through resource competition with the restored community.
2) Increased soil stabilization; decreased runoff and nutrient losses.
3) Irrigation is normally not required for establishment or maintenance.
4) Reduced fire hazard due to the relatively low thatch production of native grasses.
5) Forage production for livestock.
6) A diverse, established community may resist future weed invasions.

Our objectives are to 1) quantify and compare yellow starthistle reduction in different communities and 2) understand how light and water availability relate to a given community's resistance to invasion. The design simulates control of yellow starthistle for one year (using herbicides, tillage, or an integrated method), restoration of the native community on the cleared site, and subsequent reinvasion from the remaining yellow starthistle seed bank in the second year.

Materials and Methods

In December 2000, we planted different communities in 4 x 4 m plots on an agricultural field (sandy loam) in Davis, California. Each community contained six species, all of which were available from local native seed growers, are native to the region, and showed good potential for establishing on our site.

The communities were

Late season bunchgrasses and forbs.

1) Early season annual forbs.
2) A mixture of late season and early season species.
3) Exotic annual grasses (to be planted in 2002).

Yellow starthistle was seeded into the communities in December 2001 at a rate of three million seeds/acre. Our treatments included the four communities with yellow starthistle, the same communities without yellow starthistle, yellow starthistle alone, and bare ground. The design is a randomized complete block with five replicates.

The experiment will last three years. To quantify the effect of the restored communities on yellow starthistle and the effect of yellow starthistle on the communities, we will measure density, percent cover, and reproductive potential of each species in spring and summer. Biomass data will be collected after the third year. Soil moisture will be measured by inserting a neutron probe into a PVC tube in the center of each plot. Soil moisture measurements will be taken at depths of 30, 60, 90, 120, 150, and 180 cm below the soil surface. Light availability will be measured by inserting a ceptometer under the plant canopy.

Results and Discussion

Initial data (yet to be analyzed) indicate differences in water utilization between the communities. In September 2001, soil moisture under the late season community appeared to be lower at depths below 30 cm than beneath the early season community, with this difference appearing to increase at greater depths. Under the mixed community (containing both late and early season species), soil moisture appeared to be intermediate between the late season community and the early season community. Light measurements taken in December 2001 indicate an apparent reduction in light availability compared to bare ground in all communities, with the greatest reduction appearing to occur in the late season community.

The apparent reduction in deep soil moisture and light in the late season community compared to the early season communities indicates that late season species may be more effective competitors with yellow starthistle and other deep-rooted weeds than are early season species. Future data from this study will be combined with information from other studies to develop a cost-effective, site-specific protocol for reducing current and future weed invasions in California grassland.

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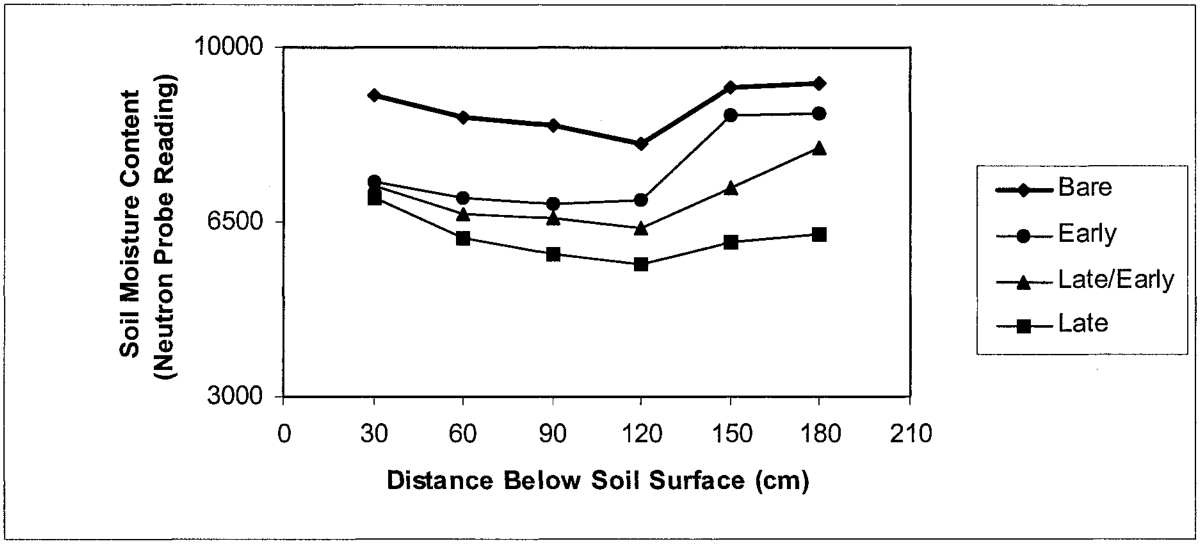
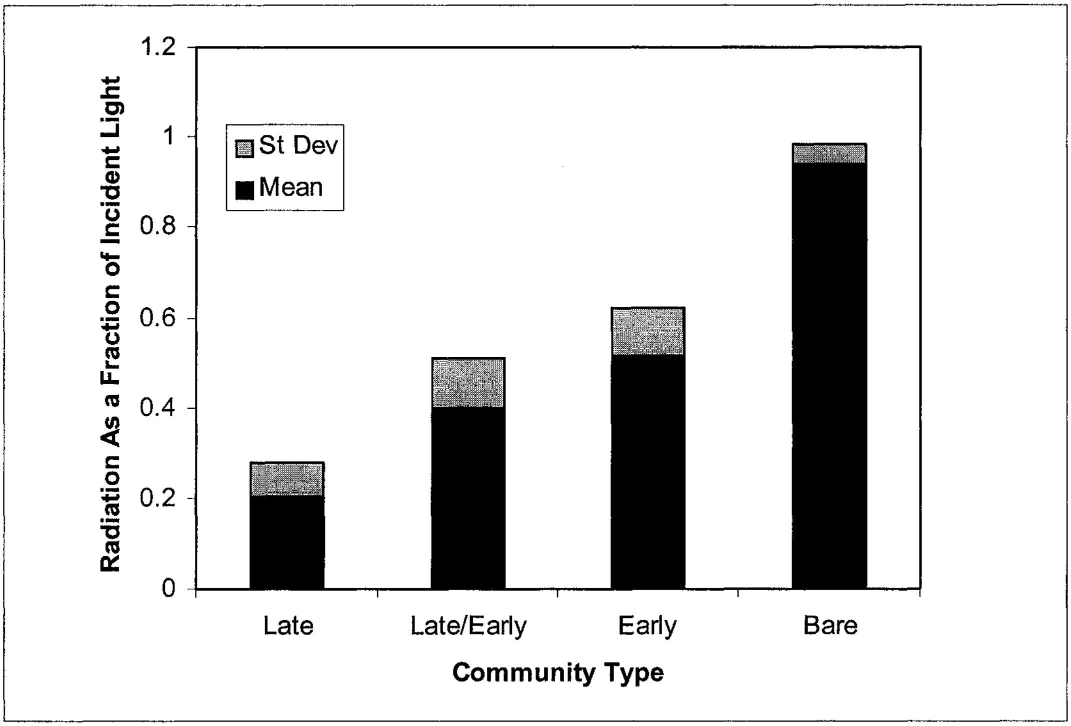


Community soil moisture profiles, 9/6/01 (error bars omitted).



Light penetration through community canopies, 12/4/01.

Presidential Address

New Millennium Weed Management: Challenges and Opportunities for the California Weed Science Society

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In considering the future directions of weed science and management it seems that we are at a transition not unlike that which occurred in the early 1970's with the formation of the US Environmental Protection Agency (EPA) and the amendments to the Federal Fungicide, Insecticide and Rodenticide Act (FIFRA). It was at that time that new requirements for certification of applicators were imposed and new classifications of certain pesticides were defined as "restricted use". States struggled to meet compliance deadlines and programs for training and continued education were initiated. To be sure, these changes were not viewed favorably by all weed control practitioners since it meant a radical shift in operations and placed more demands on everyone's time. This period also lead to improvements in product labeling aimed at increasing user-safety and reducing potential environmental impacts. Regardless of initial attitudes, the overall result has been a significantly heightened level of applicator knowledge, skill and environmental consciousness.

What is causing change now and how significant are recent shifts in approaches to weed management? In Table 1, I have listed some of what I believe are the most important drivers from both regulatory and socio-political arenas. Clearly, new technological innovations are moving weed management toward more precise and efficient methods; however from a broader societal view, the repercussions of trends and events represented in this table may have as much impact on how weed control will look in the decades ahead. Indeed, I will argue that without fundamental changes in science education-at the grade school level through adulthood- the gap between agriculture (and pest-management) and the lay-public will widen to the detriment of all.

Table 1. Regulatory and Social Challenges for California Weed Science and Management

- Demand for "organic commodities"
- Food Quality Protection Act
- Executive Order on InvasiveSpecies
- Plant Protection Act
- Genomics and Related Molecular Level Technologies
- NPDES Permits and Related Monitoring
- Public's Lack of "Weed Science Literacy" (Gap in K to 12 education)

Depending upon the commodity, organic market-demand is rising from 20 to 30% per year. Though it is still a minor component overall, this trend seems to demand more inclusion of both the science and the practitioner in CWSS. We will need to determine how best to achieve this.

Similarly, the newly defined requirements for a General National Discharge Elimination System permit (NPDES- Permit) for aquatic pesticide uses portends further environmental monitoring for all pesticide uses. The import (and impact!)of this is difficult to overstate. The US 9th District Court of Appeals in its ruling in Talent v. Headwaters last spring in essence made two fundamental changes to herbicide use, at least in western states under its jurisdiction: (1) compliance with current labeling is not sufficient to allow aquatic uses; and (2) herbicides, once entering water are to be considered a form of waste-discharge under the Federal Water Quality Act. The present scramble (amid confusion) to react to this regulatory tsunami in California, Washington and Oregon parallels the impact of above-mentioned 1970's EPA-mandated certification program- but with far less lead time. The Headwaters decision changed the compliance landscape virtually overnight. Monitoring protocols must be in place by July 2002 and the demand on analytical laboratories will be overwhelming.

Another perspective on future directions in weed management comes from comparing what I call "Pre-Millennium" and "Post-Millennium" approaches (Table 2). These are really changes more of a gradual, or evolutionary nature; no certain end-point or starting point is clear. However, over the past 5 years or so, there are clearly some shifts occurring due to both technologies and to improved understanding of weed ecology and biology. By standing back somewhat, the scale of change is more apparent and that is the intent of this table.

Table 2. Comparison of past and future weed science and management perspectives.

Pre Millennium	**Post-Millennium**
Single target focus	Ecological focus (population/community)
Specific crop/weed focus	Crop-weed complexes Beneficial insect habitat
Field-specific focus	Biogeographical scale ("Area Wide")
Single season economic thresholds	Long-term, modulated, ecologically-based thresholds Zero-tolerance seed banks
Major crop commodity-drive decisions	Commodity ***and*** Environment-driven
Herbicide dependence: Selectivity Timing Persistence Placement	Mosaic of Inputs: Synthetic and natural product herbicides Precision applications (GIS) Resistance management Cultural practices

Resistance Carryover Drift	Biological control Optimized landscape features Optimized crop geometry (canopy, spacing)
<u>Regulatory Compliance:</u> Just follow the label.	<u>Regulatory Compliance:</u> Fully integrated "environmental effects monitoring"

Some of the approaches in Table 2 are already well underway in some commodities. However, as in all changes, growers will continue to be quite conservative and carefully watch and evaluate new methods and systems. There are, I believe, some approaches that need to be examined in light of both new newly developed technologies and increased understanding of plant-plant interactions as well as plant-insect/pathogen interactions. Specifically, using GPS-guidance systems, it should be feasible to create cropping landscapes with any number or combination of elevations ranging for flats and shallow slopes to steep gradients of several feet and in any number of patterns. Such variable cropping landscapes or "VCLs" could make optimal use of differing irrigation requirements, shading benefits, canopy architecture, harvest times, nutritional demands, and beneficial insect habitat. Why do "refuges" have to be on borders? Is this optimal? The grower is really no longer limited to straight-line farming. With the use of "smart" equipment, field configurations and harvesting can be programmed to accommodate any number of variations. (Perhaps this notion comes from to having such little control of the natural aquatic and riparian environmental inputs!) I have listed a few potential opportunities and potential technologies with relevance to "New Millennium Weed Management". I'm sure there are others.

<u>Opportunities for Applying New Technologies in Weed Management:</u>

- Miniaturization and nanotechnology: e.g. soil, leaf sensors, microscale-transmitting cameras; root and rhizophere microinstrumentation (assessment of allelopathy)
- Laser and GPS/GIS guided Variable Cropping Landscapes (VCLs)
- Ultrasonic systems for detecting and measuring seed banks
- 3D- digital scanning systems to develop plant/ weed competition models
- Collaborations with the biomedical and aerospace research/industry

One of the most exciting and significant new directions in weed management is the burgeoning support and recognition of exotic invasive weeds in natural/wildlands and aquatic resources. Problems in these sites are not new, but a combination of increased introductions, public awareness and political interest has led to slowly building interest in these weeds. As mentioned in Table 1, the Executive Order singed in 1999, and subsequent formation of the Invasive Species Task Force, newly adopted Plant Protection Act speak to this new awareness. Further evidence that these impacts have reached the political radar screen comes from very recent publication of two major federal level documents. A GAO Report on Invasive Species (GAO-01-724 was published in July, 2001. This 40+ page document, requested by, and addressed to Congress, is in essence a "report card" on the progress of federal agencies in dealing with invasive species. Notable obstacles cited include:

- Lack of agreement on what "Rapid Response" means
- No nationally coordinated system to deal with invasive species
- No accountability of agencies when invasive species spread
- Lack of "authority" to act; reluctance to act without clear "mission"
- Lack of funding

These areas clearly need addressing. What can CWSS do to expedite improvements and to assist in overcoming the obstacles?

A second, even more recent publication was just released by the National Academy of Science this month entitled: Predicting Invasions of Nonindigenous Plant and Plant Pests. Several recommendations are stated including the need to pool information on non-native species, the need to develop predictive models to help identify potential problem species and the need to utilize the approved biological control agents as a means for studying introduced populations. This document is a virtual compendium of the problems we face in both stopping introductions and in coping with them.

I believe that the National Academy report, and the GAO report, as well as related reviews (e.g. see Sakai et al, 2001) point to very concrete and serious need for research, regulatory and educational reform on a scale that parallels the early 1970's reforms in pesticide usage and environmental stewardship.

Where does the California Weed Science Society fit into this effort? There are no doubt several actions that would be useful. I have listed a few in Table 3.

Table 3. Opportunities for CWSS in Invasive Weed Problems

1. Training for "Rapid Response Weed Research and Action"
2. Outreach and Extension focusing on Prevention (e.g. Certification of "plant purveyors")
3. Ecological Underpinning for Biological Control and Pest Exclusion
4. Facilitate development a curriculum for K-12th grade "Weed Literacy"
5. Facilitate teacher training
6. Educating public policy makers
7. Capitalize on emerging technologies- wherever they come from
8. Facilitate training to meet new compliance regulations
9. Respond to public perceptions by enhancing public understanding
10. Facilitate invasive species initiatives and coordinate with supportive groups

This brings me to my concluding remarks and a request that you become engaged in the newly initiated Strategic Planning your Executive Board is pursuing. I have identified some of the future trends in weed management as I see them. There are certainly others. And there are no doubt varying views on how CWSS should respond to these. However some changes are inevitable and it is important that CWSS anticipates and incorporates new demands and needs within California's weed research and management needs to sustain it's vital service to the members and stakeholders, and newly emerging stakeholders as well. Where should we be headed? How do we get there? Strategic planning means developing a reasonable prediction of where we ought to be and then taking the steps to be there- at the right time! Some of the first steps will be to:

1. Define our mission and goals
2. Examine what we do- and determine what needs to change
3. Identify way s to implement the changes
4. Set time-tables, milestones… and then DO IT!

California has the most diverse cropping production system and is blessed with some of the most important natural, wildland, riparian and aquatic ecosystems in the US. It has consistently lead in innovative approaches to agricultural production and environmental protection. We are once again poised with the opportunity to lead weed science and management into this new millennium of challenges and great opportunities. I hope many of you will become involved with the California Weed Science Society and this strategic planning – it will be exciting for us all!

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3. Sakai, Ann, K. et al. 2001. The population biology of invasive species. Annu. Rev. Ecol. Syst. 32: 305-332.

WEED SCHOOL 2002

Ecology of Interactions between Weeds and other Categories of Pests

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Introduction

The term pest includes pathogens, weeds, nematodes, mollusks, arthropods, and vertebrates. One category of pests does not occur in the absence of pests in other categories, yet most IPM systems are designed around a single category of pest. For full implementation of IPM it is essential that all categories of pests be managed in an integrated manner. Allowances for the interactions that occur between the categories of pests be incorporated into the IPM decision making process. Interactions between pest categories can be diagrammed in the form of a 'pest hexagon' (Figure 1). Not all interactions between all categories of pests are of equal significance, but due to the trophic position of weeds in the ecosystem weeds have the potential to impact all other categories of pests.

Weeds presence in agricultural systems can vary from essentially none in a highly managed monocropping system, such as that used for cotton in the San Joaquin valley, to very diverse mixture of species in small field cropping systems interlaced with hedges, fence lines, stream banks, and woodlands. Such contrasting agricultural systems provide very different habitats for all other organisms present in the systems. At the farm level there is a large difference in habitat for all organisms between fence lines that are weedy and those that are maintained weed free. Similarly, within orchards there can be large habitat differences between those managed with a weed-free floor versus those managed with vegetation cover.

There are several different mechanisms by which interactions can occur between categories of pests, including:

1. Trophic relationships
2. Alteration of habitat/environment
3. Physical factors
4. Control tactics
    4.1. Non-chemical
    4.2. Caused by pesticide use.

Trophic relationships

Ecologically organisms can be divided into two major types. One group comprises green plants that can use the raw ecosystem resources such as water, sunlight, mineral nutrients and carbon dioxide and convert them into the biochemicals that support all other forms of life. Plants are referred to as producers in ecological terms. The second group includes all other organisms that depend directly or indirectly on green plants as their food source; they are referred to ecologically as consumers. The simple food chain concept shown in figure 2 depicts these relationships. Weeds are thus unique among pest organisms as they are producers, whereas all other categories of pests are consumers.

The ecological difference between weeds and other categories of pests means that weeds can serve as a food source for all consumer organisms (Figure 3), which results in numerous interactions between weeds and other categories of pests. Weeds can support herbivore organisms that feed directly on them, and they can support beneficial organisms that feed on the carnivores. Some beneficial arthropods feed both as carnivores and herbivores at different stages in their life cycle.

Simple food chains do not represent the complexity of real ecosystems. Ecologists attempt to represent this complexity in the form of food webs, which are a depiction of who eats whom. A simplistic food web for an agroecosystem is presented in figure 4. A few of the types of interactions between weeds and other categories of pests that are included in this food web include:

1. Weeds can serve as alternative hosts for herbivore pests (A and D). Note that pest D is supported on a plant outside of the managed crop ecosystem; this type of trophic connection is important for areawide pest management.
2. Weeds can serve as alternative hosts for a beneficial insect B through provision of prey living on the weed that is growing within the crop agroecosystem. Similarly, herbivore prey that is feeding on a plant outside the managed ecosystem supports beneficial D. Plants growing outside of the agroecosystem may be important for areawide pest management.
3. Weeds can serve as direct food sources for beneficial organisms, for example weeds within the crop are food for beneficial A, and plants outside the managed ecosystem are food for beneficial B.
4. The crop has multiple herbivore pests, and the likelihood that any of the pests will be a significant problem depends on what beneficial organisms are present. Pest organisms A and D are maintained on weeds or non-crop plants. Pest A might be root-knot nematodes that are able to parasitize weed hosts such as pigweed and lambsquarters. Pest D might be lygus bugs, or a virus like lettuce mosaic, living in or on weeds in areas that surround managed fields.
5. Beneficial organism B might not be very effective, because the following could alter its population dynamics sufficiently to stop the population from ever increasing to the point where it provides effective control of pest organism B:
   - 5.1. Beneficial B requires plant food, such as nectar or pollen, and the appropriate food-source plants may or may not be present.
   - 5.2. Beneficial B is a food source for a hyperparasitic tertiary consumer (B).
6. Hyperparasites from outside the managed ecosystem could limit the effectiveness of beneficial organisms.

7. The activity of beneficial D may be modified by what entomologists refer to as a tritrophic interaction, which involves the passage of plant-derived chemical compounds across trophic levels. The vertical arrow within pest organism D represents the passage of chemical compounds derived from the crop plant to the next higher trophic level.

In reality, most food webs involve many interactions and so are much more complex than those described above.

Alteration of habitat/environment

Resource concentration

Entomologists theorize that insects are more like to be attracted, or immigrate, to uniform stands of host plants that to areas where host plants are mixed with non-host plants. It is also argued that insects are less likely to leave, or emigrate from, areas of more uniform host plants. In many agricultural situations weeds are interspersed with the crop and thus effectively decrease the concentration of the crop host, which could lead to changes in pest and or beneficial numbers on the crop.

Apparency

Related to resource concentration is the concept of apparency. Mobile pests, particularly arthropods, must be able to find suitable host plants using vision or olfactory cues. The presence of weeds, especially in situations where weeds represent a large proportion of the biomass, as discussed in the next section, could result in mobile pests being able to find their preferred host less easily.

Microenvironment

The presence of a plant canopy alters the microenvironment, such as temperature, light intensity, humidity, and wind speed. Changes in these parameters can alter the performance of pests living in the habitat. Presence of a plant canopy also provides shelter; many pests cannot survive in the open and need a plant canopy to provide protection from environmental extremes and from predators.

Weeds can represent a major component of the plant canopy in some systems, and thus can interact with other categories of pests through alteration of apparency and through provision of appropriate microenvironment. Prior to postemergence cultivation or other weed control practice weeds may represent most of the canopy present in annual row crops. In dormant perennial crops like alfalfa and orchards, weeds provide most of the living canopy present in the field during the dormant season. Many of the plants in non-cropped areas such as fence lines, ditch banks and roadsides are often weeds, and thus provide not only food but also suitable habitat per other categories of pests in these areas.

Physical factors

Interactions between pest categories that are driven by physical factors typically do not involve weeds, and are not considered here.

Control tactics

All the preceding interactions occur regardless of the control tactics used as they are driven by ecological changes brought about by the pest or the control tactic. Some interactions do, however, occur in direct response to the control tactics used.

Non-chemical tactics

Tillage impacts all soil-borne organisms. Tillage, for example, provides partial mechanical control of some arthropods, which have the pupal stage in the soil, such as cotton bollworm. Changes in intensity of tillage have been shown to alter the survival of such pests. The ultimate interaction with tillage occurs in no-till systems, in which there is essentially no habitat destruction, and no physical impact on pests. No-till systems need special attention to pests that are controlled with tillage, such as slugs and snails.

Interactions through pesticide use

There are several ways in which pesticides used for control of one category of pest may impact pests in a different category. The simplest of such interactions occurs when the pesticide is directly toxic to another category of pests. Several herbicides, are for example, weak fungicides. If a pesticide has sufficient activity against another category of pests to provide usable control then it will be registered for such use.

Herbicides are intended to alter the physiology of weeds sufficiently that they are killed. Selective herbicides that do not kill the crop often cause transitory changes in the physiology of the crop. These subtle, non-lethal, effects on the crop can lead to alteration in how other pest organisms react to the crop. Phenoxy-herbicides have, for example been shown to increase aphids on corn.

Insecticides are not usually considered to have any direct toxic impact on the crop, but there are several insecticides that do alter physiological processes in the crop. The most important of these to the use of herbicides in IPM systems are the organo-phosphate insecticides, several of which can lead to loss of herbicide tolerance in the crop; examples include propanil on rice, and metribuzin in soybeans.

Tank mixtures of pesticides intended for control of different categories of pests can sometimes result in synergism or antagonism of activity; atrazine, for example, potentiates several insecticides applied for fruitfly control. An IPM program must anticipate and allow for such interactions.

Summary

A comprehensive IPM program must consider all categories of pests and manage them an integrated fashion. The presence of weeds and the control of weeds have potential to interact with all other categories of pests. Knowledge of, and allowance for, such interactions are essential if an IPM program is to achieve true integration of control.

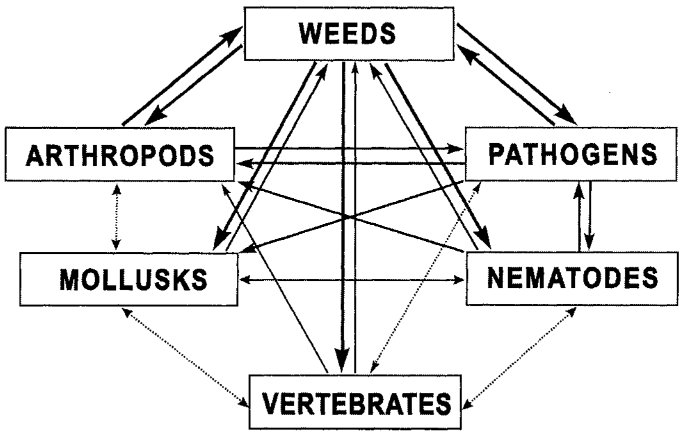

Figure 1. The pest hexagon; a diagrammatic representation of the interactions between different categories of pests.

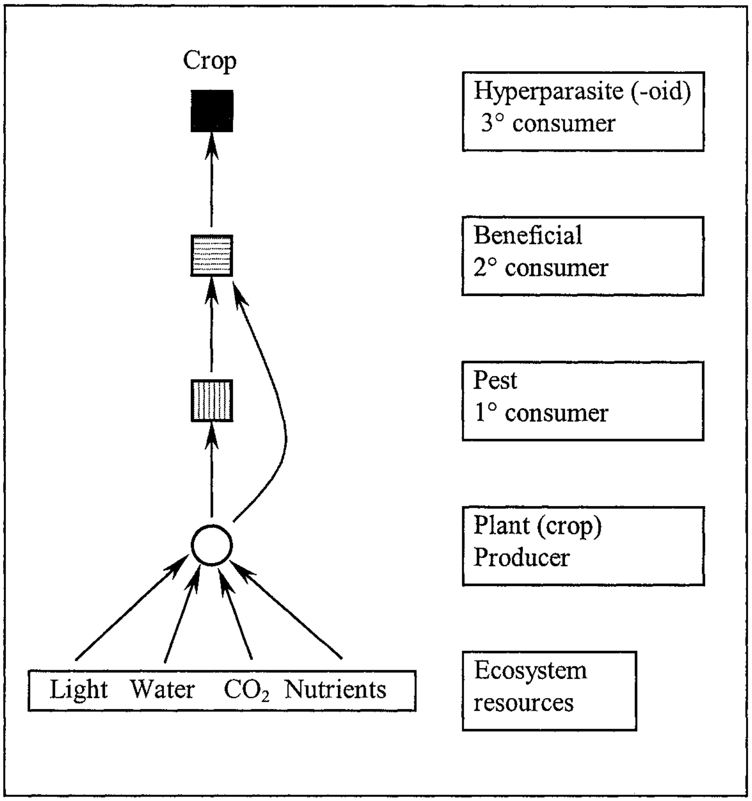

Figure 2. Example of a simple food chain showing ecological terminology.

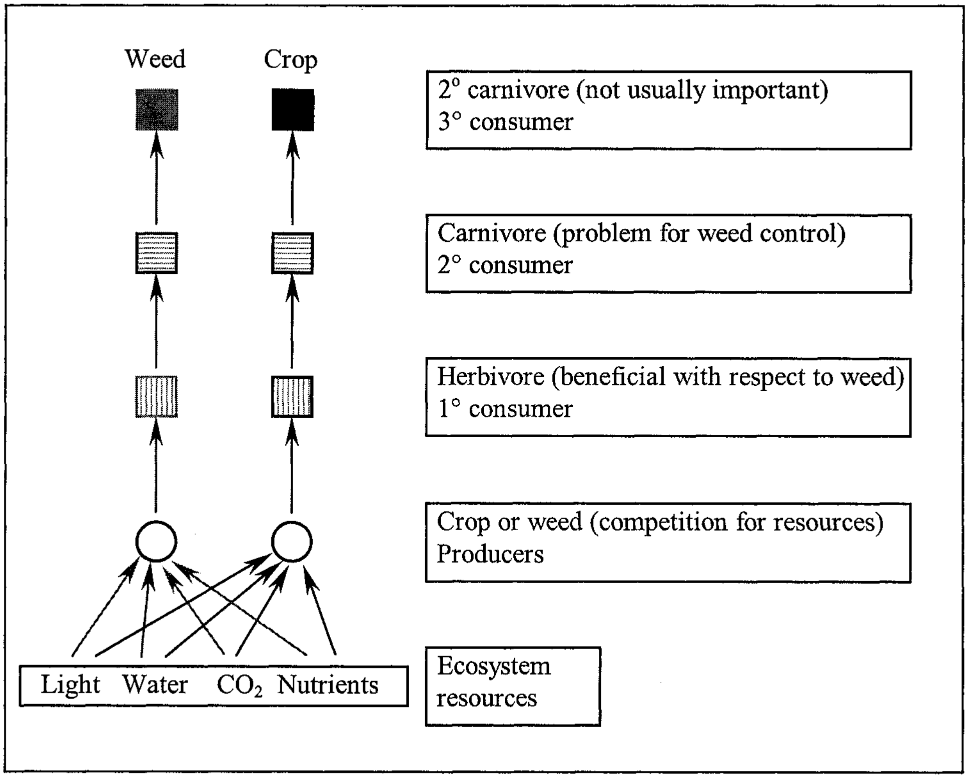

Figure 3. Example of simple food chains for a crop and a weed.

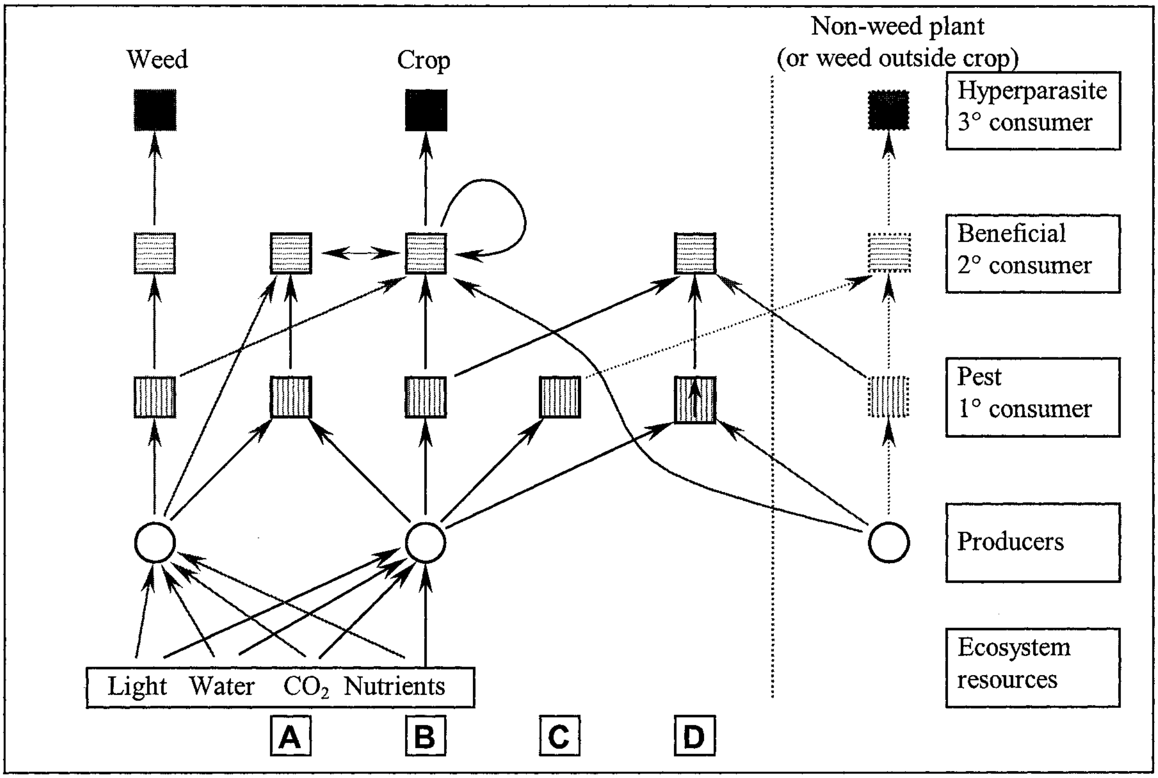

Figure 4. Diagram of potential food web connections. Vertical dotted line depicts boundary between managed ecosystem (to left) and organisms external to the managed system.

Impact of Weeds on Nematode Management

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Plant-parasitic nematode management in both annual and perennial cropping systems may involve the manipulation of crop cultivars and the management of in-field vegetation to minimize pest and pathogen problems. The status of plant as hosts for plant-parasitic nematodes can be manipulated. Depending on the particular nematode species that are present in a field and are the target of control efforts, it may be possible to reduce nematode numbers through cultivar selection, crop rotation to non-hosts, cover cropping, or fallow periods. The need to implement nematode control tactics depends on the nematode density in the field. If the nematode density is greater than the damage threshold for the primary crop, control tactics are usually deemed necessary.

Plant-parasitic nematodes are obligate parasites, and require host plants to complete their life cycles. Rotations to non-hosts can reduce nematode numbers by enhancing nematode population decline through the natural mortality that occurs in the absence of host. The anticipated rate of population decline is used to anticipate the length of rotation period. For example, rotation to nonhost plants for two-to-three years is effective in reducing numbers of sugarbeet cyst nematode, although the exact duration of the rotation depends on the nematode density in the field.

Poor weed management results in weeds remaining in the field, and those weeds may support substantial nematode reproduction. Weeds that support nematode development and reproduction negate the nematode suppressive effect of rotations to nonhosts or resistant host plants. The result is that the nematode population decline is less than anticipated, so that damage to the subsequent crop occurs despite the use of control tactics to reduce nematode numbers.

Weeds are good hosts for many nematode species (see the table). A host plant-nematode database called NEMABASE has been developed at the Nematology Department, University of California, Davis (Caswell-Chen *et al.*, 1995). The database includes information obtained from the published literature, on the host status of plants to plant-parasitic nematodes, and the database currently includes approximately 32,382 records. NEMABASE can be used via the UCD Dept. of Nematology WWW homepage to determine the host status of some weeds to nematodes: (http://ucdnema.ucdavis.edu/imagemap/nemmap/ent156html/contents).

In my lab, we have examined the effect of Northern California weed species on hatch, penetration, development and reproduction of the sugarbeet cyst nematode, *Heterodera schachtii,* under growth chamber, greenhouse and microplot conditions (Bloom, 1997). Weed species were local collections of *Sinapis arvensis*, *Raphanus raphinastrum*, *Capsella bursa-pastoris*, *Chenopodium album*, *Amaranthus retroflexus*, *Solanum nigrum*, and *Portulaca oleracea*. *Brassica oleracea* and *Beta vulgaris* were included as known good hosts, and *Medicago sativa* was included as a known poor host. Egg hatch from cysts was stimulated by root diffusates of the weed *S. arvensis*. Second-stage juveniles of *H. schachtii* penetrated the roots of all weeds in the experiments. Greater numbers of swollen juveniles and a higher ratio of swollen to vermiform juveniles were observed in roots of *B. vulgaris* and weeds *S. arvensis* and *R. raphanistrum* as compared to the other weed species. Greater numbers of cysts and eggs were recovered from *S. arvensis*, *R. raphanistrum*, *C. bursa pastoris* than other weed species. By comparing egg production on weeds to egg production on *B. vulgaris*, a relative reproductive index indicated that *S. arvensis* was a good host, *R. raphanistrum* and *C. bursa pastoris* were intermediate hosts, and *C. album*, *A. retroflexus*, *S. nigrum* and *P. oleracea* were poor hosts of *H. schachtii.* Our results indicate differential reproduction of *H. schachtii* on weeds, and that certain weeds may promote population increases of *H. schachtii* in fields during the non-host rotations that are the primary means of managing the nematode.

Proper weed management is desirable to prevent unanticipated population increases of plant-parasitic nematodes. Timely weed management is also necessary, because although cultivation will remove weeds, the roots are not immediately killed and they may survive and continue to support nematode development and reproduction after cultivation.

Weed management may be an important component of an integrated approach to nematode management.

Table. Weeds and their nematode associations as recorded in NEMABASE.

(see http://ucdnema.ucdavis.edu/imagemap/nemmap/ent156html/contents) .

All the interactions presented here were obtained from the international nematology literature. They represent interactions between particular plant and nematode genotypes, and may not be representative of the interaction for other genotypes (geographic isolates) of the weed or nematode. Additionally, taxonomic designations do change over time and the designations here represent the information recorded in original research publications without correction for subsequent taxonomic refinements. I = immune, S = susceptible, MS = moderately susceptible, R = resistant, Ri=0.47 = the value of the reproductive index (Pf/Pi) as observed by experiment.

Amaranthus palmeri (Palmer amaranth)
- *Meloidogyne arenaria race 2 - MS*
- *Meloidogyne incognita race 3 - MS*

Amaranthus retroflexus (Redroot pigweed)
- *Punctodera punctata - I (nonhost)*
- *Meloidogyne incognita - S*
- *Heterodera zeae - I (nonhost)*
- *Ditylenchus dipsaci - I (nonhost)*
- *Meloidogyne chitwoodi race 1 – R, Ri=0.47*
- *Meloidogyne hapla – R, Ri=0.0*

Ambrosia trifida (Giant ragweed)
- *Meloidogyne incognita - I (nonhost)*

Arctium minus (Common burdock)
- *Subanguina picridis - I (nonhost)*

Asclepias incarnata (Swamp milkweed)

no records found

Avena fatua (Wild oat)
Heterodera avenae - S
Meloidogyne spp. - S
Meloidogyne incognita - S
Anguina funesta - I (nonhost)
Criconemella rustica – S, Ri=5.8
Pratylenchus projectus – S, Ri=66
Punctodera chalcoensis - I (nonhost)
Heterodera avenae – S, Ri=4.4

Bellis perennis (English daisy)
Meloidogyne incognita – MS, Ri=0.231

Brassica kaber (Wild mustard)
no records found

Brassica nigra (Black mustard)
Meloidogyne arenaria - R
Pratylenchus thornei - R
Heterodera trifolii - S
Ditylenchus dipsaci - S

Bromus carinatus (California brome)
no records found

Bromus catharticus (Rescuegrass)
no records found

Calandrinia ciliata variety menziesii (Desert rockpurslane)
no records found

Capsella bursa-pastoris (Shepherd's-purse)
Meloidogyne incognita - S
Xiphinema bakeri - R
Heterodera zeae - I (nonhost)
Longidorus elongatus - MS
Heterodera schachtii - MS
Meloidogyne hapla – R, Ri=0.47

Carduus acanthoides (Plumeless thistle)
no records found

Centaurea cyanus (Cornflower)
Meloidogyne hapla - S
Meloidogyne javanica - S

Chamaesyce maculata (Prostrate and spotted spurge)
no records found

Chenopodium berlandieri (Netseed lambsquarters)
no records found

Chenopodium murale (Nettleleaf goosefoot)
no records found

Convolvulus arvensis (Field bindweed)
Meloidogyne hapla - S
Heterodera cajani - I (nonhost)
Subanguina picridis - I (nonhost)
Ditylenchus dipsaci - S
Meloidogyne incognita - R

Cyperus esculentus (Yellow nutsedge)
Meloidogyne incognita - S
Meloidogyne arenaria - R (2 records)
Meloidogyne incognita race 3 - R
Meloidogyne javanica - S
Heterodera zeae - I (nonhost)
Criconemella onoensis - R
Rotylenchulus reniformis – S, Ri=4.55
Tylenchorhynchus acutus – MS, Ri=2.67
Helicotylenchus dihystera – S, Ri=7.1

Cyperus rotundus (Purple nutsedge)
Meloidogyne incognita - S
Meloidogyne incognita race Acrita - MS
Meloidogyne javanica - MS
Meloidogyne graminicola - MR
Meloidogyne incognita - MR
Heterodera cajani - I (nonhost)
Heterodera avenae - I (nonhost)
Ditylenchus destructor - MR
Criconemella xenoplax – R, Ri=0.32
Radopholus similis (race banana) - S (2 records)
Hoplolaimus colombus - S
Heterodera mothi - S
Meloidogyne konaensis – S, Ri=7.4
Meloidogyne incognita - MS

Daucus carota (Wild carrot)
213 records found, many different nematode genus

Digitaria sanguinalis (Large crabgrass)
Meloidogyne naasi race 1 - S
Meloidogyne naasi race 2 - S
Meloidogyne naasi race 3 - S
Meloidogyne naasi race 4 - S
Meloidogyne naasi race 5 - S

Meloidogyne arenari race 2 - R
Meloidogyne incognita race 3 - R
Pratylenchus scribneri - S
Heterodera zeae - I (nonhost)
Criconemella rustica – S, Ri=3.8
Pratylenchus projectus – S, Ri=67

Dipsacus fullonum (Common teasel)
Ditylenchus dipsaci - MS
Ditylenchus dipsaci race onion - I (nonhost) (2 records)
Ditylenchus dipsaci race oat - S
Ditylenchus dipsaci race tulip - S
Ditylenchus dipsaci race onion - S
Ditylenchus dipsaci race oat - R
Ditylenchus dipsaci race rye - R
Ditylenchus dipsaci race lucerne - I (nonhost)
Ditylenchus dipsaci race red clover - I (nonhost)
Ditylenchus dipsaci race rye - I (nonhost)
Ditylenchus dipsaci race narcissus - I (nonhost)

Echinochloa crus-galli (Barnyardgrass)
Meloidogyne arenaria race 2 - R
Meloidogyne incognita race 3 - R
Xiphinema bakeri - S
Heterodera zeae - S
Criconemella rustica – S, Ri=4.4
Pratylenchus neglectus – S, Ri=256

Elytrigia repens (Quackgrass)
no records found

Eragrostis cilianensis (Stinkgrass)
Heterodera zeae - I (nonhost)

Epilobium angustifolium (Fireweed)
no records found

Erodium cicutarium (Redstem filaree)
Meloidogyne hapla - R

Euphorbia dentata (Toothed spurge)
no records found

Euphorbia esula (Leafy spurge)
Subanguina picridis - I (nonhost)

Hibiscus trionum
Meloidogyne javanica - S
Ditylenchus dipsaci race onion - S

Hordeum jubatum (Foxtail barley)
Meloidogyne incognita - S (2 records)
Criconemella rustica – S, Ri=5.6
Pratylenchus projectus – S, Ri=330

Hordeum leporinum (Hare barley)
Anguina funesta - I (nonhost)
Heterodera avenae – MR, Ri=0.64

Hypericum perforatum (Common St. Johnswort)
Subanguina picridis - I (nonhost)

Ipomoea coccinea (Red morningglory)
no records found

Ipomoea nil (Ivyleaf)
no records found

Ipomoea purpurea (Tall morningglory)
Meloidogyne incognita - S

Lamium amplexicaule (Henbit)
Meloidogyne hapla - MS
Meloidogyne incognita - S
Ditylenchus dipsaci race onion - I (nonhost)

Malva neglecta (Common mallow)
Meloidogyne incognita - S

Medicago lupulina (Black medic)
Meloidogyne incognita - S
Meloidogyne hapla - S
Heterodera cajani - I (nonhost)
Heterodera trifolii - R
Heterodera medicaginis - I (nonhost)
Ditylenchus dipsaci race onion - I (nonhost)

Melilotus officinalis (Yellow sweetclover)
21 records found, Heterodera and Meloidogyne

Panicum miliaceum (Wild-proso millet)
Meloidogyne incognita - S (2 records)
Heterodera zeae - S
Criconemella rustica – S, Ri=8.9
Pratylenchus projectus – MS, Ri=1.4
Aphelenchoides besseyi - S

Physalis virginiana (Virginia groundcherry)
no records found

Physalis wrightii (Wright groundcherry)
no records found

Plantago major (Broadleaf plantain)
Meloidogyne incognita - I (nonhost)
Xiphinema bakeri - S
Ditylenchus dipsaci - S

Polygonum aviculare (Prostrate knotweed)
Pratylenchus penetrans - S
Meloidoderita sp. - R
Ditylenchus dipsaci - S
Ditylenchus dipsaci race onion - I (nonhost)

Polygonum convolvulus (Wild buckwheat)
Heterodera zeae - I (nonhost)
Meloidoderita sp. - R
Meloidogyne hapla – R, Ri=0.53

Portulaca oleracea (Common purslane)
Meloidogyne arenaria race 2 - MS
Meloidogyne incognita race 3 - MS
Meloidogyne hapla - S
Meloidogyne incognita - S
Meloidogyne incognita race acrita - S
Meloidogyne hapla - MS
Meloidogyne graminicola - S
Heterodera cajani - I (nonhost)
Criconemella xenoplax – MS, Ri=1.7
Helicotylenchus multicinctus - S
Ditylenchus dipsaci race onion - I (nonhost)
Meloidogyne hapla - R
Meloidogyne incognita - MS

Raphanus sativus (Radish)
94 records found, many different nematode genera

Salsola iberica (Russian thistle)
no records found

Salvia aethiopis (Mediterranean sage)
no records found

Salvia reflexa (Lanceleaf sage)
no records found

Sarcobatus vermiculatus (Greasewood)
no records found

Senecio jacobaea (Tansy ragwort)

Subanguina picridis - I (nonhost)

Sisymbrium irio (London rocket)
no records found

Silene alba (White campion)
Heterodera zeae - I (nonhost)

Sonchus oleraceus (Annual sowthistle)
Meloidogyne hapla - S
Pratylenchus penetrans - S

Solanum elaeagnifolium (Silverleaf nightshade)
Ditylenchus phyllobius - S (2 records)
Globodera tabacum (race solanacearum) - S

Solanum nigrum (Black nightshade)
21 records found, many nematode genus

Solanum sarrachoides (Hairy nightshade)
no records found

Sorghum halepense (Johnsongrass)
Hoplolaimus colombus - S
Heterodera betulae - I (nonhost)
Meloidogyne incognita - S
Meloidogyne javanica - S
Meloidogyne arenaria - S
Meloidogyne arenaria race 2 - R
Meloidogyne incognita race 3 - R
Heterodera graminophila - S
Heterodera zeae - I (nonhost)

Stellaria media (Common chickweed)
23 records found, many different nematode genera

Taeniatherum caput-medusae (Medusahead)
no records found

Tanacetum vulgare (Common tansy)
no records found

Tribulus terrestris (Puncturevine)
Meloidogyne incognita race acrita - MS
Pratylenchus scribneri – S

Vicia villosa (Hairy vetch)

Meloidogyne arenaria race 1 - S
Meloidogyne arenaria race 2 - S
Meloidogyne incognita race 3 - MS
Heterodera trifolii - S
Heterodera zeae - I (nonhost)
Tylenchorhynchus claytoni – S, Ri=11.3
Pratylenchus penetrans – S, Ri=16.9
Heterodera schachtii - MR
Meloidogyne arenaria race 2 – R, Ri=0.05
Meloidogyne arenaria race 2 – I, Ri=0
Meloidogyne arenaria race 2 – R, Ri=0.03
Heterodera glycines race 4 – S, Ri=5.2
Heterodera glycines race 4 – MR, Ri=2.48
Heterodera glycines race 4 – S, Ri=5.0

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NEMABASE. A host-plant nematode database available on the WWW. (http://ucdnema.ucdavis.edu/imagemap/nemmap/ent156html/contents).

Role of Weeds in Pathogen Management

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Of the groups of plant pathogens, viruses are probably the most dependent on alternate host plants for their survival. Viruses are intracellular obligate parasites and as such are absolutely dependent on their plant hosts (Table 1). All plant viruses have host-ranges including crop and weed host plants and as such weeds can be important factors in virus incidence and epidemiology. However, just because a weed or alternate host plant is susceptible to a given virus this does not mean that it is an epidemiologically important host plant. In addition to being dependent on their plant hosts, viruses must have a means to move from plant-to-plant. For most viruses this is accomplished by a vector (Table 1). Most vectors are arthropods with insects being far and away the most frequent, and of the insects that transmit viruses to plants, aphids are the most common plant virus vectors. However, not all aphids can transmit all plant viruses; vector transmission is specific. It is determined in part by genetic information contained within the virus genome, and in some cases a given virus may have only one or a few species of vector, while others may have many. But this means that in addition to the virus having a plant host and a vector, for the virus to survive and spread the vector must encounter the host plant. It must acquire the virus from the virus-infected plant and then transmit the virus to the healthy plant. Thus, if a plant (weed) is a good host for the virus but not encountered by the vector for that virus, the plant will very likely be unimportant epidemiologically. Finally, for the host plant to be epidemiologically important as an alternate host, the virus, host plant and vector must be present at the right time and place. Therefore, each virus disease must be considered separately. Weeds, as important alternate host plants for a given virus could vary in their importance depending on many factors. Some examples are discussed briefly below.

Carrot motley dwarf (CMD; 4), lettuce mosaic caused by *Lettuce mosaic virus* (LMV; 3), and curly top caused by *Beet curly top virus* (BCTV; 1, 2) have varying dependence on weeds in regards to resulting disease. CMD, which occurs in carrots in the Salinas and San Joaquin valleys of California can be a devastating disease of carrots, especially early spring carrots. If carrot plants are infected early in their growth they will be stunted, yellowed and have very poor root growth. The viruses causing CMD are transmitted from plant-to-plant by only one species of aphid, the carrot aphid, *Cavariella aegopodii*. The viruses causing CMD and the carrot aphid both have narrow host ranges and in the Salinas and San Joaquin Valleys their host ranges only overlap in carrots (4). Thus, carrots are the sole important host plant in disease epidemiology. If carrots are over-wintered in the ground in the Salinas Valley, then these can serve as an important source of primary inoculum for subsequent CMD development. Weeds are of no significance. CMD can then be easily controlled by not over-wintering carrots or not planting early spring carrots near overwintered fields.

LMV also can cause a devastating lettuce disease and is the most important virus pathogen of lettuce worldwide. LMV has a moderate host range including a number of plants (weed, crop and ornamentals) in the family Asteraceae. LMV also can be spread efficiently from plant-to-plant by a number of aphids so adequate opportunities exist for spread. However, just because host plants exist does not mean that they are important sources of virus for subsequent disease development. Data have clearly demonstrated that weeds and other alternate host plants are not significant sources of inoculum (3). The most important source of primary inoculum is seedborne LMV. As long as lettuce seed is tested and only seed that has fewer than 1 LMV-infected seed in 30/000 is planted, significant LMV epidemics will not develop. In this example we know that weed hosts are present. It is a good idea (and in fact is done) to eliminate weed hosts nearby lettuce fields, but controlling weed host plants alone will not give adequate disease control.

Curly top, caused by BCTV, is a widespread and important disease. BCTV and its vector, the beet leafhopper (*Circulifer tenellus*), both have tremendously wide host ranges and are endemic throughout the western U. S (1). In this example, weeds and other alternate host plants have essential roles in disease epidemiology and in attempts to control BCTV. The beet leafhopper is a migratory insect and overwinters in the foothills of the westside of the San Joaquin valley of California. As viruliferous leafhoppers can carry BCTV essentially for life leafhoppers can remain viruliferous through the winter. In addition, perennial shrubs such as buckbrush are perennial hosts for BCTV and thus abundant BCTV-infected hosts are always present (2). In early spring the leafhopper migrates from its overwintering plants onto the germinating dicots on the westside foothills. This includes host plants such as mustards and filaree, good hosts for both the leafhopper and BCTV. In the spring the leafhopper populations begin to build up and many of the leafhoppers become viruliferous. As the annual dicots on the hills begin to dry up the leafhoppers migrate down into the valley floor where there are now abundant crop host plants including tomatoes, beans, peppers and sugarbeets. Curly top can develop. In this situation weeds are important in overwintering and spring population build up of the viruliferous vector. Control strategies are aimed at these two non-crop locations. However there are so many weed hosts that attempting to eliminate them would be unsuccessful. Therefore the strategy is toattempt to control the leafhopper on the non-crop, alternate plant hosts before it migrates into crop plants.

The above examples represent just three of the many different plant viruses, but these show different importance of weeds in resulting disease incidence and epidemiology. Because plant viruses are so dependent on their plant hosts for survival it is easy to make assumptions that weeds (or other alternate host plants) have important roles in the resulting disease development and epidemiology. This is not always true. Each virus situation can be different and it is important to do careful research to determine the real role of weeds in disease epidemiology.

Table 1. Characteristics of Viruses

1. Viruses are obligate parasites, they must have a living host (a plant, crop or weed host).
2. Viruses are non-cellular molecular parasites, they use the host cell molecular machinery to replicate.
3. Viruses must have a means to move from host-to-host, for plant viruses this is among a sedentary host population.
4. For movement, they depend on vectors.

Table 2. Host ranges and importance of weeds in resulting disease incidence for selected plant viruses.

	Virus	Vector**	Importance
Carrot Motley Dwarf*	Narrow	Narrow	Little/None
Lettuce mosaic Virus	Moderate	Wide	Little
Beet curly top virus	Wide	Wide	High

*Carrot Motley Dwarf is caused by a co-infection *of Carrot red leaf virus* and *Carrot mottle virus.*

**The vectors are: the carrot aphid, *Cavariella aegopodii* for the Carrot motley dwarf viruses; many aphids efficiently transmit *Lettuce mosaic virus* in a nonpersistent manner; the beet leafhopper, Circulifer tenellus is the vector of *Beet curly top virus.*

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1. Bennett, C. W. 1971. The curly top disease of sugarbeet and other plants. Amer. Phytopathological Society Monograph No. 7.

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3. Grogan, R. G. 1980. Control of lettuce mosaic with virus-free seed. Plant Disease 64: 446 – 449.

4. Watson, M. T., and Falk, B. W. 1994. Ecological and epidemiological factors affecting carrot motley dwarf development in carrots grown in the Salinas Valley of California. Plant Disease 78: 477 – 481.

Weed Impacts on Arthropod Pests

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An extensive review of the interactions of insect pests, their natural enemies, and weeds was published recently (Norris and Kogan, 2000). No doubt that review aroused the interest for the organization of this workshop. Full credit goes Robert Norris for having compiled one of the most comprehensive bibliographies on insect associations with weeds and having attempted to provide a system to classify those complex interactions. Table 1 gives a summary of the main kinds of interactions that were discussed in the review. The review includes also comments on research reports that illustrate the major interactions and it contains an extensive bibliography with over 550 citations, up to 1998. The field remains quite active and many relevant references have appeared in subsequent years. This paper that review as a backdrop but, as the title implies, it is limited to the one-way effect of weeds on arthropod pests, despite the fact that in nature, interactions are consistently multi-directional. Clearly, within the context of crop communities, arthropods have a marked effect on weeds, not the least of which is their role in the regulation of the seed bank in the soil. Just as important is the effect that weeds have on insects.

Table 1. Major weed/arthropod interactions discussed in the review by Norris and Kogan (2000).

1. **Direct Trophic Interactions**
   - 1.1. Insect feeds on weed as alternative host
     - 1.1.1. Weeds outside crop field
     - 1.1.2. Weeds within crop field

2. **Indirect Trophic Interactions**
   - 2.1. Insects (parasitoids or predators) find alternative hosts/prey on weeds
     - 2.1.1. Weeds outside crop field
     - 2.1.2. Weeds within crop field

3. **Other Interactions**
   - 3.1. Competition from weeds reduces nutritional value of crop plant for arthropods
   - 3.2. Arthropod feeding reduces crop growth and increases resource availability for weeds

4. **Effects on arthropods of habitat modification by weeds**
   - 4.1. Altered resource concentration
   - 4.2. Altered apparency
   - 4.3. Microenvironment alteration

Arthropod/Plant Interactions

In their trophic relationship with plants, arthropods exhibit a wide range preferences, from extreme selectivity of a food plant, or monophagy, in host specialists, to broad polyphagy, in host generalists. What once was referred as the "botanical instinct" of insects, is now defined in terms of the complement of unique secondary metabolites characteristic of the host-plant that serve as stimuli for the insect's sensorial mechanisms (Bernays and Chapman, 1994) that enable insects to orient towards the host, probe it, and finally accept it for feeding or oviposition. Thus, when assessing the effect of weeds on insects within the crop community, additional consideration must be given to the host-specialization of the insect. Many of these trophic associations are dynamic and may change in time and space. Some host-specialists have been known to shift hosts under certain circumstances. The length of time of the coexistence of herbivores and plants within a community often drive those shifts. Table 2 summarizes some of these relationships.

Table 2. Characteristics of insects and plants (weeds) that drive within-community associations.

	Space factor	Time factor	Level of specialization
Nature of Herbivore	Exotic origin	Recent invader	Oligophagous
			Polyphagous
		Long established	Oligophagous
			Polyphagous
	Native origin	Crop adapted	Oligophagous
			Polyphagous
		Evolving (host-switching)	Oligophagous
			Polyphagous

			Associated fauna
Nature of the weed	Exotic origin	Recent invader	Free of oligophages
		Long established	Associated oligophages
	Native origin	Recent association	Adapted native fauna
		Crop adapted	Adapted native fauna

Obviously, interactions of insects and weeds within crop communities are much too complex and multifaceted to be discussed within the limitations of this paper. Instead, I selected three case studies to illustrate specific ways in which weeds impact on arthropods, with short- and long-term implications to arthropod demographics, population dynamics, and consequently IPM. These will be presented in the following sections.

Weeds as native hosts of arthropods that are potential pests of long-established or recently introduced crops: Example of the Colorado potato beetle.

It does not take long for arthropods to colonize a crop that has been introduced into a new area. The following example demonstrates the transition of an oligophagous species from a native host to crop plants within the same family as the native host.

The Colorado potato beetle, *Leptinotarsa decemlineata*, is the most serious pest of potato in North America and Europe. The beetle is native to the central Mexican plateau, where about 19 other species of the same genus can be found. In its native range, *L. decemlineata* feeds on bur weed, *Solanum rostratum*. During the wet season, the female beetle lays clutches of about 20 eggs on bur weed leaves. Larvae emerge and feed on the leaves sequestering many of the leaf Solanum-alkaloids that serve in their protection against predators. The larvae are bright yellow, and blend nicely against the yellow blossoms of bur weed. When the Spanish conquistadors invaded Mexico in the 17th century, there were no potatoes in North America, so the beetle was but a curiosity for its colorful design. The Spanish had introduced cattle to Mexico and near the end of the 17th century, began driving them north to Texas markets. The cattle carried the spiny seeds of the bur weed and the weed also began a northward migration. American bison picked up the bur weed seeds and moved the plant farther northward in the early part of the 18th century. The Colorado potato beetle followed the northward migration of its host eventually reaching the Great Plains by 1819, where it was found by Thomas Say and described as a new species. Thus the common name of this insect is misleading because the beetle actually is of Mexican origin. While the Colorado potato beetle was expanding its range to the north and northeast within the North American continent, the potato was also expanding it range eastward across the Atlantic Ocean into Europe. Although the potato is native to the "altiplanos" of the Andes, it was in Europe that it developed as a cultivated tuber crop and was introduced into Ireland in the late 1500s. Around the 1720s, seed stock was sent from Ireland back to North America and the culture spread westward. *L. decemlineata* would have first encountered potatoes in the U.S. mid-West around 1820 and by 1859 it had made the transition from bur weed to potato. Populations exploded and the species, now a serious pest, spread to Europe and Asia. Recent studies show that the Mexican population still feeds only on bur weed and rejects potato. A chromosomal inversion in the potato eating race of *L. decemlineata* was identified as a dominant trait (Hsiao, 1985). This inversion seems to have enabled some beetles to switch plant hosts and accept potato as a preferred food. This potato adapted race produces larvae that are dark orange or reddish probably a warning coloration against predators to avoid eating the potato-alkaloid laden larvae (Lu and Lazell, 1996). Thus, a weed, *S. rostratum*, provided the bridge for the spread of the beetle into an area where a new plentiful food resource became established, as the potato completed its own cycle of dispersal from the South American Andes, to Europe, and then back into North America. The herbivore and the host plant met in the Midwest and from there the beetle population exploded becoming a major pest of potato. This is probably the oldest and best documented example of a host switch from a weed to a crop plant, but others less dramatic have occurred with regularity in most major and in many minor crops as well.

1. Weeds purposefully introduced into crop field to achieve control of target pest: Example of the rape blossom beetle on cauliflower in Finland.

The pest management tactic known as trap cropping has had many variants. Some trap cropping systems use a combination of susceptible varieties of the same crop plant that one is trying to protect, or strips or patches of other plants that are more attractive to the insect pest species than the crop itself. The following case-study (Hokkanen, 1991) demonstrates the selective use of a mix of weeds and non-weedy plants that provide a super stimulus for the attraction of an oligophagous pest. The rape blossom beetle, *Meligethes aeneus*, a common pest on oilseed crucifers, became a serious pest on cauliflower in Finland in the beginning of the 1980s. This host shift, to a plant in the same crucifer family, resulted in losses of up to one third of the whole cauliflower crop. Farmers had no means of controlling the beetles on harvest ripe cauliflower. The increased rape cultivation adjacent to the cauliflower fields produced swarms of *Meligethes* forcing farmers to abandon cauliflower production in some regions of the country.

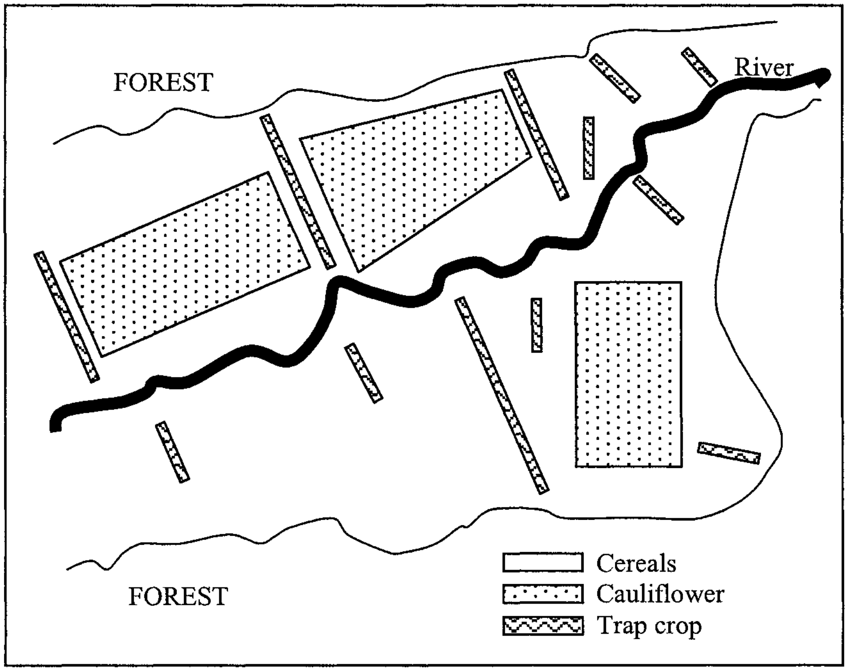

Figure1. Trap crop strips placed to intercept dispersal flights of the rape blossom beetle into cauliflower fields in Finland. (after Hokkanen, 1991).

A trap cropping system was developed using several species of trap plants that produce an intense yellow flowering, including Chinese cabbage, oilseed and turnip rape, sunflower, and marigold, often in a mixture. The trap cropping system was designed to prevent the spread of the beetles to the cauliflower plants. Because the beetles are highly mobile, the trap plants had to be grown in several strips, forming a set of barricades in the anticipated direction of infestation (Figure 1). About 15 strips, 16-65 ft wide and with a total length up to 3 mi, were used for protection of 100 a. of cauliflower. According to Hokkanen (1991) two to four insecticide sprays were needed to prevent the spread of the beetles to the crop plants, mainly because the heavy infestation quickly overloaded the trap crops unless they were periodically emptied. Despite the rather intensive management requirement of such trap cropping, the results were extremely positive, with an approximately 20% increase in marketable yield, and consequently good economic profits (Hokkanen et al.1986). This trap cropping system is practiced in Finland in areas where the blossom beetles are a problem in cauliflower. This system illustrates how weeds may interact with insects if the weed provides a super-stimulus that will divert the insect to the crop plant even if the resource is more concentrated in the crop.

2. Weeds as hosts of native pests become reservoirs for crop colonizers: Example of the areawide management of the bollworm and budworm in the southern U.S.A.

Caterpillars of the moths *Heliothis virescens*, the tobacco budworm, and *Helicoverpa zea*, the cotton bollworm, are representatives of a group of species considered the most damaging of any insect pest to major field and vegetable crops worldwide In contrast to the two species discussed in the previous sections, these are highly polyphagous; the two species have been recorded from 235 plant species in 36 families – many of those are weeds (Kogan et al., 1989). Stadelbacher (1979, 1981) reported the importance of both introduced and native early-season host plants of bollworm/budworm in the delta of Mississippi in the increase of the F1 generation. The moths of this generation subsequently invade cotton and require intensive insecticide sprays for their control. Insecticide-based control resulted in development of resistance in these species to most known insecticides. A species of wild geranium, *Geranium dissectum* (L.), an adventive , early maturing herbaceous winter annual from Europe, was the major alternate host in the area. Based on a quantitative study of larval and adult populations, as many as 180,000 bollworm/budworm larvae and 7,000 adults were estimated to be produced per acre. Stadelbacher reported that moths emerging in the spring were restricted to and concentrated in early-season alternate host plants, which occupied <5% of the total rural area. Subsequent studies on the rationale of attacking bollworm/budworm populations during this first generation and possibly the second generation suggested that a 90% reduction in areawide emergence in the first generation could be an effective management tool (Bell and Hayes, 1994a and b). An areawide IPM program was tested based on the suppression of F1 larvae with sprays of a *Heliothis/Helicoverpa* specific nuclear polyhedrosis virus over the breeding grounds where the weedy hosts were found. In this area velvetleaf was the preferred host for oviposition. The test covered an area of about

100 sq. miles. A single application of the virus reduced the size of the colonizing population on cotton by about 1/2 to 1/3 of the untreated area. The technique has been further developed for areawide application and results seem to be encouraging. Understanding the weed reservoir outside the crop area and the dispersal potential of the pest species are essential elements for the effective design of an IPM program.

Conclusions

The effect of weeds on insects is complex and manifests itself at both the physiological and ecological levels. The cases discussed here were limited to ecological effects on both oligophagous and polyphagous species. It is apparent that an intimate understanding of the responses of insects to stimuli from weeds, and the role of weeds in insect pest demographics, can offer opportunities to exploit the relationships in novel and creative ways in the context of IPM . These illustrations do not address the issue of the role of weeds in the diversification of crop communities and the effect of biodiversity on natural control. The paper by C. Picket in this workshop addresses this topic. The review by Norris and Kogan (2000) and the book by [Pickett, 1998 #284] provide insights and references on this subject.

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Conservation biological control in IPM systems: simplicity vs. complexity

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Preserves or refuges have long been used to maintain fauna and flora that could not exist otherwise. Recent interest among U.S. urban centers to promote wildlife, especially migratory waterfowl, has resulted in an upsurge in wetland restoration projects across the nation. Conservation biological control has a similar goal: the promotion of arthropods that benefit the biological control of serious agricultural pests. Although this practice existed over 1700 years ago in China, only recently has western culture placed value in this approach. Modern agriculture has done much to greatly simplify its environment and the process of controlling pest problems. Landscapes that were formerly a patchwork of farms, forests, and hedges have been replaced by vast monocultures. The replanting of annual crops in such areas disrupts populations of beneficial organisms in these fields. Although Integrated Pest Management was a response to single tactic insect control, short-term economic gain often dictates reliance on bouquets of pesticides rather than a combination of biological, cultural and insecticide control.

Conservation biological control often involves use of non-crop plants to promote or harbor natural enemies (Pickett & Bugg 1998, Landis et al. 2000). We believe one of the major limitations to understanding how natural enemies are affected by non-crop vegetation is knowing how they move or disperse within their environment: how different mixes of vegetation affect their movement between crops and surrounding vegetation. Recent advances in insect marking techniques have created new opportunities for studying insect movement. We were interested in learning if a natural enemy refuge, adjacent to field crops, could improve the biological control of silverleaf whitefly, a serious pest in the desert agricultural growing region of southern California. We marked indigenous parasitoids of silverleaf whitefly using the naturally occurring element, rubidium and studied how they moved from an overwintering refuge into small plots of either cantaloupe or cotton (Pickett et al., in prep.). Two questions were addressed: 1) will the aphelinids (Hymenoptera) *Eretmocerus eremicus* and *Encarsia* spp. move from strips of non-crop plants into an adjacent field of cantaloupe and cotton and 2) how much does the non-crop refuge contribute to the early season populations of whitefly parasitoids? Natural enemy refuges consisted of collards and sunflower. The location and proportion of trapped, marked parasitoids demonstrated that the refuges increased the numbers of *Eretmocerus eremicus* and *Encarsia spp.* in adjacent crops. Thirty-four to 100% of parasitoids caught in adjacent crops originated from these plants. However, the increased number of parasitoids resulting from the natural enemy refuge failed to increase biological control of silverleaf whitefly. The high number of whiteflies, relative to parasitoids produced in refuges during spring months, likely contributed to ineffective biological control.

Results from this study showed that a large portion of silverleaf whitefly specific parasitoids trapped in small plots of cantaloupe and cotton originated from adjacent refuges of collards and sunflower. However, the same plants produced far more of the pest than the beneficial insect. Other plants with lower affinities for the target pest, or harboring non-pest relatives would make better candidates for refuges.

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Impact of Pest Herbivores on Weeds

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Does damage to one plant affect neighboring plants? An elementary understanding of plant competitive interactions suggests that it does. What if the affected plant is a crop or other desirable vegetation and the neighboring plants are weeds? Specifically, what types of impacts do pest herbivores have on weeds? In this case, a pest herbivore is any biological organism (i.e. insect, disease, or vertebrate) that selectively feed or infects the desired plant with little or no impact on the weedy neighbors. For a subject that seems so intuitively obvious, there is very little in the published literature, especially the agronomic literature that documents or substantiates this phenomenon, so some of what is presented here will be based upon observations and anecdotal accounts.

The best papers on this subject are studies of insect damage to crops, mostly alfalfa, which resulted in increased weed growth in subsequent harvests. A review of this subject by Norris and Kogan (2000) cites several papers that verify the indirect impact of alfalfa weevils on weeds because of the deleterious effect on the crop. In a paper by Berberet, Stritzke, and Dowdy, (1987) the authors demonstrated that using an insecticide to control alfalfa weevil not only reduced the percentage of grasses in the next hay harvest, the overall hay yield was higher (see Table 1). Alfalfa weevil is a serious defoliator of alfalfa. Similar studies conducted in California by Carl Schoner and Robert Norris (see Norris and Schoner, 1975 and Schoner and Norris, 1975 in Norris and Kogan, 2000) produced similar results. Buntin and Pedigo (1986) showed that the density of variegated cutworms feeding in alfalfa had a direct correlation to weed biomass in later hay harvests (see Table 2). The conclusion that is drawn from these types of experiments is that when a pest damages alfalfa, opportunistic weeds will grow more vigorously and produce more biomass.

Examples from annual cropping systems are more varied, depending upon when in the stage of crop development the insect feeding occurs and how severe the feeding injury is to the crop. Norris and Kogan (2000) cite studies in soybean, potato, and wheat where insect feeding on the crop resulted in increased weed growth. In other studies, however, insect damage to a crop did not affect the weeds, probably because it was too late in the season and the competitive relationships between the plants was already established. These studies suggest that there is probably a greater likelihood that competition will be shifted in favor of weeds when damage occurs during the ‘critical period’. The critical period is a “window of time during which weeds must be removed or suppressed to avoid yield loss at harvest” (Radosevich, et al.1996, pg 205). This critical period starts sometime after crop emergence and ends after a certain stage of crop development.

Another excellent review of herbivory and plant competition is provided by Louda, Keeler, and Holt (1990). Again, most of the examples are insect related studies, illustrating how insect feeding on one plant species can increase growth of a competitive species. One study citing a nematode-plant competition interaction is reviewed. In this experiment (a replacement series) oats were able to out-compete barley when grown together, except when a nematode that fed just on oat roots was present.

An unpublished experiment conducted by the author provides an example of how plant diseases can influence weed growth. In this experiment, yield samples were collected from the same plots in several alfalfa fields at the first through the fourth cutting (February to July). When the alfalfa was separated from the summer annual grasses infesting the fields, an interesting and pertinent correlation was discovered. This was that the yield of alfalfa in February, before the grass had germinated in the field, would predict the yield of the grass infesting the plot in July. The correlation coefficient in this experiment was about -0.8, meaning that about 80% of the variation of the grass biomass is predicted by the alfalfa biomass 5 months earlier. Another way to view this result relevant to weed/crop competition is that as the alfalfa yields decreased, the grass yield increased. The loss of stand (crop population) in alfalfa in the low desert is typically caused by fungal root diseases, facilitated by water-logged soils, that debilitate the alfalfa over the two to four years that a crop generally lasts. Within any alfalfa field, areas will stay healthy and others will die, with lots of gradation in-between. The healthy areas will not have any grass and the weak areas will be weedy.

Examples of the relationship of vertebrate pests and weeds are hard to come by. There is lots of literature on the how grazing by large herbivores (e.g. sheep, cattle, horses) can increase or decrease the weediness of pastures or rangelands (see Bell, et al, 1996 and Harker, et. al, 2000). The grazing animal, however, is not a pest, it is the 'crop', and the premises of this paper is the impact of a pest herbivore on weeds. The author has seen incidents where gopher mounds in alfalfa fields are visible in the summer because of weedy grasses that infest the bare areas that resulted from the feeding damage of the pest. Since all herbivorous vertebrates feed selectively on some plant species in preference to others, there are undoubtedly many examples of vertebrate pests that increase weed populations because of the damage caused to the crop or desirable vegetation.

Louda, Keeler, and Holt (1990, page 420) present their reasons why selective or pest herbivory alters competition between plants. Their premise is that "herbivory can change the ability of a plant to acquire limited resources by altering key morphological traits". According to the authors, "herbivory may also change (1) internal allocation of resources, (2) root: shoot ratios, (3) nutrient turnover rates, and (4) litter accumulation", which can influence plant growth and development. The review by Louda, et al. focuses on plant competition in natural environments, which differs from the Norris and Kogan paper that discusses agricultural settings. The principals remain the same, but the desirability of the outcomes can be different. In a natural environment, there may not be any real interest in one plant "winning" the competition like there is in agriculture. But the invasive plant issue, i.e. weeds of natural areas, is of interest to this society. Louda, Keeler and Holt (1990) present a comprehensive conclusion for the role of pest herbivory on weed growth when they say, "The evidence suggests that, if competition for limited resources vary in either direction among co-occurring plants, then herbivores could be critical in the determination of relative competitive ability. In such cases, herbivory leads to patterns in the plant community that would be unlikely in the absence of herbivory."

Table 1. The influence of alfalfa weevil control on weed yield in alfalfa.

	1981			1982		
Treatment	Hay yield MT/ha	Weeds Percent	Alfalfa yield MT/ha	Hay yield MT/ha	Weeds Percent	Alfalfa Yield MT/ha
Insecticide + Herbicide	12.2	3.9 a	11.7 a	9.3 a	2.1 c	9.2 a
Insecticide only	12.5	11.1 b	10.9 a	10.1 a	23.8 b	8.1 ab
Herbicide only	10.6	4.6 a	10.0 a	8.0 b	2.2 c	7.8 b
Untreated control	11.7	17.0 c	9.2 b	7.6 b	43.6 a	4.6 c

Numbers followed by the same letter in a column are not significantly different (DMRT.05).

Table 2. How increasing variegated cutworm (VCW) density in alfalfa increases weed yield.

VCW density Numbers/0.1 meter square	Alfalfa yield Kg/ha	Weed yield Kg/ha
0	4805 a	219a
1.5	4037 ab	311a
3	4322 ab	429 a
6	4180 ab	612 ab
9	3232 bc	836 bc
12	2594 c	1199 c

Numbers followed by the same letter in a column are not significantly different (DMRT.05).

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The California Winegrape Pest Management Alliance

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The California Winegrape Pest Management Alliance (PMA) is a grower-driven collaboration with the Department of Pesticide Regulation (DPR) to promote reduced-risk pest management. The California Association of Winegrape Growers (CAWG) provides organizational leadership and a steering committee, comprised of representatives from regional and statewide winegrape organizations, guides efforts. Technical advisors include members of UC Cooperative Extension, UC Sustainable Agriculture Research and Education Program, US EPA, and USDA-ARS. Funding is provided by grants from DPR.

Inception

PMA was formed in August 1999. A number of ongoing events reflected increased concerns with pesticides and threatened uses – implementation of the Food Quality Protection Act (FQPA), increases in agricultural-urban interfaces, detections and increased awareness of groundwater contamination and other off-target movement, and raised awareness of worker exposure. The winegrape industry realized these concerns and founded PMA as a mechanism to increase adoption of reduced-risk practices, providing win-win solutions for growers, communities, and the environment. The creation and purpose of PMA is directly aligned with "Wine Vision", a strategic plan of the wine and winegrape community to be leaders in sustainable practices – environmentally sound, socially responsible, economically viable.

For winegrapes, PMA is unique in providing a strong, unified network for communicating pest management information to growers across California. A number of regional organizations have grower-led programs for promoting sustainable farming practices. These include the Lodi-Woodbridge Biologically Integrated Farming System, the Central Coast Vineyard Team Positive Points System, the Napa Sustainable Winegrowing Group, and the Sonoma County Grape Growers Association Integrated Pest Management Program. PMA complements and expands regional efforts by supplying more extensive and updated information sourced from growers across the state.

Focus

PMA has the statewide mission to promote pest management practices that minimize the potential for environmental and human harm while maintaining the economic viability of production. The Alliance advocates that improved relations between winegrowers and their neighbors and communities are fundamental to sustainable agriculture. Therefore, one goal is to further educate the public about the logic for vineyard operations and that growers care and act to reduce pesticide risks and strengthen community relationships.

But, growers must do their part by continuing to adopt practices that minimize risks from pesticides. A key goal of PMA is to educate growers about how to reduce drift incidents for sulfur and limit uses of higher-risk herbicides. Sulfur and herbicides are important tools for pest management in winegrapes across the state. However, uses are being carefully scrutinized by regulatory authorities and could be subject to further regulation. It is important to maintain the safe, effective uses of sulfur and herbicides, as well as those for other pest management tools.

The issue with sulfur is clear. Reports of drift have increased in recent years. In fact, a survey conducted by DPR found 86 reported incidents of sulfur drift from 1997 to June 1999. Approximately two thirds of these reports were attributed to applications on grapes, distributed across the state. Over 80% of reports for grapes involved dusting sulfur. The key factor for the increase in incidents seems to be an increase in agricultural/urban interfaces, leading to more public complaints.

There also are statewide concerns about effects of herbicides on the environment and human health. Herbicides used in grape production have been detected in groundwater in some areas. Further, many herbicides registered for grapes are considered higher-risk materials in terms of human health. Consequently, a number of herbicides and uses may be unavailable for the future. This is troubling since only one (Roundup, glyphosate) of the eight most commonly used herbicides on winegrapes is considered a lower-risk material. PMA intends to reduce uses of herbicides classified as potential contaminants of groundwater or FQPA high-risk (priority I) materials.

Actions

PMA is using field demonstration and outreach to communicate reduced-risk approaches for managing sulfur and weeds. Key to success is effective grower-to-grower transfer of practical information. Accordingly, 34 grower-cooperators have been recruited over five winegrowing regions – North Coast, Central Coast, South Coast, Northern Interior, and South Central Valley. Cooperators implement and record reduced-risk management practices for sulfur and weeds, which they share and showcase at field days for winegrowers and the public.

Sulfur cooperators have a history of farming near areas sensitive to sulfur (e.g., residences, school zones, busy roadways). These growers successfully integrate sulfur into management programs for powdery mildew without complaints of drift. Dusting sulfur must be managed with particular care because of its extensive use, visibility, and susceptibility to offsite movement by wind. Programs incorporate elements of neighbor relations, canopy management, mildew monitoring, buffer establishment, alternative fungicides, equipment operation, weather monitoring, and application timing.

PMA cooperators demonstrating weed management have been recruited based on their history of managing weeds using reduced-risk strategies and tactics. Pest management is a continuum from higher to lower risk. Ideally, pesticides categorized as higher risk are avoided. However, in the absence of reasonable options, PMA acknowledges that certain circumstances warrant uses of these materials. To optimize decisions for weed management, growers should have detailed understandings of weed species, soils, effectiveness of alternatives, and/or economic considerations specific to each vineyard. Growers that tolerate sub-economic populations of weeds are progressing fastest along the continuum to more reduced-risk weed management. PMA cooperators restrict uses of higher-risk herbicides to situations where alternative tactics provide unacceptable efficacy or are economically impractical.

Cooperators incorporate various reduced-risk options into under-the-vine programs for managing weeds. Nonchemical tactics include mechanical options (e.g., cultivating, mowing, hand hoeing), preventive interference (e.g., mulching, composting, cover cropping), heat (e.g., flaming, steaming), and drip irrigation (e.g., subsurface). In addition to efficient water use, drip irrigation can markedly limit weed pressure both spatially and temporally, and needs for supplemental control.

Those cooperators that include herbicides in their reduced-risk programs often rely on lower-risk, post-emergent materials such as glyphosate (Roundup). Where higher-risk preemergent or postemergent herbicides are warranted, uses can be minimized and risks reduced by accurate calibration and by using lowest effective rates, decreased spray swaths, and optimal application timings. Spot spraying via infrared technology or by hand or use of controlled-droplet applicators can minimize uses of post-emergent herbicides and associated costs.

Expected Achievements and Future Goals

Through expanded winegrower education, PMA intends to reduce or eliminate complaints of sulfur drift and decrease uses of higher-risk herbicides. Cooperators will continue to be added. Evolving practices for managing sulfur and weeds will be integrated into future demonstration and outreach activities. Over time, PMA will incorporate reduced-risk practices for managing other pests. An ultimate goal is to implement a statewide, grower self-assessment program for managing all vineyard pests.

Efforts to increase public understandings about real challenges faced by winegrowers and their commitment to making judicious choices will continue. The simultaneous education of growers and the public will lead to mutual understandings, improved farmer-community relationships, fewer pesticide incidents, and more sustainable farming systems.

For California's winegrowers, PMA is the latest and broadest effort at promoting sustainable viticulture through a cooperative effort of demonstration and outreach. Agriculture must be proactive in addressing and resolving challenges, such as risks from sulfur and herbicides, thereby helping direct and shape its own future. Through PMA, the winegrape community substantiates its lead role in sustainable agriculture by balancing the production of high quality winegrapes with high standards for environmental quality and human health.

The Efficacy, Economic and Mitigated Impacts of Low Volume Foliar Applications

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Whether vegetation management requires the control of native brush or the control of exotic species such as salt cedar or Arundo, the control of these species is a means to an end in that control is necessary for the restoration of habitat or industrial site it has invaded. It is important that the control methods provide maximum efficacy on target species with minimal impact on the surrounding environment. Stalker (active ingredient, Imazapyr) was recently registered in the State of California. This herbicide is a valuable tool for the control of brush such as oaks or eucalyptus. It is also valuable for the control of exotics such as salt cedar (tamarisk) or arundo.
The foliar efficacy of Stalker on target species is excellent. The environmental compatibilities and favorable toxicology profile minimize the impact to the environment.

The method of application can dramatically influence the impact a particular treatment will have on the surrounding environment. Low volume foliar and basal treatments allow for targeted, focused, applications that provide maximum control with minimum off target impact. Key to the success of these applications is the proper application technique, the appropriate herbicide, and the appropriate combination of surfactants.

Required application equipment consists of a backpack, low volume flat fan nozzles such as 2504, 4003, or adjustable cone nozzles such as an X-2 or a Y-2. Concentrations range from 3 to 5%. Applications volumes are less than 10 GPA. Applications are made to the upper portions of the target plant with coverage not exceeding 30%.

Once treated plants need to be left in tact for 1 year or more. Efficacy will become evident over a period of two to three months. It will be first evident in the upper portions of the plant in the apical meristems. Although the plant remains, it is no longer in competition for resources. Additionally, the remaining plants can provide shelter for emerging or planted native seedlings. After one year, target species may be removed.

Low volume foliar applications provide an economical, efficacious method of controlling brush and exotics. Stalker, applied using a low volume foliar application method, provides an excellent tool for vegetation management in industrial sites or for habitat restoration projects.

Purple Loosestrife: A Coordinated Education, Mapping, and Control Effort

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In 1999 the Integrated Pest Control Branch of the California Department of Food and Agriculture (CDFA) was awarded a grant by the CALFED Bay-Delta Program to conduct a purple loosestrife prevention, detection, and control program. Purple loosestrife (*Lythrum salicaria*) is a non-native, invasive but showy ornamental that has escaped home gardens and nurseries and moved extensively throughout the wetlands of the United States causing immense ecological destruction. Purple loosestrife is listed by the CDFA as a "B" rated noxious weed, which means it is to be excluded from entry into the State and eradicated from nurseries throughout the State, and eradicated from local areas at the discretion of the local County Agricultural Commissioner. Purple loosestrife is also listed by the California Exotic Pest Plant Council as a "B" rated weed, which means it is considered a "species with potential to spread explosively". Based on historic records and recent surveys, the current distribution of purple loosestrife in California is in multiple, mostly small and scattered populations.

The geographical focus of the program is 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 is an extensive collaborative effort with State and Federal Agencies, County Agricultural Commissioner's Offices, watershed groups, and local Weed Management Area groups.

The purple loosestrife project objectives are five-fold. (1) A broad education and training campaign- To date, over 75 talks and training sessions have been given to cooperating agencies, Weed Management Area groups, homeowners associations, California Native Plant Society Chapters, garden clubs, and the general public. A brochure has been printed and distributed widely and a website has been launched. (2) Extensive surveying and mapping- During the first field season of the project, all purple loosestrife sites were mapped using GPS and then taken back to the CDFA Geographical Information System laboratory and made into maps. Overall project maps and detailed regional distribution maps have been developed. During survey and delimitation of waterways, both positive and negative finds were recorded with GPS. In addition, control and monitoring layers have been added to the maps to assist in tracking project successes. (3) Collaborative assessment meetings of regional cooperators to develop site-specific adaptive management plans- Based on distribution maps developed during the first season of the project, a series of cooperator meetings were held to develop site-specific adaptive management plans. Regional plans outline site goals, available control options, and benchmarks for measuring control outcomes. Regional management plans will be reassessed on an annual basis. (4) Comprehensive local control and eradication efforts- Based on regional adaptive management plans, control methods were carried out during the 2001 field season. Methods of control included: mechanical removal, spot treatment with Rodeo® (glyphosate), and concentrated releases of biological control agents. (5) Project and water quality monitoring- Overall project successes will be measured against regional adaptive management plans. The California Department of Fish and Game's Pesticide Investigations Unit was contracted out to collect and analyze water quality samples for the herbicide (Rodeo®) and surfactant (R-11). Representative sites were selected within the CALFED Bay-Delta project area. Sites included the end of a slough, a pond, and a flowing river. In addition to analyzing samples for the presences/levels of Rodeo® and R-11, toxicity tests were carried-out.

Prevention and early detection are the most economically and environmentally viable options in noxious weed eradication. Eradicating single isolated plants or small patches early on before a population gets firmly established and builds up a seed bank, is the best way to control purple loosestrife. Hand removal of small populations (<100 plants) is feasible in some circumstances. Mechanical control is often an option for localized, homeowner pond infestations. However, many sites in the Sacramento-San Joaquin Bay-Delta are difficult to control mechanically due to an impenetrable rocky substrate and unstable accessibility from a boat.

For large sites, and where mechanical removal is not an option, chemical control may be the best tool though herbicide options are limited. In the literature, 2,4-D has been reported to have inconsistent control results. Rodeo® (glyphosate) has been shown to be the most effective means of control. Spot treatment is recommended to preserve the surrounding vegetation, which provides competition and helps prevent reinvasion by purple loosestrife or other invasive species. While treatment success with Rodeo® has been noted throughout flowering, the best time to treat is when the stand is in full bloom, as the plant is easily seen and skips are avoided. It has also been noted that a follow-up treatment may be necessary for large, bushy plants or clumps (plants greater than 3 feet tall and clumps greater than 2 feet wide). A third herbicide, Garlon®3A (triclopyr) has yet to be registered for aquatics use in California. If registered, Garlon® 3A would likely be a very effective tool in controlling purple loosestrife due to its selectivity for broadleaves, thus allowing surrounding aquatic vegetation (e.g. cattails and reeds) to be preserved.

Several biological control agents have been approved for release in California. Since 1998, a root weevil (*Hylobius transversovittatus*), a seed/flower weevil (*Nanophyes marmoratus*), and two leaf-eating beetles (*Galerucella calmariensis and G. pusilla*) have been released at several locations throughout the state (Siskiyou, Shasta, Butte, Nevada, and Kern counties). To date, very limited establishment has been recorded. However, states in the northeastern United States and other western states have reported great success with the leaf-eating beetles. Due to successes elsewhere, in 2001 concentrated releases of higher numbers of leaf-eating beetles were released in Shasta, Butte, and Kern counties. Similar releases will continue in 2002. It will take several more years of releases and monitoring to determine if biological control is a viable option for purple loosestrife control in California.

In 2002, the project will enter its last year of current funding. Two proposals that would continue funding for the project are currently pending. Through continued education, survey, and eradication efforts, eradication of local populations is possible and containment and/or eradication of widespread populations are achievable.

Hydrilla: an Aquatic Weed Threat to the Delta and Bay

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Hydrilla (*Hydrilla verticillata*) is the only "A" rated submerged aquatic noxious weed in California and the Legislature has charged the California Department of Food and Agriculture (CDFA) to survey and eradicate it from the State (California Food and Agriculture Code Section 6048). As an "A" rated weed, CDFA is charged with the responsibility to 1). Properly identify this weed, 2). Exclude entry of this weed into the State, 3). Establish interior quarantine in all infested counties that contain infested water bodies, 4). Survey all high hazard water bodies in the State for this weed, 5). Eradicate it wherever it is practical, 6). Educate the public to clean hydrilla from boats and boat motors and report the weed if sighted, and 7). Sponsor research on the ecology and control of hydrilla.

The CDFA Integrated Pest Control Branch (CDFA-IPC) is charged with managing the State's Noxious Weed Programs, including hydrilla eradication. In the CDFA-IPC's Strategic Plan, the first item is "to prevent establishment the establishment of hydrilla in California." An important aspect of this is preventing new infestations, such as new infestations in the Sacramento-San Joaquin River Delta and San Francisco Bay. CDFA-IPC discharges this responsibility in cooperation with other Federal, State, County and private organizations such as the U. S. Department of Agriculture's Exotic and Invasive Weed Control Program, the U. S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the California Department of Boating and Waterways, the University of California, the local County Agricultural Commissioners, and Yolo County Flood Control and Water Conservation District.

The Sacramento-San Joaquin River Delta is the most important water body in the State, with 47 percent of all the runoff water in California moving through the Delta. It provides water for residential, industrial, and agricultural uses in both the North and South State areas. The Delta supports approximately 120 fish species, and approximately 750 plant and animal species (CALFED Bay-Delta Program 2001). In addition, it is the largest wetland habitat in the western United States (CALFED Bay-Delta Program 2001). Any blockage of this water flow by hydrilla would impede navigation, clog water control structures, choke hydroelectric generators, imperil native plant, fish, and animal life and diversity; and raise the cost of water delivery to users.

Hydrilla is classified as a noxious weed because of its invasive and hard-to-control nature. Hydrilla spreads through plant fragments, tubers, and turions. The tubers can stay viable in the hydrosoil for up to 10 years (Encycloweedia, 2001). In addition, hydrilla has a rapid growth rate, forms large, submerged mats, and is a fierce competitor for sunlight in the water column (Langeland 1996). And last, because hydrilla is not indigenous to California, there are no natural predators to keep its spread in check.

The CDFA-IPC Hydrilla Eradication Program began in 1976 after hydrilla was found in Lake Ellis in Marysville, California. Since then, hydrilla has been found in 17 counties in the State and eradicated from several water bodies in 13 of these counties, including Lake Ellis. However, active eradication projects are on-going in water bodies that could potentially drain into the Sacramento Delta through the Sacramento River, the San Joaquin River, or Cache Creek and other tributaries (see Figure). These projects are: 1). Two infested ponds near the Sacramento River near Redding in Shasta County, 2). Several infested ponds and an infested canal in Yuba County near Oregon House, 3). Clear Lake in Lake County, 4). One pond along Bear Creek in Calaveras County, 5). Eastman Lake and the first 26 miles of the Chowchilla River upstream from the lake in Madera and Mariposa Counties, and 6). Several ponds in Tulare County above Lake Success (California Department of Food and Agriculture 2001.). All of these infestations could infest the Delta either through direct hydraulic connection (water flow) or by way of infested boats, boat trailers, boat motors, livewells, trucks, fishing gear, clothing, etc. Of these active projects, the closest and most direct hydraulic connection to the Delta is the infested pond along Bear Creek in Calaveras County, which drains into Disappointment Slough and from there into the San Joaquin River near Stockton.

These active sites are surveyed by CDFA-IPC personnel for hydrilla at least three times per year in order to determine if the infestation is spreading, stable or decreasing. In addition, all water bodies within approximately 5 miles or more of each active site are surveyed by CDFA-IPC personnel several times per year in order to determine if they remain hydrilla free. In order to help the survey and detection effort, CDFA-IPC personnel also conduct training for other agencies and groups on the recognition and identification of hydrilla and where to report it if found (the local County Agricultural Commissioner). These agencies and groups include the California Department of Fish and Game, local County Agricultural Departments, Irrigation Districts, Pest Control Advisors, botanical and native plant societies, golf course managers, and irrigation managers. The assistance of these agencies and groups is essential to the survey and detection effort in order to assure that all water bodies in the State are surveyed at some level. CDFA-IPC personnel follow up on all reported hydrilla sightings from the public or from the local Agricultural Commissioners in order to confirm identity. In addition, hydrilla brochures describing the plant are given to County Agricultural Commissioners, marinas, bait and tackle shops, and other interested parties for distribution to the public.

The hydrilla infestation at the active hydrilla sites is decreasing. For example, the number of infested ponds near Redding has declined to 2 in year 2001 from the 17 originally infested and the number of plant finds in Clear Lake has declined to 41 in year 2001 from 208 in year 1997. In the Eastman Lake/Chowchilla River complex, the number of plants found has declined from uncountable in 1992 to 6,500 in year 1993 to only five in year 2001 and the number of tubers has declined from 35,451 in year 1991 to 1,400 in year 2000.

CDFA-IPC uses an Integrated Pest Management approach to hydrilla eradication. Eradication methods include manual removal and dredging; drawdown and drainage; screens to prevent movement of plant fragments, tubers, or turions; and chemical control. The herbicides used are primarily a liquid copper ethylenediamine complex, liquid fluridone and fluridone slow release pellets. (In Imperial County, but not in the waterways associated with the Delta, CDFA-IPC and the Imperial Irrigation District also use the triploid grass carp as a biological control agent for hydrilla.)

Each year, personnel from CDFA-IPC conduct a survey of the Sacramento-San Joaquin Delta and the lower reaches of the tributary rivers for hydrilla. The presence of other aquatic weeds is also noted. In the years 2000/2001, this survey included Suisun Bay, Middle River, Old River, Franks Tract, Potato Slough, White's Slough, Disappointment Slough, the Stockton Deepwater Channel, Victoria Channel, the Grant Line Canal, Cache Creek, Bear Creek, the Sacramento River, the Feather River, and the San Joaquin River. The survey is made in late fall when hydrilla plants and mats are easiest to detect. No hydrilla has ever been found in the Delta, though other non-native, aquatic pest plants, such as *Egeria densa*, *Cabomba caroliniana*, and water hyacinth (*Eichhornia crassipes*) have been found, sometimes in large numbers. If hydrilla were ever to be found in the Delta, early detection of an incipient infestation by way of this annual survey would be essential to eradicating hydrilla before it became permanently established and began to spread.

In summary, the CDFA-IPC Hydrilla Eradication Program is succeeding at eliminating hydrilla from infested water bodies, and is succeeding in keeping the Sacramento Delta and San Francisco Bay hydrilla free.

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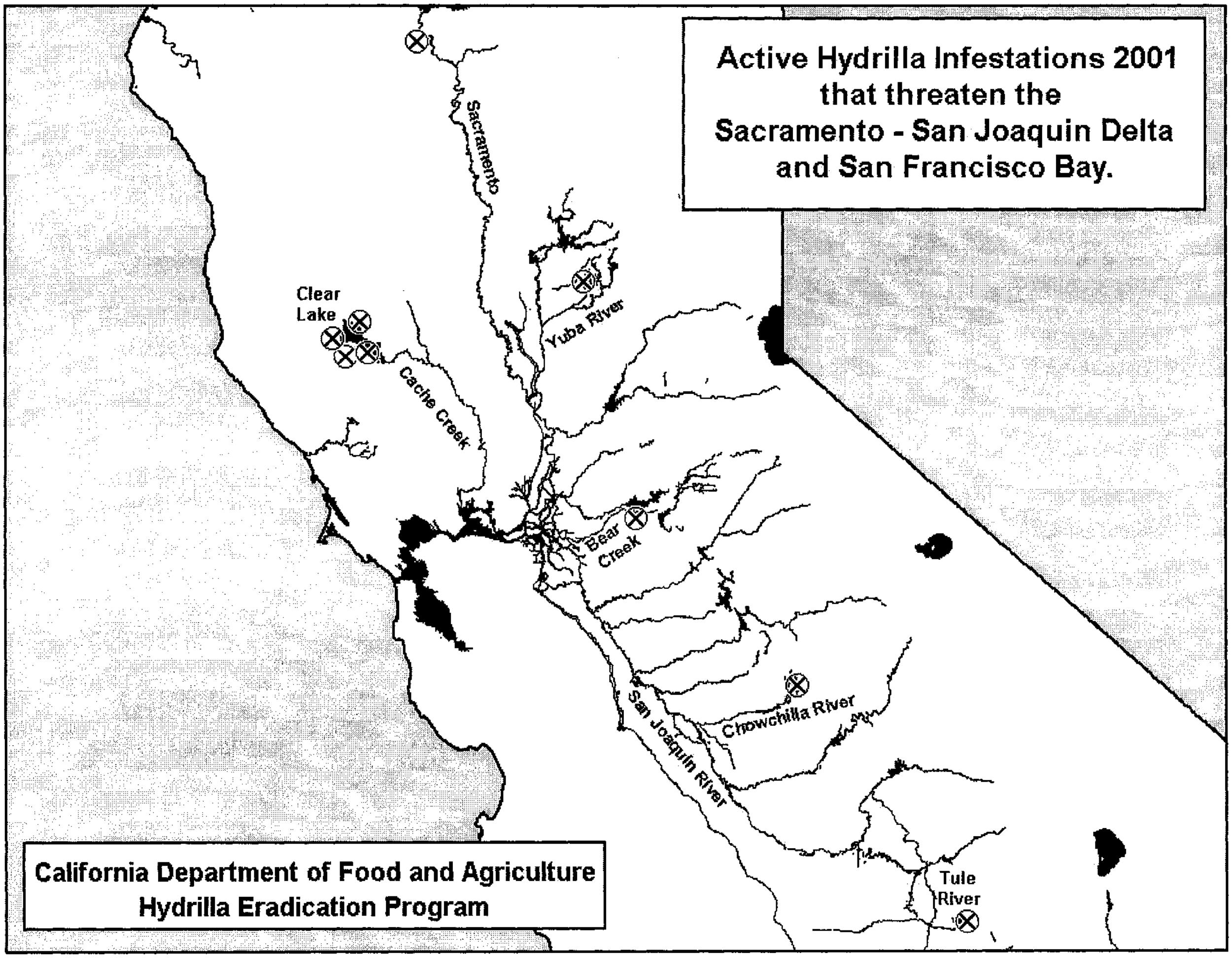
Figure. Active hydrilla projects in the CDFA Hydrilla Eradication Program where the water could potentially drain into the Sacramento-San Joaquin Delta and San Francisco Bay.



Aquatic Plant Management in Oregon

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Aquatic plant management is critically important in water resource management in Oregon; yet, fish management issues, public perception, and court decisions have created conditions in the State that are antithetical to implementation of aquatic plant management efforts. Noxious aquatic weeds, such as *Egeria densa* (Egeria) and *Myriophyllum spicatum* (Eurasian watermilfoil*)*, and other invasive aquatic plants degrade water quality and fish habitat in most Oregon lakes. A recently completed economic assessment of weeds found that aquatic, estuarine, and wetland weed infestations cause $39 To $666 per acre in economic losses in Oregon (Oregon Department of Agriculture 2000). This is a conservative estimate that in some instances does not include the costs of management or loss of fish habitat and production from water quality degradation. Because aquatic systems have high value, on a per area basis, aquatic and wetland weeds far exceed the cost of terrestrial weeds.

Despite the costs and obvious ecological and recreational impacts, conditions in Oregon are not conducive to effective aquatic plant management. A general mistrust of government regulation, including EPA requirements for registration of herbicides; reports of impacts of terrestrial pesticides on salmon olafactory capabilities (Moore and Waring 1996) and predator avoidance behavior (Scholz *et al.* 2000); effects of some aquatic herbicides on mortality of smolts during seawater entry tests (Lorz *et al.* 1978; Lorz *et al.* 1979); and recent court decisions have severely limited aquatic plant management activities in Oregon. The March, 2001 9th Circuit Court of Appeals decision requiring National Pollution Discharge Elimination System permit for aquatic pesticide applications halted all legal aquatic herbicide applications to lakes because no such permit exists in Oregon.

Conflicts between managing water quality impacts and lack of adequate resources and motivation within agencies to formulate rational management policies have created a schizophrenic condition. The Department of Environmental Quality (DEQ) is charged with implementing the Clean Water Act (CWA) in Oregon. Under Section 303(d) of the CWA, the State must list those waterbodies in the state that fail to meet water quality standards. The DEQ has been quite progressive in recognizing that noxious weeds are a form of biological pollution and has used the presence of noxious aquatic weeds as a criterion for listing waterbodies as water quality limited under the CWA. The CWA requires that states address problems in water quality limited waterbodies.

The DEQ is also charged with issuing NPDES permits in Oregon. California and Washington reacted to the 9th Circuit Court of Appeals decision by initiating development of an NPDES permit for aquatic pesticide applications. In order to address the immediate need for weed control in irrigation canals last summer, however, the Oregon DEQ developed a Mutual

Agreement and Order (MAO) that stated the necessary notification and application procedures for application of acrolein and xylene to irrigation canals in Oregon in 2001. While not an NPDES permit, the MAO allowed some districts to use these compounds for weed control in 2001 without threat of civil penalty, but left them vulnerable to third party lawsuits under CWA. In addition, EPA stated that enforcement of the 9th Circuit Court of Appeals decision would be a low priority in 2001. Thus, some irrigation districts were able to apply acrolein and xylene in 2001, but others resorted to mechanical control methods to reduce exposure to third party lawsuits for failure to comply with the court decision requiring a NPDES permit. The MAO did not apply to any waterbodies other than irrigation canals. Thus, the legal application of aquatic herbicides for control of weeds in lakes was stopped in Oregon in 2001 because the NPDES required by law, or a MAO in lieu of a permit, was not available.

Other aquatic weed control methods, such as mechanical harvesting and triploid grass carp, are available in Oregon. Grass carp are permitted only in lakes under 10 acres, and cannot be in a waterbody that lies within the 100-year floodplain when there is risk of flood. The narrow constraints on grass carp typically limit their use to small artificial ponds, *e.g.*, golf course, irrigation and stock ponds. Mechanical and other harvesting methods are used for aquatic weed management in Oregon, however, costs and potential "take" of threatened species, *e.g.*, juvenile coho salmon in coastal lakes, limit applicability of mechanical harvesting. Other harvesting techniques, such as diver dredging are not cost-effective on large infestations.

Lake Lytle Case Study

Lake Lytle and its associated waterbodies Moroney Canal and Cresent Lake, on the central Oregon coast just North of Tillamook Bay, are water quality limited because of a Eurasian watermilfoil infestation. An integrated aquatic vegetation management plan was developed for the 70-acre lake in 1999 (Rosenkranz and Sytsma, 1999). The Plan called for selective removal of Eurasian watermilfoil from the lake using a three-year program of low-rate, long contact-time treatments with Sonar aquatic herbicide. The initial year of the Plan was implemented in 2000 with good results (Shrestha and Sytsma 2001).

A second year of treatment was planned in 2001, however, the 9th Circuit Court of Appeals decision in the Spring of 2001, and lack of a NPDES permit in Oregon for application of aquatic herbicide, forced use of a diver-operated dredge for Eurasian watermilfoil management in 2001. The method was not capable of adequately managing the weed in Lake Lytle in 2001, and as a consequence, the infestation expanded throughout the summer to a point where all the gains of the previous year were lost (Table). Failure to completely implement the integrated management plan resulted in failure of the control program and will require reevaluation of the goals and objectives of the management plan, or restarting the three-year program when herbicide application permits are available.

The Future

The future of aquatic weed management in Oregon is difficult to discern. Noxious aquatic weeds will continue to degrade water quality and fish habitat, interfere with recreation, and decrease property values. Presence of threatened fish species within infested waters will continue to complicate and perhaps prohibit management actions. Many lakes will continue to be listed as water quality limited under the CWA because of noxious aquatic weed infestation, and require State action to alleviate the cause of the listing. DEQ is considering development of necessary permits, however, there has been no action to-date on development of the required NPDES permit. At best, a MAO may be available for application herbicides in irrigation canals and lakes in 2002, however, it is important to note that an MAO is not a NPDES permit, and application of herbicides under an MAO leaves the applicator vulnerable to third-party lawsuits under the CWA. Lack of information on sublethal impacts of aquatic herbicides on threatened and endangered salmon species may result in prohibition of aquatic herbicide use under the Endangered Species Act, even if the problems with the CWA are resolved.

Prevention is often cited as the most cost-effective invasive species management option. In Oregon, prevention may be the only effective management option available in the future, regardless of the cost. Oregon does not have any known infestations of hydrilla, water hyacinth, salvinia, or smooth cordgrass; aquatic weeds that have caused serious problems in neighboring states. Preventing the introduction of these and other aquatic invasive species is a high priority element of the Oregon Aquatic Nuisance Species (ANS) Management Plan, which was submitted by the Governor and approved by the federal Aquatic Nuisance Species Task Force in 2001. Oregon is one of two western states with approved ANS Management Plans.

The Oregon ANS Management Plan includes public education, surveillance and detection, contingency plan development, management, and research elements. Funding for the Oregon ANS Management Plan from the federal ANS Task Force and the Oregon Watershed Enhancement Board is expected in 2002. The federal and state funding will supplement ongoing efforts by the Oregon Department of Agriculture, DEQ, and the Center for Lakes and Reservoirs at Portland State University to address aquatic weed issues, and will permit a more coordinated and comprehensive approach to aquatic invasive species management in the state.

Frequency of aquatic plants in samples collected in Lake Lytle and associated water bodies before Sonar (BS) and after Sonar (AS) treatment in 2000 and before harvesting (BH) and after harvesting (AH) in 2001 (Shrestha and Sytsma 2001).

Plants Sampled	**Lake Lytle**				**Moroney Canal**				**Crescent Lake**			
	2000		**2001**		**2000**		**2001**		**2000**		**2001**	
	BS	AS	BH	AH	BS	AS	BH	AH	BS	AS	BH	AH
Myriophyllum spicatum	42%	5%	13%	55%	100%	17%	61%	42%	28%	4%	4%	2%*
Najas flexilis	77%	0	40.5%	71%			11.5%	58%			10%	56%
Potamogeton pectinatus	18%	0	4.5%	30%	40%	17%	90%	67%	92%	92%	90%	92%
Sagittaria subulata	6%	3%	25%	0	10%	16%						
Elodea canadnesis	23%	28.6%	17%	70%	20%	8%	4%	17%				
Chara vulgaris	29%	44%	35.5%	17%								
Utricularia vulgaris	25%	14%	14.5%	2.6%		25%	8%	17%				4%
Nitella sp	17%	18%	17%	9%			8%					
Potamogeton nodusus	2%	2%	4.5%	13%	40%	17%						
Isoetes lacustris		5%	1.8%	4.5%								
Potamogeton richardsonii		2.8%	5.4%	13%								
Callitriche sp.												4%
Ruppia sp.			5%	14%								4%

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Caulerpa taxifolia: The West Coast Marine Invader

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Introduction

In June, 2000, California once again became the leading edge in dealing with a new invasive weed: the marine alga, *Caulerpa taxifolia*. This exotic, tropical and commonly available aquarium plant was discovered just 30 miles north of San Diego, California, in Agua Hedionda lagoon, a stone's throw from the City of Carlsbad. The discovery was the result of the sharp-eyed awareness of biologist Rachel Woodfield, who was conducting revegetation work with Merkel and Associates. Within days after noting the presence of this bright-green alga, various state and federal agencies were notified and the identification was confirmed at UC Berkeley. Just weeks later, an ad-hoc advisory group met and shortly thereafter the first treatments were made. This group included representatives from California Dept. of Food and Agriculture, California Dept. of Fish and Game, San Diego Regional Water Quality Control Board, US Dept. of Agriculture-ARS, National Marine Fisheries Service, an Agua Hedionda citizen representative and several other stakeholders. Now called the Southern California Caulerpa Action Committee, or SCCAT, the group has spearheaded the eradication effort over the past year and a half. Since the first eradication applications were made within just a month of finding *Caulerpa taxifolia* in the northern hemisphere, this event provides a model for a true "rapid response".

Why Worry about *Caulerpa*?

In the mid 1980s' this unusual, single-celled alga spread in the Mediterranean off the coast of Monaco from a few square meters to over 20,000 hectares over the past 17 years. It's aggressive growth overtops and smothers native algae and eelgrasses while at the same time providing almost no forage for herbivores due to its toxic constituents. With the ability to grow several inches per day and achieve lengths form 0.5 to 1.5m, it creates a kind of tough Astroturf-type mass that disrupts the normal ecological functioning of mid and lower tidal areas to depths of 200 to 300 ft in clear water. It can become established on a variety of substrates from sandy to rocky shores and can tolerate temperatures from about 8C to 30C. Therefore, allowing the alga to become established would threaten coastal marine waters from probably as far north as Santa Barbara (perhaps even San Francisco) to well into Mexican shores and bays. With its rapid clonal growth, and the ability to become dislodged and transported, stopping it immediately is critically important.

Thanks to Dr. Meinesz's book and other publications, US scientists were enough aware of the threat from Caulerpa to get it placed on the Federal Noxous Weed List in 1999. However, as is unfortunately typical, public awareness and enforcement from this action was nearly non-existent. In fact, when the discovery was made in California in 2000, a survey of aquarium shops quickly revealed that the plant was widely available for sale. This is no surprise since the alga is so easily transplanted from small pieces and grows readily, this "weedy" characteristic has made it a popular plant for the marine aquarium hobbyists. And, in spite of much improved awareness of this pest, it is still available on the internet without much search time needed.

Not satisfied with the limitations of the Noxious Weed List enforcement (pertaining only to inter-state movement), the SCCAT and California stakeholders prompted the California state legislature to pass and the Governor (Gray Davis) to sign into law a very important bill last Septemver 24 (AB 1334) that completely bans the sale, possession and transport of 8 species of the genus *Caulerpa*. The importance of including several "look-alike" species in the ban cannot be underplayed. Enforcement depends upon timely, correct identification, and even knowledgeable phycologists often cannot easily distinguish between the variety of growth forms of *C. taxifolia* and related species. This bill, coupled with the newly activated role of the California Dept. of Fish and Game and leadership of CDFG's new Invasive Species Coordinator, Susan Ellis, should help tremendously in keeping further introductions form occurring.

California's Action: A True "Rapid Response"

In spite of what seemed (to some) to be a clear threat to the marine habitat off Monaco, the response to the Mediterranean spread was plagued with delays and disagreements about the severity of the situation. While this unfortunate circumstance still persists to some degree in Europe, it was clear to agency scientists and managers in California in June, 2000, that delays could not be tolerated. In fact, the San Diego Regional Water Quality Control Board took the creative and expeditious stance that C. taxifolia was in fact a "pollutant" and this triggered the release of emergency funding. That decision, coupled with additional support from the local power generator, Cabrillo Power, LLC, and NMFS, provided the initial funding needed.

Coincident with the obtaining funding, the combined experience of federal, state scientists and managers involved with California's hydrilla eradication program, and the Merkel staff, were able to weigh practical options, quickly test potential algicides, and develop the operational method of choice: cover each colony and inject liquid chlorine. Although hydrilla (*Hydrilla verticillata*) is a flowering, freshwater aquatic plant, its growth habit, mode of spread by rhizomes and shoot-fragments, provided a reasonable model. Three key elements allowed the Caulerpa eradication to move ahead quickly: **Consensus to act (Eradicate!)**, Consensus **of Authority to act** (i.e. Lead Agency), and **Immediate Availability of Resources** (emergency funds from the Water Quality Control Board, Cabrillo Power, and the in-field action team (Merkel and Associates). The success of this approach could serve as a model for broader Rapid Response strategies for other incipient invasive species.

Current Status of the Eradication Program

Shortly after the discovery of *C. taxiflolia* in Agua Hedionda, a small populations was found in Huntington harbor south of Los Angeles. It was surveyed and treated in much the same way as the Carlsbad infestation. Additional surveys have been conducted in near-shoreline areas-both bays and some open-coastal areas using SCUBA divers, side-scan sonar and aerial photography. So far, no evidence of other infestations has been found. However, the survey will continue since there are many potential sites along the southern California coast and bays.

Over the first full year since its discovery, additional, small colonies of *C. taxifolia* have been detected and treated in Agua Hedionda. Over time, the search- pattern in this lagoon has been tightened and now is conducted on a one-meter grid by divers. This is time-consuming, but necessary due to often poor visibility and the need to detect any new (or previously missed) colonies. In Hunting Harbor (a very small, nearly-enclosed area, well-removed from the open ocean), 10 colonies were covered separately in an overall site of approximately 6 acres . In Agua Hedionda, about 45 colonies over 100sq.ft (0.3 acres of colonies) have been covered and treated in a total area of about 350 acres in the total lagoon. So far, all the infestations have been found only the inner-most part (aobut one-third the total area) of the lagoon.

As part of the eradication program, use of the lagoon by vessels (e.g. jet skis, "wave riders' and other boats, as well as fishing activities have been greatly curtailed. Further restrictions are likely as the potential of moving small fragments and colonies through wave-action, as well as the need for efficiency and safety for surveillance heightens. With the current fine-scale search grids, it's likely that any new colonies will be detected and treated quickly.

In December 2001, sediment core samples were taken from representative treated areas in Agua Hedionda to assess the effectiveness of the earlier chlorine treatments. Intact cores were transported to the USDA-ARS Exotic and Invasive Weed Research laboratory at UC-Davis and placed under grow-out conditions (20C, 14:12 LD under 300 $\mu E\ m^{-2}\ sec^{-1}$fluorescent light). Additionally, cores from untreated areas were inoculated with either stolons with rhizoids, or stolons with rhizoids and emergent fronds of *C. taxifolia* to serve as controls. This study is ongoing, but as of 30 days post planting, no *C taxifolia* has emerged in the cores from the treated areas, and the inoculated plants are growing well.

The costs of *Caulerpa taxifolia* in Agua Hedionda Lagoon will probably exceed $1.1million for the first year, and will probably be similar for the second year since a major effort is surveillance and monitoring. Expenditures for Huntington Harbor site are similar. These funds have come from a variety of sources including the Sand Diego Water Board, National Marine Fisheries Service, California Dept. of Fish and Game, Cabrillo Power, LLC. Not included are significant resource as "in kind" support, including security from the City of

Carlsbad, staff and scientists' time from the dozen or so agencies involved at the onset of the program.

Most recently, the SCCAT has formalized its advisory task under the leadership of a Steering Committee with representatives of the following agencies:
California Dept. of Fish and Game (Co-Chair), San Diego Regional Water Quality Control Board (Chair), National Marine Fisheries Service, and the US Dept. of Agriculture-Agricultural Research Service. The Steering Committee is now establishing a working dialogue with a newly formed citizen group of stakeholders, the Agua Hedionda Recreation Advisory Group. Their first formal meeting will be held in January, 2002.

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Meinesz, Alexander. 1999. Killer Algae. Univ. Chicago Press, 360 p. (Translated by Daniel Simberloff)

Jacobs, William P. 1994. Caulerpa. Scientific American. (Dec.): 100-104.

Gacia, E. , Rodriquez-Prieto, C., Delgado, O. and Ballesteros, E. 1996. Seasonal light and temperature responses of Caulerpa taxifolia from the northwestern Mediterranean. Aquatic. Bot. 53: 215-225.

Komatsu, T., Meinesz, A., Buckles, D. 1997. Temperature and light responses of alga Caulerpa taxifolia introduced into the Mediterranean Sea. Marine Ecol. Prog. Ser. 146: 145-153.

For more information, log on to the following websites:

http://www.swrcb.ca.gov/rwqcb9/News/Caulerpa_taxifolia/caulerpa_taxifolia.html

http://swr.ucsd.edu/hcd/caulerad.htm

http://www.anstaskforce.gov/Caulerpa.htm

http://www.sbg.ac.at/ipk/avstudio/pierofun/ct/caulerpa.htm

Integrated Vegetation Management
A Philosophy of Utilizing All Tools to Optimize Resource Values

Scott A. Johnson, Vegetation Management Specialist, Wilbur-Ellis Company, Rio Linda, CA

Summary: Integrated Vegetation Management (IVM) is a philosophy of optimizing resource values through the combination of physical, cultural, biological, and chemical methods of vegetation management. IVM encourages resource managers to use all of these management methods. Additionally, vegetation management programs that incorporate the IVM philosophy may be more acceptable to both funding organizations and the public than programs that emphasize only one or two management methods.

The goal of this presentation is to encourage CWSS members to adopt a systems approach to managing vegetation. This approach is called Integrated Vegetation Management. I hope to define it for you and explain why IVM is a highly effective philosophy for optimizing resource values. The term "Integrated Vegetation Management", as I know it, was first used by utility right-of-way foresters in the Eastern United States about twenty-five years ago. I personally picked it up from a California utility forester in 1990.

Vegetation management programs can have several goals, depending on the perspective of individual land managers. The goals can include:

- Infrastructure maintenance and protection
- Fuels management/Fire safety
- Rangeland improvement for livestock
- Management of noxious and exotic weeds
- Habitat improvement/restoration for wildlife
- Aesthetics

Integrated Vegetation Management is the vegetation management component of Integrated Pest Management. It is a philosophy of optimizing resource values through the combination of physical, cultural, biological, and chemical methods of vegetation management. IVM encourages land managers to use all of these management methods.

We should probably step back a bit here to define Integrated Pest Management. "Integrated Pest Management (IPM) is a practice where pest management is but one component in an overall crop production system. IPM is based on the principle of providing growers and land managers with the widest array of options to control pests, e.g., physical, cultural, biological, chemical and genetic techniques. The ultimate goal of IPM is to ensure production of abundant, high quality food and fiber in an environmentally and economically sound manner." Source: *IPM: The Quiet Evolution — An overview of Integrated Pest Management (IPM) and its* *impact on Western Agriculture; Western Crop Protection Association (WCPA). Note: WCPA is called the California Plant Health Association.*

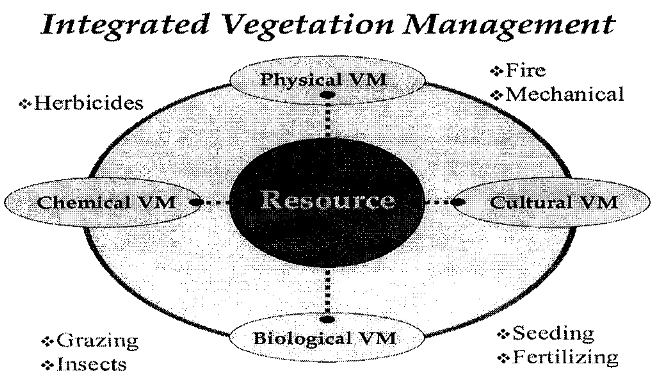
Physical vegetation management methods include manual, mechanical, and prescribed fire techniques. Seeding and fertilizing desirable plant species, such as range grasses, are types of cultural vegetation management strategies. Biological methods include livestock and wildlife grazing to manage fuel levels, as well as introduction of biological control by insects. Cultural and biological methods also include encouraging native plant and wildlife species.

Any professionally responsible Integrated Vegetation Management program should, by definition, include the judicious use of herbicides to prepare a site for burning, minimize resprouting brush, or eliminate exotic invasive weeds. The properly timed application(s) of site-appropriate herbicide(s) can eliminate non-productive and noxious plants, improve wildland and rangeland productivity, increase biodiversity and species richness, and lengthen the interval between fires through reduction in undesirable fuel loading.

In the past, it was common for wildland managers to use physical management methods, e.g. "crush and burn", to open up or reclaim rangeland. Seeding and/or fertilizing of grass may have followed this site preparation. What often happened then was that woody species, including brush and trees, re-sprouted and re-occupied the site. This then required burning the area again — a vicious cycle of events.

The introduction of herbicides added a new element to the vegetation management cycle. By treating brush to prevent sprouting, the burn cycle can be greatly extended. This longer cycle allows the so-called "smoke budget" in a given airshed to be spread over more acres over a longer time than without the use of herbicides. When herbicides are combined with mechanical brush control, fire may not be needed at all.

The IVM systems approach can be demonstrated in the following graphic:



Each of the four main types of vegetation management has an influence on the resource being managed. No one technique used alone can fully provide the benefits of a plan that uses the "full circle" Integrated Vegetation Management system shown here. Physical methods can remove biomass in the short run but it usually grows back. Herbicides can kill the brush, but they will not remove the biomass. Seeding desirable grass will not work if noxious or invasive weeds choke out the grass. Animals will graze some, but not all species of plants or growth stages of plants. The properly timed use of multiple methods can, though, achieve the desired outcome.

In summary, I hope that you, as vegetation managers, will adopt and support the inclusion of Integrated Vegetation Management in any program you undertake or support. I believe that use of IVM will answer questions that funding agencies will ask in grant proposals. I also feel that many members of the general public will find it easier to support programs that use all techniques over those that emphasize one vegetation management method.

Proper Herbicide Application Can Help Your Bottom Line

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Background Information

Before any application can be contemplated one must have sufficient information to make informed decisions. Weed Records can be an important tool to allow one to make these decisions with regard to which herbicide to use, rate of application, method of application and timing. One should be aware of which species are present, their density, and distribution. Are they annuals or perennials? Recordings of weeds present need to be taken at several times during the year. I prefer January for winter weeds, June for summer annuals, and perhaps an additional notation of weeds present in September. Weed records are particularly helpful in planning preemergence herbicide applications.

Site conditions

Site conditions determine to a large extent the probability of a successful application. Site uniformity could be one of the factors contributing to the weedy nature of the site. The long-term solution might lie in improving the uniformity of irrigation, fertility, slope, or turf species. Soil texture and organic matter has an effect on the activity of soil-applied herbicides (more active in sandy soils low in organic matter). Nutrient status of the soil helps to determine which weeds will be present (e.g. clovers under low nitrogen) and how competitive the turf will be.

Disease and insect pressure also affect the competitive ability of the turf. The extent of turf use or wear also affects the competitive ability of the turf and may help to determine which weeds will become problems (e.g. knotweed in compacted soil). Soil moisture determines whether weeds and turf will be under stress, which in turn can affect the outcome of herbicide application. Long-term soil moisture can determine which weeds are present (sedges and *poa* favored by moist conditions).

Time of the year determines which annual weeds will be present and the growth status of perennial weeds. Time of the year is also important in planning the use of preemergence herbicides (e.g. crabgrass preemergence herbicides must be applied by February in most of the warmer regions of California). The age of the weeds is important particularly when using postemergence herbicides (annuals are most easily controlled when in the early seedling stages—older weeds may require higher rates of application or not be controlled at all).

The Application

Granules: Periodically check to uniformity of equipment by operating the equipment over a clean uniform surface. Observe the distribution of granules and the overlap. Make sure that no illegal herbicide residues are left in the process. Do periodic calibration checks. Lay out a large sheet or tarp of known area. Operate the granular applicator over the sheet. Weigh the granules from the known area and determine if the uniformity and rate of application are as desired. The following example used a 10x20 ft sheet.

Example: 10X20ft = 200ft sq if deposit 75 grams of granules
75/454 = 0.165 lbs   200/43560 = 0.00459 acres
200/1000 = 0.2 (for per 1000 ft sq)
rate/acre = 0.165/.00495 = 40 lbs/A
rate/1000 ft sq = 0.165/.2 = .83 lbs/1000 ft sq

There are various types of granular applicators used in turf. These vary from gravity-flow-gated types, spinning plate types, and air-flow types. Commonly, fertilizer spreaders do double duty as granular applicators. Granules and fertilizers vary in size and density and have varying ballistic characteristics. Therefore, re-calibrating the applicator for various formulations would seem to be prudent.

Sprayers: Hose end sprayers are often used in turf for applying fungicides and insecticides. In my opinion they have no place in the safe and accurate application of herbicides. Check sprayer nozzles for uniformity of flow rate, spacing along the boom, height and overlap. Check sprayer for proper boom pressure, tank agitation and leaks. Operate sprayer at proper speed and make sure that skips and improper overlaps are avoided. Make sure that the sprayer is accurately calibrated to apply the proper rate. An excellent description of sprayer calibration is contained in the first chapter of *Turfgrass Pests* University of California publication 4053.

The some of the most common difficulties that are seen with herbicide spray applications are:

- Wrong herbicide selected
- Wrong rate used
- Non-uniform application
  - Varying nozzle sizes
  - Varying pressures
  - Varying speed
  - Overlaps and skips
- Insufficient tank agitation
- Drift of herbicide to sensitive species
- Spray volume wrong for particular herbicide

All of these difficulties are easily avoidable.

Overall

For best results—keep turf healthy and dense. Do this by selection of competitive turf species, proper management, and occasional "touch ups" with herbicides. *Herbicides should be used to supplement good management.* Know when to hold 'em or fold 'em

Sometimes it's best to "walk away". Very weedy turf may need complete renovation and a new start with a better management program.

Environmental Considerations When Choosing a Herbicide

Cheryl Wilen
Area Integrated Pest Management Advisor

Herbicides, pesticides used to kill plants, are efficient products when used to control weeds in large areas or where it is difficult to use other methods of weed control such as mulching, tillage, or hand-weeding. When selecting a herbicide the user needs to consider:

- the weed species that are to be controlled
- their stage of growth
- whether the herbicide will affect desired (crop) plants
- the residual
- movement away from the site

Obviously, there are many other considerations when choosing a certain pesticide, e.g. toxicity class, formulation, ease of use, and cost. However, in my opinion, the first three items listed above are usually what drives, or at least narrows down, the choice of which herbicide to use.

Nevertheless, the last two points in the above list should be included as an important factor when selecting a herbicide. The residual or how long the product remains where placed, can affect the crop rotation, harvest interval, and off-site movement (leaching and runoff). Herbicide persistence is influenced by the physical and chemical properties of the pesticide and the soil as well as the soil's microbiology. Movement away from the site, particularly the soil, can cause groundwater and surface water pollution.

In some cases, persistence is good. A herbicide that is effective over the entire cropping period will reduce or eliminate additional weed control efforts. In the landscape, a herbicide with a long residual reduces the number of times a herbicide must be re-applied. On the other hand, if a herbicide remains in the soil after the tolerant plants are removed or harvested and a susceptible crop is planted, herbicide injure may occur.

Factors that are important in determining herbicide persistence:

Some factors that affect herbicide persistence include microbial and chemical breakdown. These are often affected by moisture and temperature. In general, herbicide breakdown occurs more rapidly when the soil is moist and at warm temperatures.

Factors that are important in determining herbicide movement:

<u>Soil adsorption</u>

Soil adsorption is the process by which a material associates with a surface ("stickiness") and is reported as a Koc value. "OC' refers to a standard test using **O**rganic

Carbon. If a herbicide is not adsorbed at all the Koc=0 while a herbicide with a Koc greater than 1000 indicates that the herbicide is very strongly adsorbed to the soil particle.

Soils texture is also important when discussing adsorption. Soils high in clay or organic matter generally will adsorb pesticides to a greater extent than sandy soils.

Water solubility

Water solubility is a measure of how easily a pesticide may be dissolved in water. This is important to know in order to determine if the herbicide will leach. It is designated in terms of parts per million (ppm) which is the same as milligrams per liter (mg/l). The higher the number, the more soluble the herbicide and consequently the more likely to leach. Herbicides with low solubilities (1 or less) tend to remain at the soil surface although they may move off-site in runoff. Pesticides with solubility greater than 30 ppm are more likely to leach.

Half-life

Half-life is a measure of how long a pesticide persists. It is the time that it takes for one half of the material to degrade. For example, if a herbicide has a half-life of 5 days and 2 oz were applied, after 5 days, only 1 oz of the original material could be recovered. The longer the half-life, the more persistent the pesticide is and therefore, has a greater the potential for pesticide movement through either leaching or runoff because it is more likely to be exposed to conditions that would favor off-site movement. Factors that affect half-life include microbial decomposition, degradation in light, and volatility,

It is important to remember that the interaction of the above factors, rather than the individual parameters need to taken into consideration when considering how long a pesticide stays in a particular environment. For example, the water solubility of glyphosate is very high (900,000 ppm or about 1 oz/qt, see table 1). Given that, one would expect it to move easily through soil. However, the Koc value is 24,000, which indicates very strong adsorption to soil. Therefore, even though it is very soluble the soil holds and "traps" it so it is unlikely to move as an active molecule.

The following table of common herbicides can be used as a guide to help determine the whether a herbicide will move off-site or persist in the soil. Remember, that many conditions will affect a herbicides activity and that these numbers will vary according to soil type, irrigation method, weather, and other factors.

Active Ingredient	Product	Use	Water Sol (ppm)	Koc	Half-life (days)	Mobility
2,4-D amine	Many names	POE	796	20	10	Mobile but degrades rapidly
Atrazine	Aatrex	PRE	33	100	60	High due to long half-life
Dichlobenil	Casoron	PRE	21.2	400	60	Low but breakdown product is high
Diquat	Reward	POE	718000	1000000	1000	None, binds strongly to clay
Dithiopyr	Dimension	PRE	1.4	1638	17	Low
Fluazifop	Fusilade	POE	1.1	5700	15	Low
Glufosinate	Finale	POE	1370000	100	7	High but due to short half-life and microbial breakdown, little found >6"deep
Glyphosate	Roundup	POE	900000	24000	47	Low due to strong adsorption to soil
Halosulfuron	Manage	POE	1630@pH7, 15@pH5	87	4-18	Low - moderate
Isoxaben	Gallery	PRE	1	190-570	50-120	V. low
Norflurazon	Predict	PRE	28	700	45-180	Low but depends on OM and clay content
Oryzalin	Surflan	PRE	2.6	600	20-128	Low under natural rainfall
Oxadiazon	Ronstar	PRE	0.7	3200	60	Low, strongly adsorbed
Oxyfluorfen	Goal	PRE/POE	0.1	100000	35	Immobile on most soils but sl. mobile in sandy soils
Pelargonic acid	Scythe	POE	low	No info	Not reported	Not reported
Pendamethalin	Pendulum	PRE	.275	17200	44	V. low
Prodiamine	Barricade, Factor	PRE	0.01	13000	69-120	V. low
Sethoxdim	Vantage	POE	257 at pH5, 4390 at pH7	100	5	Not reported
Simazine	Princep	PRE	6.2	130	60 but persists longer on high pH soils	Low
Trifluralin	Treflan	PRE	0.3	7000	45	Low due to strong soil adsorption

Use	PRE=preemergent, POE=postemergent
Water Sol (ppm)	Higher number indicates more soluble
Koc	Measure of how strongly bound to soil; high number indicates more strongly bound
Half-life (days)	Time for 1/2 of active ingredient to degrade
Mobility	Movement in soil under "normal" rainfall

From WSSA Herbicide Handbook 7th ed. 1994 and Supplement to 7th ed. 1998

Responding to Customer Concerns: Diagnoses of Ornamental Plant Injury

John T. Law Jr., Ph.D. Environmental Industries Inc.

Diagnosing plant injury can be a process of identifying what the problem is, and/**or** eliminating what the problem is not. **It is also a process of analyzing landscape risk factors**. You should tell the customer something that indicates you have a good understanding of what damages plants. Some people may think chlorotic plants got that way from herbicide damage; after all, herbicides are designed to damage plants. Some customers assume the landscape maintenance company did something wrong because normally plants "just grow". When you can not figure out what is wrong with a plant, you want to confidently inform the customer what is **not** wrong. There are only so many ways that plants get injured, and with experience you can quickly identify insect, disease and herbicide damage to the tops of plants. They usually have distinct signs, symptoms, and patterns of damage. There are two western web sites that can guide you through the diagnostic process, one from Oregon State and one from Arizona: http://www.orst.edu/dept/hort/dpd/, http://ag.arizona.edu/pubs/garden/mg/damage/index.html Even if you can not figure out what the problem is, these sites will help you generate an impressive list of what the problem is not and why. http://www.agnr.umd.edu/users/hgic/diagn/home.html is a diagnostic web site from the University of Maryland and uses pictures to guide the diagnoses.

Once you think you know what the problem is, it can be verified by two University of California web sites that have good pictures. http://axp.ipm.ucdavis.edu/ is good for insects and diseases. This site also lists some very good books from the University of California. The other California site: http://wric.ucdavis.edu/information/herbicideinjury/herbicideinjury.html is good for herbicide damage. You can also verify the diagnoses by using the http://plantfacts.ohio-state.edu/ search engine to get fact sheets that are on the web.

A very important reference is the book, *Arboriculture - Integrated Management of Landscape Trees, Shrubs, and Vines, third edition,* by Richard W. Harris, James R. Clark and Nelda P. Matheny, 1999, Prentice Hall. In my opinion, if you don't read and understand this book you will not be very effective in diagnosing woody plant problems on commercial landscapes in California.

Once you have eliminated specific pests, except perhaps phytophthora, specific toxins and herbicides and freezing weather, you get to the topic of this paper and talk. On commercial landscapes the most common cause of poorly performing, and ultimately failing, plants is poor root growth.

The root problems are usually caused by some combination of some of these problems or risk factors:

- compacted/disturbed soil from construction – there are not enough free draining pores for air to get to the roots. Clay in the soil makes the problem worse

- root rot prone plants – usually any plant that needs good drainage, includes many drought tolerant plants.
- irrigation problems – it takes a long time to see the effects of too much water, you usually see the effects of too little water quickly. Overwatering is common.
    - poor coverage – this can lead to overwatering part of the landscape to avoid have another part dry out. At least parts of many landscapes get overwatered.
    - too many clocks to adjust for weather – this can lead to too much water during cool weeks to ensure that you apply enough water for hot weeks.
- turf competition – proper water for turf is usually too much water for woody plants, unless the excess water can easily drain away in sandy soils. Turf is very tolerant of overwatering. Fescues are also directly toxic to plants (allelopathy).
- planting too deep. Many people like the look of a plant "securely" in the ground.
- girdling roots – often no flair at base of part of trunk – happens with container stock
- salts from reclaimed water.

You can not always distinguish "the cause" from among these risk factors, although high enough levels of salt will give distinct symptoms of margin and tip burn, and salts in soil, water and tissue can be measured.

If you are examining plants that are growing slow, or are off color, you have to dig to examine the roots and root crown area. If the roots or root crown area is dead, the plant has failed and should be replaced. If the plant has been in the ground for six months and no roots have grown into the surrounding soil. the plant is failing and any risk factors should be reduced or eliminated. If you find girdling roots, the plant will likely fail some time in the future, and if the girdling is extensive, it is probably the cause of the symptoms. If you don't find obvious problems with the roots or crowns, try to reduce any of the above risk factors that are present. More time and effort can be put into watering so the surface few inches dry out before another cycle begins; turf can be removed from around plants; drainage can be improved or excess water intercepted by French drains; and soil can be removed from around crowns and from over-buried root systems.

Root problems often slowly degrade plant function over a period of years, and may not cause distinct symptoms. Remember that the above situations are risk factors, not necessarily distinct causes. The more risk factors there are, the greater the risk the plant will perform poorly. So most of the time you are dealing with probabilities of failure, e.g. I can tell you that these plants are not growing well, and some will fail, but this particular plant may or may not fail. Communicating this to a client who wants "the answer" can be a challenge. Customers want a solution and may want to know whose fault "it" is. In many cases, failing plants are an inevitable part of commercial developments, eliminating or greatly reducing the plant risk factors is far too expensive or at odds with the design. Furthermore there are a number of concepts for dealing with failing plants that can be difficult for customers.

Plants do not die like animals - they decline or fail

Plants don't move, don't breath, and do not have a brain. You may get concerned when an animal is not moving, and is not in a typical sleeping or resting position. You may prod the animal to get it to respond. If that gets no result and *rigor mortis* has not set in, you check for breathing. If the animal is not breathing you usually assume it is dead. Since people may be put on a respirator you may have to check to see if they have brain activity before assuming they are dead. Many people assume a plant is dead when the leaves or needles are all brown. Someone used to dealing with plants will often cut through the bark to see if the inner bark is white or yellow and moist. If the inner bark is brownish or is dried out, the plant, or that branch, is usually dead. On a landscape, the problem is that the plant stopped growing, months or years before it "died". A plant that is not growing should usually be replaced. Usually you want plants to get bigger and fill in the landscape. Even if you are happy with size of the plant, a plant that is not growing is usually (but not always) irreversibly proceeding to brown leaves or needles and dead wood. A plant that is not actively growing, is in fact actively "dying". This is why a better term may be failure of the plant, rather than death of the plant. Another term is decline. Decline is like death, in that the more the decline has progressed, the less likely that it can be reversed. For further discussion of decline see http://www.msue.msu.edu/msue/imp/moduf/07279524.html.

A plant may also grow slowly because of lack of fertility. Most landscapes get fertilized to some extent, and total lack of fertility is not usually problem in the west. The limiting fertilizer element is usually nitrogen, Most woody plants in California will respond to nitrogen fertilizer with increased growth, and a plant that does not respond to nitrogen fertilizer usually has one or more of the above risk factors. If a plant does suddenly wilt or turn brown it is usually an acute lack of water. This can be because the soil was allowed to dry out from an irrigation failure, or water was not getting to the tops because of root or vascular failure. The root or vascular failure was probably slow, fitting the decline concept, even though the water deficit was acute and suddenly expressed.

Woody plant failure usually proceeds in specific order

Trunk caliper growth (cambium) is usually the first part of a landscape plant to stop growing. Trunks of trees that are declining or failing are usually thinner (less caliper) than actively growing trees. Pruning and other wounds do not callous over or seal. The risk of cankers and boring insects is higher. Woody plants store starches and other energy sources in woody tissue. Wounds that do not seal get infected which reduces energy storage volume. This is why leaving lower temporary scaffold branches on new trees reduces the risk of failure. See http://www2.champaign.isa-arbor.com/arbnews/apr01/feature2.html for more information on proper pruning. See http://www.chesco.com/~treeman/SHIGO/AUTO.html for pictures and further description of the effect of wounds on energy storage in wood. It is relatively common to examine pruning cuts on landscape trees and find that on some trees they are healing and on some trees they are not. The tops may be green and leafy on all of them, and roots may have grown into the surrounding soil, but the plants that have pruning wounds that don't heal, are at much higher risk for failure. Reduce any risk factors you can.

Roots are usually the next part of a landscape plant to stop growing on a failing plant. Once the roots stop growing, woody plants rarely recover unless the root environment can be improved. A plant's main defense from root rot is outgrowing the fungi. When growth is too slow, the fungi win. At this point the green color of the plant may go off color (usually yellowish, but maybe reddish). Sometimes only some of the roots have stopped growing and only leaves or needles on the branches supported by the declining roots turn yellowish. It is relatively common to dig around the root ball of a tree or shrub that has been in the ground for six months and find no roots growing into the surrounding soil. The tops may be fine, but these are failing plants, reduce risk factors.

The production of new leaves is the third growth process to stop. By the time that you see branches that have no leaves or needles (dieback), the plant's trunk and roots have stopped growing from a few months to years ago. A plant with green leaves may be irreversibly failing. People may be reluctant to replace a plant with green leaves. However if you allow the customer to wait, they will loose growing time on the replacement plant. It is like compound interest, the earlier you start saving, the more money you will have: the sooner you replace a plant that is failing, the sooner you will have a large valuable plant.

Potential Mismatch Between What Customer Wants and What Plants Need

When analyzing plant problems on commercial developments, keep in mind that the needs of the plants have to fit into other needs and priorities. Land is very expensive to develop. No revenue is being generated while an office or apartment complex is being developed. Typically money is borrowed for the construction. These loans can be expensive and are relatively short term. It is usually important to get the construction done quickly to minimize interest expenses. It is also important to get the building filled with paying tenants quickly so payments can be made on the loan. Money for items not important to tenants, like a high end irrigation system, may be hard to justify. Loans for developed property with paying tenants are much cheaper than construction loans.

Usually the soil on the whole property has to be graded and compacted to make a stable base for buildings, pavement and hardscape. This process destroys the soil structure and makes the soil less suitable for plant roots. Leaving areas undisturbed for plantings is usually not possible on sloping land, and even on flat land, working around the undisturbed areas would slow down the construction. Going back latter and excavating areas of the compacted soil for plantings is expensive and usually not practical because the buildings, pavement, and hardscape present too many obstacles. Also the planting areas would have to filled with a planting mix that would be expensive to buy and again, difficult to put in place.

Land is usually very expensive, so space for plant material is often limited. This means surface areas close to where most roots grow is limited, and plants that have different needs are put close together, e.g. turf and woody ornamentals. Prospective tenants usually want to move into a development that looks finished and has a relatively mature looking landscape. This means planting at least some large trees. Large trees have a proportionally smaller root system, so any root system risk factors are proportionally higher. Many of the other plants are installed as relatively large container stock. Plants grown in containers have a higher risk of girdling roots, and every time the plant is moved up to a larger container, the risk increases. People tend to like a park or campus like atmosphere, which usually means turf. Turf is a risk factor for woody plants because of the frequent watering. A particular problem is narrow strips of turf, corners and isolated islands of grass that are difficult to water without wetting the adjacent landscape.

What all this means is that money has to be budgeted for plant changes, just like money has to be budgeted for broken windows, damaged carpets, leaking window seals, cracked pavement and other facts of building life. Part of the goal of diagnosing plant problems is too help the customer make the transition from new construction landscape to a more sustainable landscape, prioritize plant replacement, and help maintain a reasonable landscape budget.

Clipping Management and Herbicide Residue in Home Lawns

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There are many agronomic benefits to returning grass clippings to the turf canopy during mowing (often called mulching or grasscycling). However, this practice is too often not followed, for a variety of reasons. Rainy seasons can make mulching difficult. Landscape contractors may not be able to schedule mowing frequently enough to avoid clipping accumulation. Often times, it is simply the preference of the property owner to collect the clippings. In many states, it is discouraged or even illegal to send yard waste, including grass clippings, to landfills. Alternative means for disposal of these collected clippings must be used.

Two possible alternatives include using clippings as garden mulch or compost feed stock. Research conducted at Michigan State University during 1991-92 showed that clippings collected between 2 and 14 days after being sprayed with the herbicides 2,4-D, triclopyr, clopyralid, or isoxaben caused unacceptable injury to tomatoes, beans, and impatiens when applied as mulch around these plants (Branham and Lickfeldt, 1997). Composting these clippings was also examined to determine if the herbicides break down during the process. All of the herbicides except clopyralid degraded to non-detectable levels during 128 days or less of composting. Clopyralid was still detected after 365 days of composting (Vandervoort et el., 1997). Based on this research, labels of herbicides containing clopyralid state that turfgrass clippings treated with the herbicide should not be used as a garden mulch, and treated clippings should not be used to make compost during the season of herbicide application.

During the 1990's, composting has become an important method of waste recycling. In some communities, programs have been established that collect yard waste and deliver it to commercial composting facilities. In and around Spokane, Washington, in 2000, plant injury in several gardens was traced to clopyralid in compost produced at the local regional facility. Several factors contributed to this problem. The Spokane area has a relatively high concentration of residents who utilize commercial lawn care services, perhaps as much as twice the national average (Dow AgroSciences, 2001). Clopyralid is a popular herbicide in the area due to its effectiveness. Combined with a curbside clipping collection program, these factors contributed to a high concentration of treated grass clippings becoming compost feed stock. The persistence of clopyralid through the composting process resulted in herbicide-contaminated compost.

Another important contributing factor was herbicide and clipping custody. Label language prohibits the use of treated clippings in compost, yet this requirement was not followed. Commercial applicators who apply the material are usually not responsible for mowing the lawns. Residents may have been unaware that clopyralid was applied, and they were probably also unaware of the composting restriction. Whether they mow their own lawns, or have a contractor mow, the custody of the herbicide and clippings was lost in the process. Better notification and communication may have limited or prevented the contamination problem.

During 2001, research was conducted at the Washington State University – Puyallup turfgrass research facility to address the contaminated clipping problem. The objective was to determine if there were management practices that could be used to limit the amount of clopyralid entering the compost stream. Clopyralid was applied at the rate of 0.25 lb ae per acre in two different formulations. The first was a sprayable formulation, Lontrel, which is commercially available. The second was a granular formulation, which was developed for research purposes by embedding clopyralid on granules of 12-12-12 fertilizer. Sprayed plots received equivalent rates of fertilizer nutrients. There were two mowing regimes. In the first, the turf was mowed weekly and clippings were bagged and removed each time. At each mowing, a sample was collected form a known area, clippings were weighed, and a subsample was analyzed for clopyralid content. In the second, plots were mowed twice weekly with a mulching mower. Again at each mowing, samples were collected as above for analysis. A different plot was sampled each week so that all clippings were returned (mulched) up until the time a sample was collected. The formulation and mowing treatments were combined to result in four treatment combinations: sprayable collected, sprayable returned, granular collected, granular returned. Samples were collected at 0, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 weeks after treatment.

Regardless of formulation, the mowing treatment did not impact clopyralid concentration in clippings. Clopyralid concentrations in samples collected approximately six hours after application were much higher for the sprayable formulation (55,000 ppb average) than the granular formulation (15,000 ppb average). By one week after treatment, the concentrations were essentially no different (approximately 15,000 ppb average). By four and ten weeks after application, clopyralid concentrations in clippings were 7% and 0.4% of their initial concentrations, respectively, averaged for all treatments. Although the concentrations had dropped drastically, they still averaged 150 ppb in clippings at ten weeks after application. Concentrations of this level in compost would be high enough to cause injury to many plants. What is not known at this time is what the final clopyralid concentration in compost would be based on an initial concentration of 150 ppb. A companion study measured clopyralid degradation during composting in bench top composting vessels. Data collection is still ongoing.

This research substantiated the information already on herbicide labels: do not allow clopyralid-treated grass clippings to be used as compost feed stock. Using a mulching mower to return clippings to the canopy is the best way to manage these clippings. In Washington, we are currently recommending that gardeners ask their compost supplier about clopyralid contamination. (Many compost manufacturers are monitoring their feed stocks and products). Contaminated compost should not be used in vegetable gardens, but it is probably safe to use it as a soil amendment for lawn or landscape areas, as most of the plants in these areas are not sensitive (although there may be exceptions). As has always been the case, compost should not be used as a sole growing medium, but should be mixed with soil at rates of up to 20% compost by volume. Microorganisms present in soil can break down clopyralid.

For additional information on clopyralid in compost, see the following WSU web pages: www.puyallup.wsu.edu/soilmgmt/Clopyralid.htm and www.css.wsu.edu/compost/compost.htm.

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Mapping Weeds for Site-Specific Weed Control in Field Crops

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Farmers have been mapping weed locations in their minds and on paper for a very long time. They have used this information to a limited extent to improve weed control. New technologies allow very accurate weed mapping. The locations of individual weeds can be reliably mapped using the global positioning satellite (GPS) system. Computer programs exist to organize and use this geo-spatial information. The difficult part remaining is to determine cost-effective, practical ways of using this information to improve weed control.

Site-specific weed control can currently be done using manual labor. To control weeds with manual labor, a large and very inexpensive workforce must be available. They must be tolerant of doing very boring repetitive work under very poor working conditions much of the time. Most of the world has this kind of labor force. California clearly does not have this kind of work force. However, this is an opportunity for farmers to use technology to continue successfully competing in a world economy. California farmers have effectively incorporated many new technologies during the past 100 years to produce a wide range of reliable, affordable, and high quality agricultural commodities.

Weeds which are difficult and expensive to control in field crops are an obvious place to start with site-specific weed management. Site-specific weed management works best if weeds are in small parts of a field, preferably as individual plants or small patches. There are three weeds which fit this description in many fields in the Sacramento Valley: johnsongrass, nutsedge, and velvetleaf. These weeds clearly have the potential to be widespread and difficult to control weeds in many Sacramento Valley fields. In fields where these weeds are just getting established, there is an opportunity to use weed mapping for site-specific weed control.

Mapping Equipment for Site-Specific Weed Control

GPS equipment of varying accuracies can be purchased for between \$100 to \$50,000. The equipment needed to accurately (within 1.0 meter) locate individual weeds costs around \$5,000. This equipment is a real-time differential correcting global positioning satellite (DGPS) receiver which is accurate within 1 meter. In addition to the satellite reception, it receives a separate radio signal to more accurately locate its position. This same equipment cost \$6,000 last year, and over \$10,000 a couple of years ago. As the price of this equipment continues to decrease, and as uses other than weed control are developed, it should make it affordable for any interested field crop grower or Pest Control Advisor.

The hand held computer to record and view previously mapped weeds is included in the \$5,000 purchase price. This small 32 megabyte hand held PC is running Windows CE (compact edition) and uses a touch sensitive screen instead of a mouse. Since it is a Windows based computer it takes very little time to learn how to use it, if you are already familiar with a Windows operating system.

The software receiving, managing, and displaying the DGPS location is a simple and very easy to use Windows program. It is called SiteMate Scout™, by FarmWorks, and is included in the $5,000 price. Its most valuable feature is its 3 by 4 inch map display. SiteMate Scouts's™ zooming tools allow viewing hundreds of acres on one screen view or displaying areas as small as a 30 by 40 foot area.

The SiteMate Scout™ program allows the user to easily change the small table of information describing the weeds associated with each weed location in the field. Templates can be used to provide defaults for most of this information with the person doing the mapping only making minor entries with a keyboard on the touch sensitive screen. To further minimize keyboard use, drop down pick lists, common on Windows programs, can be created. These lists also avoid slight variations in spelling which making searching and sorting later very difficult.

Software for Weed Maps

The weed maps are transferred to a desktop PC for storage, viewing, and analysis. The site-specific weed maps are small files. A $50, 128 megabyte CompactFlash card (typical for digital cameras) would store around 250,000 individual mapping points of weed locations. Each point has a small table with several entries describing the weed, intensity of the weed, date, field name, etc.

ArcView, by a company called ESRI™, is software which conceptually is very similar to the Excel software, by Microsoft. Both programs are Windows programs for storing, managing, and analyzing information in tables. The big difference is ArcView's powerful and flexible ability to display its information as maps on the screen. This view can show the whole earth's surface, without much detail, or can be zoomed in to a few square feet in a particular field in the Sacramento Valley with detailed weed information about that location.

Practical and Cost-Effective Uses in Field Crops Site-Specific Weed Control

If there are only a few individuals of a problem weed in a field, the easiest and most cost effective way to control them is to pull them up. The weed location can be marked with a DGPS to create a map on the small hand held computer. Depending on the crop and weed, one or two well timed trips to the field, using the GPS to get back to the original location, would allow control of any remaining seedlings or plants, and could prevent expensive problems in the years ahead. GPS equipment makes it possible to even find a few weeds hidden in a crop taller than the weeds. Without this kind of equipment it can be very difficult to locate weeds, even if you know the general area to look for them.

If there are just a few patches of weeds in a field, then spot spraying may be the next level of control. An advantage to this would be the ability to use herbicides which might destroy the crop along with the weed, but would only destroy a fraction of an acre when treating many spots.

If a few to 20 percent of the field is infested with weed patches, then the DGPS equipment could be mounted on a tractor sprayer to only spray the patches of weed present, or known to be emerging soon. This weed location knowledge, prior to weed emergence, allows the use of both pre and post emergence herbicides in these weed patches. Since many herbicides are expensive, this might allow a herbicide costing $30 per acre to only be used on the 10 percent of the field where it is needed. Thus, the cost of the herbicide is only $3 per acre, on average, for the field. This may provide many practical uses of expensive herbicides for field crop growers.

Future Directions

The manual mapping of weeds is a combination of low technology (manual weed observations) and high technology. This is something that can be done now. Its has the potential to very economically control difficult perennial weeds in field crop production.

In the years ahead, remote sensing for weed mapping in individual fields may be possible. Tractor mounted cameras may also someday be used for mapping of weeds. However, at the present time, a few well timed observations may allow field crop growers to do more cost effective weed control on some particularly difficult weeds.

Use of Geospatial Technology to measure the yield impact of Bearded Sprangletop (*Leptochloa Fasicularis*) in California Rice.

A.Roel , J.F. Williams, A.J. Fischer, and R.E. Plant. UC Davis.

Bearded Sprangletop (*Leptochloa Fasicularis*) has long been considered a secondary grass weed problem in California rice and has not received much research attention. Sprangletop is an opportunistic weed that will establish in drained or shallow-water fields. Profuse seeding often leads to rapid expansion of an infestation. Phytotoxicity and efficacy problems with current herbicides discourage many growers from using them. Absence of data showing impact on yield prompted the current research. We are also interested in developing a predictive ability to determine the economic value of herbicide applications. Since the establishment of experimental plots to statistically determine the yield reduction under different weed pressure is very time consuming, difficult to achieve and expensive the following two approaches were done:

Methodology

1) A 15.8 ha field with sprangletop infestation was visually rated for weed control on a grid pattern using a Geographic Positioning System (GPS). The weed rates were then interpolated over the entire field using a Geographic Information System (GIS) (Figure 1). The field was harvested with a combine equipped with a yield monitor. Aerial photos were taken in both visual and near-infrared wavelengths.
2) Small plots of varying weed densities were selected and measured percent weed density visually, by counting panicles and by weighing both fresh and dry weed biomass.

In the whole field evaluation, the weed map generated from the interpolation procedure explains a high percentage of the yield variation of the field. Correlation of weed density to yield was $r^2 = 0.65$. In the small plots visual ratings were correlated at $r^2 = 0.72$ with rice yield.

Conclusions

Sprangletop infestation severely reduces rice yield. This is useful information to substantiate yield loss data requirements for product registration. The data were collected late in the season. If such yield loss x weed density relationships are to be useful for weed control decisions, they need to be determined earlier than was done in this preliminary project. Low infestations may not warrant cost of control; however, if not controlled in one season, weeds are likely to be economically significant in the next.

The good agreement in the relationship between weed density and yield reduction among the large scale and the small plots studies indicate the potential use of the former for estimation of yield impact by weeds with potential significant reduction in time and money.

The Limitations of Modern Weed Control Tools in Other Countries

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I have appreciated the challenges that growers face around the world, having worked in Latin America and traveled to several countries. Keep in mind that my comments in this presentation are based on my own limited observations.

Weed management tools in most of the developed countries have moved progressively in from human to animal to mechanical to chemical and now plant biotechnology or using a combination of these. While the United States and Australia have the most acreage of field crops using plant biotechnology, the rest of the world is slower to adopt this technology mostly because of political concerns and the cost and availability of various seeds.

I could summarize my presentation by stating that the limitations in other countries in adopting more advanced technologies are variable depending on the country and the individual grower. This is similar to any technology in California where often technology adoption depends on the crop, and individual farmer preference. In most countries one can find farmers using modern weed control side by side with the older systems.

The limitations or obstacles to adoption of modern weed control tools in different countries also depends on the following areas: Perception of weeds as friends or foe; yield expectations; scale of production; availability and cost of technology; level of training; stability of infrastructure; government policy incentives; and loan incentives.

Perception of weeds as friends or foe

Some growers in Mexico and Guatemala view weeds in cornfields as forage for cattle, which are harvested by hand, or scythes. Yellow nutsedge is harvested for the nutlets in some countries including Mexico. One grower in the Copper Canyon region in Northern Mexico said he benefited by having weeds in his cornfields on steep soils because they have helped control water erosion.

In the same region in the highlands of Northern Mexico I talked with a graduate student from New Mexico studying the medicinal benefits of plants growing in fields and surrounding fields. In her opinion weeds were beneficial for the Tarhumara Indians for both medicinal purposes and food. I was shown one plant used as a tea, another one to help urinate, and one that helps with stomachaches. There are several other plants including lambsquarters and purslane that are eaten in soups and help to sustain the Indians during poor crop years.

Yield expectations

During low rainfall years when yield expectations are low there is often reduced production inputs from the growers including weed management. If they feel that the crop may fail or yield low they will put their efforts in other labor activities such as caring for their livestock or attempt to earn money off the farm. Conversely if yield expectations are good they are more apt to fertilize and pay closer attention to weed management.

Scale of production
Farm size and terrain make a big difference in which technology is used. For example in parts of Italy, Central America, including Guatemala and parts of Mexico, much of the land is cut into small parcels and on steep slopes. This limits most weed practices to hand labor, tillage and cultivation with livestock, and in some cases backpack sprayers. In China the average grower farms ½ to 1 acre. They use hand labor, animal, machinery, and selective herbicides to control weeds.

Availability and cost of technology
Many farms are somewhat isolated and limited by transportation. Therefore herbicide options may be reduced and growers use what is readily available such as hand labor or animals. The extra cost of transgenic seeds and not being able to save the seed discourages growers from using genetically engineered varieties where they prefer non-hybrid varieties.

Level of training
Level of education can influence production practices. For example, among the Tarahumara Indians in the State of Chihuahua, Northern Mexico students are only required to attend to school until 6th grade. Secondary schools and beyond are usually only available in cities and not in the country. A certain amount of training is needed for safe application of herbicides. In some countries even protective clothing like shoes are not used. Drinking paraquat is a common way to commit suicide among Guatemala Indians.

In China students are required to attend school through secondary ages. There are, however, many opportunities in Agricultural technical colleges and beyond for those with more resources. These colleges train thousands of farm supervisors and pest control advisors.

Stability of infrastructure
A sound agricultural infrastructure is critical to provide a marketplace for products and readily available machinery, chemicals, and fertilizers. Obstacles include being at war, lack of trust in government officials, not having good roads and transportation, electricity, lack of schools, and poor health care.

Government policy incentives
In Western Europe growers are highly subsidized for producing wheat and several other crops. This is an incentive for a high input system, combining mechanical and chemical weed control. Spain allows aerial applications while other countries like the Scotland, England, Germany, France, and Italy are limited to ground application for applying herbicides. This system uses "tramlines' or the same wheel tracks for multiple herbicide,

fungicide, and insecticide applications. In Germany chemical application equipment is inspected and calibrated by government officials before they can be used each year.

In addition to receiving high prices for cereals, growers are given points, which relates to additional money if they are practicing conservation tillage, or using fewer chemicals. There is also an incentive to contract an even higher price growing organic crops on part of the farm.

In parts of China, several large collective farms have shifted from corn and rice to greenhouse vegetable enterprises. Farmers that used to farm the land are now hired back as laborers in the greenhouses. These new farms are run similar to corporate enterprises with millions of dollars from both government and foreign investment. Some of the largest greenhouses in the world are producing high quality vegetables for the many three to five star hotels in large cities such as Beijing, Shanghai, and parts of Japan. They promote their products using a green label, which is one-step below organic. They use some inorganic micronutrients, and occasionally spray for spider mites. There is very little weed management and what little there is is done by hand. This type of production has found a marketing niche, which is almost organic but also ensures the buyers that it is not being fertilized with composted human wastes like most of the crops grown there.

Plant biotechnology, specifically BT cotton, has widespread use in China but according to officials, is not seen as needed in other crops at this time. Monsanto and Delta Pine are currently working to introduce Roundup Ready cotton. Chinese scientists are working toward introducing their own varieties of different plant biotech crops. Although China buys a lot of plant biotech produce in several meetings we attended officials stated they would still prefer to buy conventional grain if given a choice.

Loan incentives

Having money to farm and to purchase supplies and equipment is fundamental for giving growers the confidence to try new technologies. How does a grower best decide how to spend the few dollars he has? Do you use what little cash you have to buy fertilizer, medicine, food, equipment, or transportation? For example, after visiting Tarhumara Indian farmers in the mountains of Northern Mexico, it was evident that considerable research had shown how to improve yields with proper varieties, plant population, weed control, and fertilizer. But it wasn't until a fertilizer loan program was established that growers started using chemical fertilizer. Corn yields increased as much as five fold with fertilizer. The same incentives are necessary to implement optimum weed and pest management strategies.

Conclusion

It is readily apparent that weed control or agriculture in general, is vastly different in other countries compared to the United States. The infrastructure that we take for granted is absent in less developed countries. While in other countries, subsidies and other incentives greatly improve the profitability of farming. Regardless of the country, growers from around the world seem to face some unique challenges. It is important, especially in an increasingly global agricultural economy, to be aware how farming and weed management practices are done throughout the world.

Impacts of Choice of Production Systems: Genetically-Engineered Cotton and Tillage System Changes

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Growers have a broad range of cropping and management choices which all have potential to impact how other components of the production system "perform". Everyone knows of examples of production practices that you changed which resulted in multiple impacts on the crop, soil or weed situation, some for the better and some worse. Primary goals of this presentation are: (1) to provide a few examples of possible impacts of the choice of use of genetically-engineered cotton or alternative tillage systems; and (2) give some background information on general experiences (positive and negative) with these production system changes. In U.S. cotton production, this is largely a discussion brought about by increasing adoption of major production practice changes such as introduction of a broad range of varieties that are genetically-engineered for traits such as herbicide-tolerance or insect resistance as well as the adoption and continued testing of no-till and reduced tillage production systems. Even though this is a Weed Management conference, some examples will be used which cover transgenic, herbicide-resistant cotton, insect resistant Bt-types of cotton, ultra-narrow row systems, and reduced or no-till systems.

Impacts of Genetically-Engineered Cotton

For the purposes of any discussion of newer types of cotton varieties on the market, it is useful to start with a few definitions. Plants produced through recombinant DNA technology, for the purposes of this discussion, will be termed "transgenic" or "genetically-engineered" (GE) since these terms are more specific in describing how genetic materials get into the new types of plants. GE or transgenic plants can be produced by a wide range of biotechnology approaches which transfer genetic material from one organism to another, allowing the genetic material to be expressed then as a desirable trait in the plant.

In the case of transgenic cotton, acreage has expanded greatly in the past 5-6 years, starting with the early introduction of Bt-cotton (with resistance to insects such as several types of bollworm and budworms) in commercial acreage in 1996, followed by commercial plantings of a herbicide-resistant cotton (glyphosate-resistant, or "Roundup-Ready") in limited plantings in 1997. During the first year of wide-scale release of commercial Bt cotton varieties (1996), planted acreage reached 1.8 million acres in the U.S. (USDA figures). By the time of the 2000 growing season, transgenic cotton of all types (largely Bt and glyphosate or Buctril-resistant) was planted on about 9.6 million acres worldwide, so interest in these technologies has been great and adoption rapid. In California, plantings of glyphosate-resistant and buctril-resistant cotton varieties has expanded from a total of about 12,000 acres in 1998 to over 150,000 acres in both 2000 and 2001 (Seed company figures).

The Bt-types of cotton have been of significant interest and value to growers in southern CA desert areas (Imperial and Palo Verde Valleys) due to their effectiveness with Pink Bollworm suppression, and represent most of the planted acreage in those areas. Currently-available Bt-types of cotton are generally perceived to be of less value and interest commercially in the San Joaquin or Sacramento Valleys due to limited damage in these areas from insect pests targeted with Bt cotton. The level of interest may change with second or later-generation Bt-cotton which may have a broader range of effectiveness which might include better suppression of pests such as armyworm, a pest of considerable economic impact in San Joaquin Valley cotton.

The potential for transgenic cotton to significantly impact production systems is widely acknowledged to be great, and so far discussions have been raised at many levels. This paper cannot begin to address all potential impacts on production systems and other important issues, so instead will briefly identify some issues and relevant findings with both Bt and herbicide-resistant cotton. Interested readers can find a great deal of technical information and results of surveys of cost benefits and efficacy by going to the web site of the National Cotton Council http://www.cotton.org and reviewing an article available there entitled ("*Comprehensive Cotton Biotech Report - Report of an Expert Panel on Biotechnology in Cotton*" - November, 2000).

Bt-cotton Production System Questions and Issues. Most field evaluations and surveys have found current-generation Bt varieties to be very specific in the pests that they control, with good to excellent efficacy with some pests (Cotton bollworm, Salt Marsh caterpillar, European Corn Borer, Pink Bollworm, Tobacco Budworm and Cabbage looper) and only limited suppression of other worm problems, and little or no impact on other cotton pests. The technology fee charged with use of Bt varieties has an impact on cost-effectiveness, but this spectrum of control/suppression is why these varieties have been widely accepted and have proved cost-effective in areas of the southern U.S. and in Arizona where bollworms and budworms can be dominant pests. As these pests have not been widespread in the San Joaquin Valley, they have not generally proved cost-effective in that region. Impacts on cotton production costs and reductions in total insecticide sprays by switching from conventional spray programs and varieties to Bt cotton have been documented widely (see National Cotton Council report previously mentioned), and have demonstrated:

- Total insecticide applications per year have been reduced about 35 to 65 % in southern U.S. cotton fields in several large surveys done over the past 3+ years
- Changes in spray programs & materials have resulted in shifts in dominant insect pests in some areas (presumably some pests formerly suppressed by worm control sprays)
- The cost-effectiveness of Bt varieties versus conventional is not seen in all cases - it is dependent upon the following factors (as well as others in some situations):
  - year and location differences in pest severity
  - pricing of technology fee

    - availability of the Bt trait in varieties with good agronomic performance (yield and quality issues impacting price)
- Adequacy of refugia approaches to delay resistance problems and retain a susceptible pest population, and analysis of needs to refine and monitor efficacy of these approaches
- Development of newer, multiple-gene transgenics which many researchers believe may prolong efficacy and delay resistance problems
- Potential impacts of widespread use of Bt crops on non-target organisms & their survival

Herbicide-Resistant Cotton Production System Questions and Issues. Grower field evaluations, surveys, and University studies have generally indicated good to excellent control of target weeds when Bromoxynil (Buctril) or Glyphosate (Roundup, others) are applied according to label directions over BXN and Roundup-Ready cotton, respectively. Research and field observations show that not all weeds can be adequately controlled by relying solely on either system, but each has distinct advantages that have proven quite cost-effective in many cotton production systems across the United States, including in CA. Several BXN and Roundup-Ready cotton varieties have been available for commercial production in CA since 1998, but high fiber quality commercial Acala BXN and Roundup-Ready varieties only became widely available starting in 2000 and 2001, respectively. Ron Vargas and Steve Wright of the University of CA Cooperative Extension have reported to this conference in previous years results of field evaluations with these systems, and their results have generally agreed that weed control can be very good and costs for practices such as hand weeding can be significantly reduced or eliminated. However, they also have also stressed that a number of factors should be considered in deciding to what degree growers should adopt Buctril and Glyphosate use with these BXN and Roundup-Ready cottons (Vargas et al, 2001), including:

- Severity of weed problems, annuals versus perennials, mix of weed species present
- Density and distribution of weed problems within production fields
- Can hand weeding be eliminated by switching to one of these systems
- Is weed pressure severe enough to impact yield
- Costs (technology fees, alternative herbicides, seeding rate needed)
- Availability of transgenic varieties with good yield performance and acceptable quality (see Hutmacher, 2001 for discussion of some performance issues) and importance of strict adherance to timing of glyphosate applications on current types of Roundup-Ready varieties (prior to 5th leaf) to avoid impacts on yield (Hutmacher, 2001)

Vargas et al (2001) point out that these systems can be very useful on at least some grower acreage as another weed control option to supplement existing weed control programs based upon use of pre-plant, selective over-the-top, and layby herbicides, but caution that relative costs should be carefully considered. Another factor widely mentioned by weed scientists with transgenic, herbicide-resistant varieties is the need to assess impacts of early season rainfall and access to the fields (ie. whether or not the target weeds can be controlled within the application period available (a long period with current BXN varieties but a short period with Roundup-

Ready varieties). This short application window may be extended considerably with second-generation Roundup-Ready varieties now in early field testing, but this "feature" won't be widely incorporated into well-adapted varieties for at least a couple of years (more for CA-suited varieties). Another area to "watch" relates to concerns with development of resistant weeds through repeated use of very limited spectrum of herbicides. Evidence of weeds resistant to materials such as glyphosate has been found in recent years (Vargas et al, 2001), supporting the contention that long term weed management strategies must incorporate concepts of resistance management approaches, including herbicide and crop rotation and control of weed escapes.

"Acceptability" of Transgenics. Impacts on grower profits and production practice impacts can take a back seat to a wide range of other issues if the public develops concerns regarding food safety and environmental impacts of use of GE crops. Other issues that can appear secondary, but can become very important (from a "perception" standpoint) include: labeling and segregation issues with GE crops, safety of transgenic crops for animal feed, and allergenicity and toxicity issues. All production system research, cost and regulatory issues can become much less important if the public has problems accepting and purchasing products from GE plants. Therefore, it will remain important for researchers, companies and regulatory agencies to provide accurate information and retain public trust in the answers provided.

Potential Impacts of "True" Ultra Narrow Row Cotton

In the U.S., Ultra-Narrow Row (UNR) cotton has generally been defined as cotton produced in planted rows less than 15 inches apart. Rows can either be on beds or more routinely flat-planted. This represents quite a departure from the more traditional planting geometry of single rows planted 30, 38 or 40 inches apart. Grower interest in such alternative systems was largely spurred by studies and grower experiences that indicated: (1) lower overall production costs by switching to UNR practices; (2) some potential for yield improvements with UNR, particularly in marginal soils and locations where uniformity of growth is a consistent problem; and (3) the suitability of transgenic, herbicide-resistant varieties for this system. Some field research also indicated that with UNR production practices, improved crop earliness and shorter growing seasons can often be achieved (impacting exposure to damaging weather conditions).

With close row spacing (less than 15 inches) in UNR cotton, many cultivation practices and some post-directed herbicide applications become difficult if not impossible, resulting in a high degree of interest in and dependence upon transgenic, herbicide-resistant varieties. Close row spacing means that there is considerable difficulty in ground-applied applications once the plants are large enough to suffer significant injury from tires and implements. Since the herbicide-resistant traits (Roundup-Ready, Buctril-Resistant, etc.) are not available in all cotton varieties, growers and researchers have had to conduct variety trials under the UNR systems to identify acceptable varieties with a good-performing combination of herbicide-resistance (ie. Roundup-Ready, Buctril-resistance, etc.) and good agronomic performance (yields, quality, earliness).

In addition, current picker equipment is not generally compatible with close row spacing, resulting in use of some type of stripper harvester (such as a finger stripper). The switch to a stripper harvester has positive and potential negative aspects. On the plus side, for cost control, the strippers are inherently simpler machines than spindle pickers, and are much cheaper both to purchase and maintain. On the negative side, there remains concern in the industry regarding possible increases in foreign matter, neps and short fiber content, and impacts on fiber micronaire with the change from conventional, picker-harvested cotton to UNR, stripper-harvested cotton.

A lot of recent research on modifications possible at the level of cleaning operations on the harvester and in various operations during ginning have all shown potential to deal with some of these concerns. However, a recent Cotton Incorporated and USDA-ARS study evaluating properties of textiles from conventional and UNR cotton still points out significant on-going concerns related to the prevailing harvest methods used for UNR versus conventional cotton (Valco et al, 2001; Anthony et al, 2000.). Consistent problems that cannot be dealt with via improved harvesting or ginning practices, or through availability of varieties with fewer quality problems, can result in grade reductions that lower crop value and offset cost reductions achieved through UNR. Fiber quality impacts are not a trivial concern, and must be addressed satisfactorily for UNR cotton to be accepted in the marketplace and work out economically for growers. Growers remain interested in and in need of lower production cost alternative production systems, but can't tolerate any major impacts on fiber quality (and therefore price) unless the reductions in production cost or improvements in yield have a much greater impact on the "bottom line" (profits).

Ultra-Narrow Cotton in California and Other Row-Spacing Variations. The "jury" is very much "still out" on experiences with true UNR cotton in California, but there are several San Joaquin and Imperial Valley growers currently experimenting (2001) with large-scale variations of finger-stripper harvested UNR with 10 inch or 15 inch row spacing. Growers interested in these systems to date have gone with transgenic, herbicide-resistant cotton varieties (either Roundup-Ready or Buctril-Resistant) and flat plantings. Ten inch row spacings have worked out in coarse and medium-textured soils where soil water holding characteristics or sprinkler irrigation capabilities allow the seed to be placed in moist soil. Under other conditions, 15 inch row spacing was considered a minimum to allow adequate soil to be pushed aside at planting to reach adequate soil moisture at planting depth. A broad range of plant populations are also being investigated by these growers, since optimal planting densities for UNR are not known for CA conditions. Changes in growth regulator management may also be required, as cotton vegetative growth must be more tightly controlled with stripper harvesting in order to limit quality problems. These are just a few of the possible changes in production practices that may be needed if a "niche" for UNR production can be found in CA cotton. Since the climate and growing season length, and varieties widely-grown in CA production areas are so different than those represented in the Southeastern and Southern areas just discussed, it is not a "given" that CA-produced UNR cotton will have quality problems when compared with conventional, spindle-picker harvested cotton. The next few years of field results on yields, fiber quality and price, and actual production cost savings with UNR will help answer the questions of viability of UNR approaches in CA.

Double-Row 30-Inch Cotton. This should not be confused with Ultra-Narrow Row cotton, although it has been referred to as "California-Style UNR" in some popular press articles. This production system is based upon the use of two seed rows per bed with conventional 30-inch beds, with the two seed rows ranging from 7 to 10 inches apart on the bed. The areas of interest for growers switching to this system have been centered around several ideas: (1) in combination with higher plant populations, this planting geometry can achieve more rapid leaf cover, giving better competition with weeds and capturing more available sunlight for early growth; (2) more rapid growth and higher plant populations mean earliness and fewer bolls per plant to achieve yields; (3) reduced need for cultivations for weed control and related operations.

Although this system has been tested primarily in Merced County in the northern San Joaquin Valley, growers and Dr, Bill Weir of the University of CA Cooperative Extension have about four years of experience with variations of this system. To date, they have seen some promising results, with consistent 7 to 9 percent average cotton yield increases and reductions in production costs ranging from about $25.00 to over $50.00 per acre. There remain questions to be answered regarding optimal plant populations in different parts of the San Joaquin Valley, and the need for changes in growth regulator and irrigation practices to optimize the system and achieve desired earliness. However, since the planting geometry doesn't preclude early and mid-season use of tractors and cultivators in the field, unlike UNR, this system is not inherently dependent upon transgenic, herbicide-resistant cotton varieties. The row spacing also still allows use of spindle-pickers for harvesting, so may lessen concerns regarding fiber quality issues.

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Summary of Control of Herbicide Resistant Watergrass in Northern California Rice with Regiment™

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Introduction

Watergrass and barnyardgrass are serious weeds in California rice culture. There are four forms of watergrass and barnyardgrass indigenous to California that infests rice. The early form of watergrass, *Echinochloa oryzoides*, blooms about 40 days after flooding. Its' spikes are heavily awned and the heads are drooping or pendant. A similar form of watergrass is *Echinochloa crus-galli var. oryzicola. Echinochloa phyllopogon* is a late blooming form that upright foliage, erect panicles and awnless spikelets. It begins flowering at the same time as rice, about 90 days after flooding. This species resembles rice in the vegetative stage of growth and is an example of a weed mimic. Barnyardgrass, *Echinochloa crus-galli var. crus-gali* is common throughout the rice growing areas of California. Barnyardgrass is small seeded and quite variable in appearance. It is especially prevalent in fields where intermittent (pinpoint and leathers) flood-culture is utilized.

Over the last 5 years, many growers and PCAs in the Sacramento valley have experienced difficulty controlling watergrass species in various fields. Late watergrass (rice mimic) was identified as the major problem, however, control failures of barnyardgrass and early watergrass have also been observed. The major geographical area of concern is near the town of Princeton (Glenn County) where numerous growers have reported herbicide failures. The problem however, is not limited to the Princeton area, control failures have been documented throughout the Sacramento valley.

Watergrass control problems were observed with maximum label rates of thiobencarb (Bolero® and Abolish®), molinate (Ordram®) and fenoxaprop-ethyl (Whip®). Failures were observed with singular and sequential applications of the above mentioned herbicides. In 1998, Dr. Albert Fischer, UC-Davis, conducted greenhouse studies to confirm that resistance to thiobencarb, molinate and fenoxaprop-ethyl had developed in all three forms of *Echinochloa species* indigenous to California. His findings were based on bioassays of watergrass and barnyardgrass grown from seed samples collected from suspected resistant fields the previous fall. His findings also indicate that resistance to all three herbicides is probably due to enhanced degradation.

Summary

Regiment 80 WP (bispyribac-sodium) is a post-emergence herbicide that has excellent efficacy against certain grasses, sedges and broadleaf weeds with selectivity for rice. It inhibits the plant enzyme acetolateate synthase (ALS), thus blocking branched-chain amino acid biosynthesis.

Regiment 80 WP has a wide application window for control of barnyardgrass and watergrass. The herbicide can be applied to watergrass and barnyardgrass from the 1 leaf to 2-3 tiller stages for growth. Use rates range from 10 to 18 grams ai/Acre. Optimum use rates for non-resistant watergrass and barnyardgrass are 10 to 12 grams ai/A with the grass being in the 3 to 5 leaf stage. Higher use rates, up to 18 grams ai/A, are required for herbicide resistant grasses. Best timing for these biotypes is the 1 to 2 tiller-growth stages. A non-ionic silicone based surfactant is required for optimum efficacy.

Valent USA first tested Regiment™ (V-10029) in California in 1995. In 1996, a small plot test was established in a field where the grower had experienced total herbicide failure. Results were promising and in 1997 full scale testing was initiated in the problem watergrass areas.

By the end of 1999, a total of 10 trails had been conducted on herbicide resistant watergrass (Table 1). Eight of the trials were conducted on late watergrass and 2 on early watergrass. All trials were established in fields containing herbicide resistant grass as confirmed by Dr. Fischer at UC-Davis. In all cases, the trial locations had histories of multiple herbicide failures.

Table 2 is a summary of efficacy data resulting from early and late applications of Regiment for control of late watergrass *(E. phyllopogon)* in rice. Early application timing was made at the 4 to 5 leaf stages and the late application timing was made at 1 to 2 tillers.

TABLE 2. Control of Herbicide Resistant Late Watergrass with Regiment.

RATE TIMING	10 GM AI/A	12 GM AI/A	14 GM AI/A	15 GM AI/A	18 GM AI/A	24 GM AI/A
EARLY 4 TO 5 LEAF	56.3 (2)	77.7 (4)	84.3 (3)	30 (1)	88.9 (5)	86.5 (1)
LATE 1 TO 2 TILLER	74.2 (3)	78.3 (4)	90.7 (3)	95.0 (1)	94.2 (6)	97.7 (2)

All Regiment treatments had a silicone-based surfactant @ .125 to .25% v/v.
() Number of trials.

The data clearly indicate-that Regiment at 14 grams ai/A and higher provided economic control of resistant late watergrass. The late timing, 1-2 tiller, gave better control than the early timing. The difference in control between early and late application is probably a result of coverage, susceptibility or subsequent watergrass emergence. Better control at the later application timing was consistently observed in all trials.

Table 3 is a summary of Regiment data at 18 grams ai/A compared to the standard treatments for control of late watergrass. Of the three standards in the trials, SuperWham provided the best control when compared to Ordram and Whip. SuperWham was the most consistent performer of the three standards but did not control the late watergrass at the same level as Regiment. With the exception of one trial, Ordram and Whip did not provide economic control of late watergrass.

TABLE 3. Control of Herbicide Resistant Late Watergrass with Regiment vs. the Standard herbicides.

RATE TIMING	SUPER WHAM 6 QT/A	WHIP 1.2 PTPR/A	ORDRAM 4 LBS AI/A	REGIMENT 18 GMAI/A
EARLY 4 TO 5 LEAF	**79.5 (5)**	**90 (1)**	**56.7 (1)**	**88.9 (5)**
LATE 1 TO 2 TILLER	**83.3 (4)**	**48.2 (5)**	**56.7 (1)**	**94.2 (6)**

All Regiment treatments had a silicone-based surfactant @ .125 to .25% v/v.
() Number of trials.

Table 4 is a summary of efficacy data for control of early watergrass *(E. oryzides)* comparing Regiment to the standards, SuperWham, Ordram and Whip. Regiment application was made at either the 4 to 5 leaf or the1 to 2-tiller growth stage of rice.

TABLE 4. Control of Herbicide Resistant Early Watergrass with Regiment.

RATE TIMING	10 GM AI/A	12 GM AI/A	15 GM AI/A	18 GM AI/A	ORDRAM 4 LBS AI/A	WHIP 1.2 PT PR/A	SUPER WHAM 6 QT/A
EARLY 4 TO 5 LEAF	81.3 (1)	90.0 (1)		88.0 (1)	65.0 (1)		
LATE 1 TO 2 TILLER	90.5 (1)	98.0 (1)	94.3 (2)	86.2 (3)		49.1 (3)	69.4 (2)

All Regiment treatments had a silicone-based surfactant @ .125 to .25% v/v.
() Number of trials (data points).

The data clearly indicate that Regiment at 12 grams ai/A and higher provided economic control of early watergrass. The late timing, 1-2 tiller, provided slightly better control than the early timing. None of the standards, Ordram, Whip or propanil gave adequate control of resistant early watergrass.

Early watergrass appears to be more sensitive to Regiment than the late species. Furthermore, application timing does not appear to be as critical to the control of early watergrass as it does to the late species.

KEEP IT IN THE GARDEN: INVASIVE PLANTS AND THE NURSERY TRADE

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An estimated 5,000 introduced plant species have escaped and now exist in natural ecosystems in the U.S. (Pimentel et. al 1999). Most introduced species fulfill their intended role and do not interfere with natural processes, however about 12% of intentional introductions cause economic or environmental damage (OTA 1993). These plants are considered invasive because they have spread into ecosystems where they are not native to establish self-sustaining populations without direct human assistance. In the U. S., an estimated 40% of rare, threatened, and endangered species are at risk from these alien invaders (Wilcove et. al 1998).

Horticultural origins of invasive plants

Horticultural stock is a significant source of known and potentially invasive plants. Reichard (1997) determined that 85% of the 235 introduced woody plants that have naturalized in the U.S. were introduced for landscaping and other ornamental purposes. In California, nurseries in the state have propagated 41 of the 78 plants listed on the California Exotic Pest Plant Council's (CalEPPC) list of "Pest Plants of Greatest Ecological Concern". In Florida, 69% of the plants on a similar list developed by the Florida Exotic Pest Plant Council (FL-EPPC) are of horticultural origin. Across the ocean in Australia, the story is much the same: 65% of the invasive plants that have naturalized on the continent over the last 25 years were introduced ornamentals (Groves 1997).

The commercial seed trade was one of the earliest avenues of spread of weeds in the U.S. (Mack, 19991). Prior to the 1860's most seed trade was local, direct from the nurseryman. With the advent of the railroads, widespread mail order became the norm as seed were transported across the country faster than ever. Plants like salt cedar, Scotch broom, and tree-of-heaven became available in the west where the warm climates proved conducive to their spread into natural areas. Weedy alien grasses like goatgrass, pampasgrass, and medusahead were popular plants for the dried Victorian flower arrangements called "immortelles".

A significant proportion of these intentionally introduced ornamental plants have become a serious threat to wildland biodiversity and ecosystem processes for two main reasons. First, a good ornamental plant often has many traits that can also make it a good weed. Horticulturists want plants that are easy to propagate, establish rapidly, mature early, produce abundant flowers, and are environmentally fit and free from major insect and disease pests. The perfect weed has many of the same characteristics: broad germination requirements, early maturity, fast growth, prolific seed production, and few natural predators. Collectively, these traits increase the ability of a plant to survive without human assistance and become established in the wild. Second, several breeding practices in the industry tend to facilitate selection for weedy characters. The sale of seeds is not only successful at dispersing plants across many different regions, it also selects for hardy seed that lack complicated dormancy mechanisms or germination requirements. Many nursery plants are repeatedly introduced into the landscape where they can reproduce and further increase the genetic variation of existing escaped populations. Hybridization, although useful for creating sterile cultivars, can produce polyploids that are better adapted and more weedy than their progenitors.

Invasive plants for sale

Disagreement exists as to the number of invasive plants that are currently available for sale. Campbell (1998) compiled a list of 452 "worst invasive plant species in the U.S." (excluding Hawaii) and found that 271 species, or 60%, were for sale through Andersen's Horticultural Library. While 49% of the herbaceous weeds were for sale, 85 and 73% of trees and shrubs, respectively, were available through the library. Seed catalogs also remain an important avenue of spread of known invaders. More recently, internet sales of nursery stock have skyrocketed and known invaders are available on garden product websites that will ship anywhere in the country.

While the sources of invasive plants are many, it is difficult to assess the magnitude of the problem. Weed invasions are an inherently regional problem. A plant that acts as a noxious weed in one part of the country (or state) may be a perfectly behaved ornamental in another. The industry does not track the sale of individual plant species, so the impacts from banning the sale of a particular plant species cannot currently be determined. Invasive ornamentals probably occupy a small share of the total market, but no one really knows for sure.

The regulatory framework

California has a unique and somewhat complicated regulatory system for the nursery industry. All grower and retail nurseries require a license from the California Department of Food and Agriculture (CDFA) for each location where plants are grown or held for sale. Each year CDFA licenses 3,500 grower nurseries, 3,000 retail nurseries, and 3,500 "incidental dealers" such as supermarkets, drug chains, and big box stores. The California Agricultural Commissioner (CAC) system locally enforces mandates of CDFA and oversees aspects of the agricultural sector including nursery stock and seed inspection. All 58 counties have a CAC that conducts nursery inspections, implements plant or pest quarantines, and carries out control plans.

In California, the regulatory scope extends only to plants listed on the Federal Noxious Weed list or with a CDFA noxious weed rating. The CDFA weed ratings of A, B, C, D, or Q have no legal standing, but are policy and regulatory guidelines that indicate different possible actions. Nurseries must be completely free of A and B-rated pests. C-rated pests are not subject to state action and may be tolerated in nurseries at the discretion of each CAC. Actions against B and C-rated pests in non-nursery locations are also at the discretion of the local CAC.

The central problem with invasive ornamentals plants is that no mechanism exists in the current regulatory framework for controlling the propagation, distribution, and sale of unlisted species with known invasive tendencies. Most invasive plant species are not listed on the federal or state lists, especially those that primarily invade "areas not managed for economic return".

Reichard (1997) estimated that at least 750 species that meet the definition of the Federal Noxious Weed Act remain unlisted. The current federal noxious weed list has only 96 taxa, 25 of which are species of mesquite (*Prosopis* sp.). Only one of the 78 species on the CalEPPC list is found on the federal list. With 10 new additions this year, 25 species from CalEPPC's list now appear among the approximately 140 plants on the CDFA state noxious weed list.

The horticulture industry up close

As the unintentional source of many invasive plants, the horticulture industry is a major stakeholder in the effort to control invasive plants. According to the USDA Economic Research Service (ERS), the environmental horticulture and floriculture industry is the fastest growing sector of U.S. agriculture. In 1998, grower cash receipts totaled $12.1 billion. Retail sales for all nursery related crops and products reached $38.3 billion. The California industry alone generated $2.4 billion, representing 20% of the total nursery crop production in the country. Other states with a significant proportion of nursery crop production include Florida (11%), North Carolina and Texas (8%).

Levels of awareness about invasive nursery stock vary by region and within different facets of the horticulture industry. Horticulturists are quick to point out the regional nature of weed problems and are strongly opposed to statewide or national bans on most plant species. Many weeds have restricted distributions that make them problematic only in particular settings. Instituting local restrictions on plants in areas where they are known to invade would minimize economic impacts to the industry, but the proportion of the market that would be affected is unknown.

The industry generally favors voluntary guidelines for controlling the spread of invasive species. The threat of nationwide bans, which could pose a significant economic impact, provides a strong incentive for the industry to self regulate and avoid federal or state legislation. Nationwide mandates would require governmental enforcement and may not be perceived as fair. In contrast, voluntary guidelines, paired with a rigorous education campaign, could promote a high level of awareness of the problem. Establishing voluntary guidelines at an academic level would require input from industry, cooperative extension, and government agencies.

What can be done about invasive ornamentals?

A primary obstacle to dealing with invasive ornamental is the lack of agreement on objective criteria for what makes a plant invasive. Clearly establishing such criteria is a critical precursor to defining the issues surrounding invasive horticultural stock and taking steps toward possible solutions. An active dialogue must be maintained between weed scientists and horticulturists on how an invasive species is defined. The issue is not simply native vs. non-native. In the effort to quantify invasive characters, some see an opportunity to rethink current horticultural practices. Increased research on alternatives to invasive species may lead to new cultivars and breeding techniques that could actually increase numbers of new plants and diversify nursery stock.

It is necessary for the horticulture industry to share the responsibility of preventing the spread of existing invaders by discouraging their use in landscape settings and offering non-invasive alternatives. A rigorous education campaign is required to combat further releases and introductions of invasive exotic plants into California's natural landscapes. It is critical to develop regional lists of invasive ornamental plants that should not be sold in California. It is equally important to increase research efforts in order to provide non-invasive alternatives that will help nursery owners make an informed decision to stop selling known invasive species.

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THE BIOLOGY AND ECOLOGY OF GIANT REED (*ARUNDO DONAX*)

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Introduction

Invasive plants are receiving increasing attention because of the impacts of human activities on native vegetation and the continual introduction of exotic species into disturbed habitats. Riparian habitats are particularly susceptible to invasion by exotics because water acts as a dispersal agent and flooding creates openings in vegetation cover. *Arundo donax*, giant reed, is a vigorous, invasive perennial grass that has established and spread rapidly in California's riparian habitats. The presence of giant reed in these areas impacts water conservation efforts and causes a severe fire hazard during the dry season. Giant reed appears to replace native vegetation, which may impact endangered species such as the least Bell's vireo (*Vireo bellii pusillus*) in southern California. Although giant reed was introduced into California as an ornamental plant and for erosion control, it easily escapes cultivation and spreads rapidly along irrigation and drainage canals as well as in riparian habitats. Giant reed is thought to have originated in Asia, and is now widespread in Europe, North Africa, the Middle East, Australia, and North and South America.

In California, numerous state and private agencies are actively working towards removing giant reed from riparian habitats. Some of the issues complicating these efforts are regulations regarding use of heavy machinery and herbicides in riparian habitats, the need in some areas for restoration for mitigation purposes, and the lack of biological information on giant reed with which to design effective management. The lack of biological information is surprising given the many real and potential uses of giant reed described in the literature, such as for reeds in woodwind instruments, for biomass as an energy source, and for production of allelochemicals for deterring pests. Despite these uses, giant reed currently has little commercial value in North America and its presence in riparian habitats is a serious problem.

Biology of Giant Reed

Giant reed is a large-statured perennial species in the grass family (Poaceae) and is the most common of the six species in the *Arundo* genus. This plant has many common names including giant reed, bamboo reed, giant cane, donax cane, and reed grass. It can grow up to 25 feet in height with stems up to 1.5 inches in diameter that root at the nodes. In southern California, emergence of primary shoots begins in spring and peaks in early summer. Plants grow vigorously during summer, flower in fall, and go dormant in winter. During the following year secondary branching occurs. Giant reed possesses a deep, fibrous root system and large creeping rhizomes. It is a hydrophyte, growing best near water, which has facilitated its establishment and spread in riparian habitats throughout warm, mostly coastal freshwaters of North America, including the southwestern United States. While flowers are often seen, seed production is apparently absent in North American populations and vegetative reproduction predominates, similar to many other clonal species. Dispersal of vegetative propagules (fragmented stem and rhizome pieces) of giant reed typically occurs during winter floods. The rapid spread of giant reed, a C_3 species, is likely due to high rates of photosynthesis and productivity, which are comparable to those of some C_4 species. Its occurrence in habitats from the Pacific coast inland to the Mojave Desert in California is indicative of plasticity in adaptation to a wide variety of growing conditions; in addition, propagules will sprout under a range of environmental conditions. It is not surprising that this species has become a serious riparian invader; however, little is known about its development, phenology, and rate of spread or its response to environmental factors.

Research Findings at UCR

Management of giant reed often results in severed pieces of stems and rhizomes, which can easily reinfest a site. We conducted controlled experiments on sprouting potential of vegetative propagules, effects of propagule storage duration and conditions on sprouting, and survival and growth of propagules in various soil types and moisture regimes. In all experiments, over 90% of stem and rhizome pieces with at least one node sprouted. Stem sprouting was affected by prior storage duration, temperature, and moisture, while only storage duration and moisture affected rhizome sprouting. Sprouting was reduced by drying propagules at 30°C for one week and by storage in a soil slurry. After 16 weeks, even propagules maintained optimally in moist soil showed reduced sprouting. Rhizome pieces sprouted readily from 25 cm, while stem pieces sprouted from less than 10 cm. Responsiveness of giant reed asexual reproduction to environmental cues suggests that mechanical control can be achieved by careful timing and treatment of cut biomass pieces to minimize or inhibit resprouting.

To examine seasonality of giant reed sprouting, vegetative propagules were collected monthly from two southern California sites and planted in a greenhouse over one year. Rooting and emergence frequency of planted pieces, and time to emergence, growth rate and number of developing shoots were recorded; soluble carbohydrates were analyzed. Response variables were regressed against climatic, seasonal and site effects using a stepwise model. Rhizomes established much more frequently than stems in all months. Time of year of collection was found to be the most important factor determining establishment of all propagule types. The interaction of maximum daily temperature and precipitation at the field sites had a lesser, but significant effect on rooting frequency. The lack of a consistent correlation between any of the response variables and climate or site may indicate broad environmental tolerance. Seasonal patterns in emergence, growth, and soluble carbohydrates suggest that control by shoot removal would be most effective in fall when rhizome carbohydrate reserves are the lowest, resulting in the greatest reduction in regrowth. Chemical control with phloem-mobile herbicides would be most effective in late summer or early fall, when carbohydrates are moving from leaves to below-ground structures, but prior to natural leaf senescence.

We also conducted field research to evaluate demography of giant reed populations in two California riparian communities. Sites differed in the seasonal pattern of precipitation and in resource availability, as effluent from a water treatment plant enriched nitrogen in surface waters at one site. Quadrats were established along 100 m transects at each site and oriented across the advancing fronts of established populations. Morphology and phenology were assessed monthly over one year for calculation of demographic parameters and rhizomes were excavated and mapped at the end of the experiment. No shoots in any of the quadrats flowered during the experimental period, supporting the observation that giant reed is obligately asexual in California. Seasonality affected the number of sprouts, spreading rate, and shoot deaths at both sites. Plant factors related to rate of spread included spatial advance of populations from buds on rhizomes and shoots as well as age and maturity of the populations. Giant reed at the nutrient-enriched inland site appeared to be spreading more rapidly than at the coastal site as evidenced by greater production of new shoots and higher linear and areal additions to clumps. At the coastal site, most clumps were dense at the beginning of the research and giant reed spread more slowly there than inland. However, several recently established clumps were found in gaps at the coastal site suggesting a greater frequency of flood-mediated dispersal of giant reed propagules. Inferences about local population invasiveness and hence, development of local management strategies for giant reed, could be made from the condition of the populations and their habitats.

Management of Giant Reed

It has been estimated that 90% of the riparian habitat in southern California has been lost to agriculture, urban development, and other human impacts. Giant reed and other exotic invasive species threaten the remaining 10%, thus, management of this weed is critically important. Eradication of giant reed is impossible due to the depth of viable rhizomes and ease of movement of propagules in water. Therefore, prevention is particularly important, especially of infestations upstream of any area under active management. Unfortunately, no natural enemies have been found that would be potential biocontrol agents and in fact, giant reed is known for possessing an array of secondary chemicals that appear to deter insects. Management techniques available for giant reed include mechanical and chemical methods, as well as cultural control through restoration of competitive native species. The specific approach used must be tailored to the habitat, including the presence of native species and wildlife, terrain, season, etc. In all cases, the key to effective management of this weed is destruction of the belowground biomass.

Mechanical control of giant reed is commonly attempted using bulldozers, chainsaws, brushcutters, and hydroaxes, which, although effective at removing stems, are very destructive to fragile ecosystems. However, they are often the preferred means of control in solid monoculture stands of giant reed with little remaining native vegetation. Even after these methods are used, the problem remains of how to dispose of giant reed biomass. Cut stems may be left to dry with little threat of sprouting unless they are cut up, which separates the nodes and encourages sprouting from axillary buds. Stems chipped into pieces so small that nodes are damaged do not sprout and may be left on the site. Following stem removal, some means of killing the rhizome biomass is necessary to prevent resprouting.

The most common herbicidal treatment against giant reed is glyphosate, primarily in the form of Rodeo®, which is registered for use in wetlands. The most effective applications are made after flowering but before the winter dormant period, when plants translocate carbohydrates to belowground roots and rhizomes. Methods that have been used include foliar applications in late summer followed by removal of dead stems several weeks later, direct applications by painting or spraying herbicide on cut stems, and cutting of stems in spring followed by foliar application to shoot regrowth. Aerial spraying in some areas has also been used to control giant reed. All treatments require vigilant follow-up care.

Conclusions

In spite of some attractive ornamental qualities of giant reed, it is a serious invasive weed in California and other coastal parts of the US. Its vigorous growth, prolific vegetative reproduction, adaptation to disturbance and fire, lack of herbivores and competitors, and unsuitability for food or habitat for wildlife make it one of the major threats to native riparian habitats in the western US. Management of giant reed requires a whole watershed approach since it moves and establishes readily downstream. To date the best control is achieved by a combination of mechanical and chemical means in combination with replanting of native species. However, greater understanding of the biology of this weed is desperately needed to improve its control.

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Team Arundo del Norte Web Site—http://ceres.ca.gov/tadn/

Developing management programs for perennial pepperweed (*Lepidium latifolium* L.)

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BACKGROUND

Perennial pepperweed has been rapidly invading the western United States for the past decade (Young et al. 1995). While this plant preferentially establishes in wetlands, seasonal marshes, floodplains, riverbanks and riparian areas it can also establish along roadsides, alfalfa fields and native hay meadows. Although many acres are infested throughout California, perennial pepperweed distribution is still limited. Many acres of land throughout California remain highly susceptible to perennial pepperweed invasion. Developing effective management plans will prevent the spread of perennial pepperweed and recover previously infested lands to more desirable habitats.

Several control methods have been shown to be effective in controlling perennial pepperweed (see table) (Fredickson and Murray 1999, Renz 2000, Renz and DiTomaso 2001 a & b, Young 1998). Selection of the most effective control method can be difficult if information regarding specific infestations is not known. Our objective is to provide land managers with information to assist in developing effective, biology based, management programs for perennial pepperweed.

LAND OBJECTIVES

Before selecting the most appropriate management tool, it is essential to determine the specific land use objectives. Many control strategies, while extremely effective, provide limited reestablishment of resident plants after management is achieved. This may compromise the success of the management objectives, therefore eliminating the option as a control method. Some herbicides effective for control of perennial pepperweed are registered for use only in specific areas, further limiting management options. Due to the limited tools available within specific areas it is recommended that land managers first develop a list of potential methods that complement land use objectives.

PRIORITIZING INFESTATIONS

As with management of any weed species, it is extremely helpful to prioritize individual patches or infestations. The highest priority areas should be along watercourses and roadsides where propagules can spread to new areas. Although few seedlings are found in the field, both perennial roots and seedlings can form viable propagules.

Patches that do not have the potential for long distance spread can also be prioritized. Recent work has shown that large dense patches move 1-2 m^2 per year on average with few satellite populations appearing over a 3-year period, while small establishing patches tended to spread more rapidly (unpublished results). In addition, small less dense patches are easier to control and control measures have less of an impact on resident plant species (Renz and

DiTomaso 2001a). Thus, by assigning these small patches a higher priority, they can more effectively and efficiently be eliminated before focusing on the large dense infestations. Large infestations will require more resources to control, and since they expand at a predictable rate, management can be delayed without dramatically increasing control efforts.

SPECIFIC MANAGEMENT TOOLS

To maximize effectiveness when selecting a management method, it helps to know specific information about each infestation, including: the age, the density, the canopy structure, the location, and previous management of the infested area. This information will help in selecting the most effective management methods for that particular area.

If infestations are large, dense, and old they likely have a large amount of perennial roots present within the soil. These roots will have large pools of carbohydrates available for growth making these infestations difficult to control. Previous research has shown reducing the amount of stored energy below ground can dramatically enhance control (Renz and DiTomaso 2001b). Many methods exist for reducing belowground carbohydrate pools, including disking, flooding, several mowings per year, continual grazing and treating with a postemergence herbicide.

If infestations do not have an excessively large amount of stored energy belowground, but are dense and have a closed canopy, some type of above ground disturbance will increase the effectiveness of systemic herbicides. An early season mowing followed by herbicide applications to resprouting shoots greatly enhances the efficacy and long-term control (Renz 2000). This is likely due to the reduction in aboveground sinks present in resprouting shoots and the synchronization with maximal belowground translocation rates.

Previous and current management practices of the land will also greatly impact the future management of perennial pepperweed and should be considered when developing a long-term plan.

MONITORING

Because roots are difficult to eliminate, diligence is critical when monitoring areas where perennial pepperweed is being managed. Areas should be monitored in early spring and late summer, if possible. Typically perennial pepperweed is one of the first species to emerge in the early spring, and is often the only green foliage visible. In large dense infestations, plants are most visible when flowering and producing fruit. Efforts should be made to locate the source of the infestation and, if possible, this source should be eliminated. Water sources, imported soil and hay bales used for erosion control should also be monitored to ensure they do not contain perennial pepperweed roots or seeds.

CONCLUSIONS

Perennial pepperweed is a very effective competitor and requires site specific management programs to succeed. While effective control methods are known for perennial pepperweed, site specific approaches will maximize the effectiveness. Little is known on how to restore areas to prevent reinvasions from occurring once control is obtained, thus extensive monitoring is extremely important. While not an easy task, coordinated attempts to manage perennial pepperweed can be very successful given sufficient information and resources are available.

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Table: Most common control methods demonstrated to be effective in controlling perennial pepperweed (Fredickson and Murray 1999, Renz 2000, Renz and DiTomaso 2001a & 2001b, Young 1998).

Control method	Herbicide	Rate	Best Fit	Limitations
Flooding	-	Season long flooding	Wetland, floodplain	Availability of water all season long
Herbicides	2,4-D (Weedar 64)	2.13 kg a.e./ha (0.5 gal/A)	When desirable monocot species are present; Dense stands require 2 applications/year; can be used near/or in water	1 application/year has limited long-term success in dense stands
	Chlorsulfuron (Telar)	0.11 kg a.i./ha (2 oz/A)	Dense or establishing infestations with no desirable dicot species present	Registered in noncrop areas; soil persistence can be long; limited plant reestablishment can occur
	Glyphosate (Roundup) (Rodeo)	3.33 kg a.e./ha (1.0 gal/A) (0.75 gal/A)	Dense stands require 2 applications/year; can be used near/or in water	Nonselective herbicide; 1 application/year has limited long-term success in dense stands
Mowing & Herbicides	2,4-D (Weedar 64)	2.13 kg a.e./ha (0.5 gal/A)	Dense old infestation where chlorsulfuron is not an option and desirable monocot species are present	Minimal effectiveness if soils are dry and plant resprouting is limited; Control not as consistent as glyphosate
	Glyphosate (Roundup) (Rodeo)	3.33 kg a.e./ha (1.0 gal/A) (0.75 gal/A)	Dense old infestation where chlorsulfuron is not an option	Nonselective herbicide, minimal effectiveness if soils are dry and plant resprouting is limited
Disking, mowing & herbicides	Glyphosate (Roundup) (Rodeo)	3.33 kg a.e./ha (1.0 gal/A) (0.75 gal/A)	Dense, old infestations with large root systems present; Stimulates germination of seeds within seedbank	Disturbs soil and resident plants; Intensive management that cannot be performed in many habitats

New Developments in the Biological Control of Invasive Weeds

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The application of classical biological control to help manage weeds in California has had several important successes (e.g., St. Johnswort, tansy ragwort, puncturevine, and musk thistle; see Nechols et al. 1995). However, research activity by federal agencies on biological control of weeds that are important in California decreased during the 1980s and 90s. This trend has recently changed. Over the past four years, the number of scientists working on biological control of weeds at the USDA Agricultural Research Service laboratory (ARS) in Albany, CA, has increased from 1 to 6. The ARS European biological Control Laboratory (EBCL) in Montpellier, France, is now occupying a new building and has a new entomologist and a plant pathologist working on weed targets. Scientists in other state, federal and foreign institutions are also involved in research on an increasing number of target weeds. This paper presents a brief update on activities and accomplishments of many of these projects.

Yellow starthistle (*Centaurea solstitialis*)

Five of six insects introduced to control yellow starthistle have become established in California (Smith et al. 2000). California Department of Food and Agriculture (CDFA) scientists have widely distributed these five insects, but only three are widely established. A seventh species, the false peacock fly (*Chaetorellia succinea*) was accidentally introduced in 1991 (Balciunas & Villegas 2001) and is now widespread. CDFA scientists have been intensively monitoring at least 3 sites to measure impact of these seedhead insects on yellow starthistle populations; however, these insects have not substantially reduced the weed population (Pitcairn et al. 2001). The hairy weevil (*Eustenopus villosus*) and false peacock fly (*Chaetorellia succinea*) appear to be having the most impact on seed reduction, but there are still too many seedlings being produced. Two sites in Oregon, where there are large numbers of these insects, show substantial reduction of yellow starthistle, but it is unknown how much of this reduction was caused by the insects (E. Coombs, personal communication).

The accidentally introduced, false peacock fly has been studied to determine if it poses a risk to safflower or to native *Cirsium* thistles. Although this insect can oviposit and completed development on several safflower varieties in no-choice laboratory experiments, in open field experiments it did not (Balciunas and Villegas 2001). In a survey of 47 commercial fields, infested seedheads were found in only one, which was planted as a cover crop rather than for commercial harvest, and only 1-5% of the seedheads were attacked. A survey of *Cirsium* thistles near infested yellow starthistle found no infestations of *Cirsium* species by this fly (Villegas et al. 2001). However, the false peacock fly has been reared from Napa thistle (*Centaurea melitensis*) and Sicilian thistle (*Centaurea sulphurea*) (Woods and Popescu 2000) and can develop on the native species *Centaurea americana* (Woods et al. 2001).

Scientists are currently evaluating new agents to attack vegetative parts of the plant. A petition to release the rust pathogen, *Puccinia jaceaee* var. *solstitialis*, has been recommended for approval by the Technical Advisory Group (TAG), a scientific advisory group to USDA-APHIS, and we are anticipating the first releases after sufficient quantities of the agent are available. The root weevil, *Ceratapion basicorne*, which is very common in central Turkey, is now being evaluated in quarantine to determine if it is sufficiently host specific. The insect can oviposit on safflower in no-choice experiments, but further laboratory and field experiments in Turkey will be conducted. Several other prospective agents have been identified, including a stem-borer (*Psilliodes* sp. nr. *chalcomera*), a blister mite (*Aceria* sp.), a rosette fly (*Botanophila turcica*), and a phytoplasma-like organism.

Salt cedar (*Tamarix* spp.)

The leaf beetle, *Diorhabda elongata*, introduced from China has been released in 6 states, including 3 sites in California. Initial releases were in field cages to observe the effects on the target weed, because of concerns for nontarget effects on the southwestern willow flycatcher. The insect has multiplied well inside the cages and caused extensive defoliation of salt cedar. However, it appears to do better in northern states, where it has multiple generations. In California, it apparently enters diapause in midsummer, so scientists plan to test insects from the Mediterranean to see if they are better adapted to our latitude (R. Carruthers personal communication). In 2001, the cage was removed from the first Californian release site, and studies on insect population dynamics, the effect of indigenous predators, and impact are being conducted.

The ARS laboratory in Temple, TX has submitted a petition to USDA-APHIS for permission to release the flower gall weevil, *Corimalia tamarisci*. Two other insect agents have been introduced into quarantine laboratory for host specificity evaluation: another flower gall weevil, *Corimalia palidula*, and the gall midge, *Psectrosema nigrum*, both from France. Other prospective agents include: a gall moth (*Amblypalpis tamaricella*) from Kazakhstan, and a leaf-feeding weevil from France.

Russian knapweed (*Acroptilon repens*)

The stem gall-forming nematode, *Sanguinia picridis*, which was first released in 1984, appears to have impact only at wet sites. CABI-Bioscience, in Switzerland, and Montana State University have been evaluating new agents for introduction. Petitions for release have been submitted to USDA-APHIS for two seedhead gall flies, *Urophora kasachstanica* and *U. xanthippe*, from Uzbekistan and Kazakhstan. Although these flies oviposited on a few other plants, including *Centaurea americana*, in the laboratory, they were very specific in field experiments. Scientists expect to submit a petition for the stem gall wasp, *Aulacidea acroptilonica*) in 2002 (J. Littlefield, personal communication). Other agents being evaluated include a foliage mite (*Aceria sobhiani*), root boring moth (C*ochylimorpha nomanda*), and a root/stem mining fly (*Napomyza* sp. nr. *lateralis*).

Cape ivy (*Delairea odorata*; =German ivy; =*Senecio mikanoides*)

Agents for Cape ivy are being evaluated by the ARS Albany laboratory and their collaborators in South Africa. The stem gall fly (*Parafreutreta regalis*) and stem-boring/leaf-mining moth (*Acrolepia* n. sp. [Plutellidae]), both look specific so far, but more testing is needed before submitting a petition. The moth larvae seriously damage the leaves and stems, frequently killing the whole portion above the area attacked. The gall fly appears to inhibit further growth of the stem. The stem-boring moth (*Diota rostrata* [Arctiidae]) attacks several host plants in no-choice tests and in the field in South Africa and may be eliminated from consideration (J. Balciunas, personal communication).

Brooms

Australian CSIRO and CABI-Bioscience scientists have been evaluating agents for Scotch broom (*Cytisus scoparius*), with the support of New Zealand and Oregon. Recently, French broom (*Genista monspessulana*) has been added to this project. Great efficiencies could be realized by creating a single project to develop agents for these and other closely related weeds: Gorse (*Ulex europaea*), Portuguese broom (*Cytisus striatus*), and Spanish broom (*Spartium junceum*). Attempts are being made to obtain long-term funding for an "International Broom Initiative" by a group including CDF, CDFA, CalTrans, CDPR, USDA and others. More information is available on the internet at http://www.caleppc.org.

French broom. There are two agents for French broom which appear to be host specific, but they still require further testing: a psyllid (*Arytainilla hakani*) and seed weevil (*Lepidapion argentatum*) (A. Sheppard, personal communication). Other potential agents include: 2 moth leaf miners (*Trifurcula serotinella*, *Coleophora trifarella*), two beetle seed feeders (*Bruchidius villosus*, *Pachytychius sparsutus*), a beetle root feeder (*Peritelus senex*), and a stem miner fly (*Chyliza leptogaster*).

Scotch broom. The seed beetle, *Bruchidius villosus*, was accidentally introduced in North Carolina. Host specificity tests showed this beetle to be specific to Scotch broom and other closely-related broom species and was approved by USDA-APHIS for movement within the United States. It was recently released in Oregon in 2000 (E. Coombs, personal communication); petition to release *B. villosus* in California is being developed.

Gorse. A petition will soon be submitted to TAG for the introduction of the thrips, *Sericothrips staphylinus*, to control gorse (E. Coombs, personal communication). The spider mite, *Tetranychus lintearius*, heavily infested gorse soon after being established in the late 1990s, but it is now compromised by predatory mites. The seed weevil (*Apion ulicis*) appears to be widely distributed. The tip moth (*Agonopterix nervosa*) was accidentally introduced in the 1920s, but its host specificity is unknown.

Russian thistle (*Salsola tragus*)

Two previously released moths, a stem borer (*Coleophora klimeschiella*) and a leaf-mining case-bearer (*C. parthenica*) are considered to be widespread in California; however, their numbers are too low to impact the weed (Goeden and Pemberton 1995). The ARS laboratories in France and Albany are evaluating several new agents. A blister mite (*Aceria salsolae*) looks specific so far, and is now in the Albany quarantine undergoing further testing. A gall midge (*Desertovelum stackelbergi*) also looks very specific in field tests in Uzbekistan, attacking Russian thistle type A much more than type B (*S. tragus* has 3 known genotypes; Ryan and Ayres 2000). This midge failed to oviposit on any test plants in the Montpellier laboratory last summer, delaying further work. The plant bug, *Piesma salsolae*, has failed host specificity tests, but testing will continue on the seed moth, *Gymnancyla canella*. Several other potential agents are also being studied including a root weevil (*Baris soricinae*), stem weevil (*Lixus salsolae*). rust pathogen (*Uromyces salsolae*).

Scotch thistle (*Onopordum acanthium*)

Two insects (seedhead weevil, *Rhinocyllus conicus* and crown weevil, *Trichosirocalus horridus*) introduced for musk thistle (*Carduus nutans*) control do not attack Scotch thistle. Australia has an active program and has released six insects, four of which are well established. This gives us a head start, except that Australia does not have any native *Cirsium* species to worry about. The ARS Albany laboratory has evaluated two of these agents: a rosette weevil (*Trichosirocalus* n. sp.) and a stem-boring weevil (*Lixus cardui*). *Trichosirocalus* n. sp. oviposited on 11 other thistle species, and developed on 1 other species (*Cirsium occidentale*) in quarantine tests (J. Balciunas, personal communication). Two populations of *Lixus cardui,* from France and Greece, oviposited and developed on some native *Cirsium* species, so both of these insects have been eliminated. Additional agents that could be tested include: a seedhead weevil (*Larinus latus*), a rosette moth (*Eublema amoena*), a rosette fly (*Botanophila spinosa*) and a seedhead gall fly (*Urophora tenebrans*). However, ARS activities have been suspended until additional funding is obtained.

Rush Skeletonweed (*Chondrilla juncea*)

Three introduced agents (a gall mite (*Eriophyes* [=*Aceria*] *chondrillae*), gall midge (*Cystiphora schmidti*),
and rust pathogen (*Puccinia chondrillina*)) are established but have not controled the weed in all areas (Rees et al. 1996). Good control of rush skeletonweed occurs in California where plants are susceptible to attack by the rust. Plants in Idaho appear resistant to the rust so control has not been achieved there. CABI-Bioscience, in Switzerland, and Montana State University have been evaluating new agents for introduction. A root moth (*Bradyrrhoa gilveolella*) from northern Greece has been evaluated for specificity, and a petition has been recommended for approval by TAG, and USDA-APHIS is working on the Environmental Assessment (EA). Permission to make the first release is anticipated for 2002 (J. Littlefield, personal communication). Exploration in the Republic of Georgia has found several new pathogens and a fly leaf-miner.

Hoary cress (*Cardaria draba*) - EBCL & CSIRO

Both CABI-Bioscience and the ARS-EBCL are working on the discovery and evaluation of new agents for hoary cress. The gall mite, *Aceria drabae*, has been found in many countries in eastern Europe. So far the mite has attacked only hoary cress in field and laboratory trials, and has not attacked four *Lepidium* species (Littlefield, personal communication). Threatened, endangered and rare plant species still remain to be tested. Several species of *Ceutorhynchus* beetles that attack the seeds, stem and root are also being evaluated.

Purple loosestrife (*Lythrum salicaria*)

Biological control agents have achieved high levels of control in the eastern U.S. and at sites in Washington and Oregon. Available agents are: Two leaf-feeding beetles (*Galerucella calmariensis* and *G. pusilla*), a root-feeding weevil (*Hylobius transversovittatus*), and a flower-bud weevil (*Nanophyes marmoratus*). CDFA began releasing these insects in 1996 at sites in California, and 3 of 4 agents appear to have established. Population numbers still occur at low levels.

Giant reed (*Arundo donax*)

ARS-EBCL and ARS-Albany began exploring for agents for giant reed in 2001. Several agents worthy of further evaluation have already been found: a bagworm, leaf-mining moth and flower moth (in the Indian subcontinent); a stem-mining wasp (*Tetramesa*, Eurytomidae) and a root-borer (in the Mediterranean). Other agents are still being identified.

Knapweeds (*Centaurea* spp.)

Spotted knapweed (*Centaurea stoebe* ssp. *micranthos* [*maculosa*]). Six agents are established in California on spotted knapweed, but this weed is generally targeted for eradication. Three insects attack the seedhead (*Urophora affinis, Urophora quadrifasciata* (not released but immigrated and now common), *Terellia virens*, and *Larinus minutus*) and two attack the root (*Agapeta zoegana*, and *Cyphocleonus achates*). These agents may be beginning to exert pressure on spotted knapweed in other states (Story et al. 2000), but it is likely that additional agents are needed, especially in colder habitats (Smith 2001). ARS-EBCL is reactivating foreign exploration to find new agents that attack the rosette crown.

Diffuse knapweed (*Centaurea diffusa*). Weed populations have decreased to innocuous levels within a few years in the presence of high densities of the seedhead weevil (*Larinus minutus*) and root insects (*Sphenoptera jugoslavica*, *Agapeta zoegana*, and *Cyphocleonus achates*) in Montana, Washington and Oregon. Six agents are established on diffuse knapweed in California. CDFA has documented 85% infestation of seedheads by two weevils (*Larinus minutus* and *Bangasternus fausti*) at a site in Trinity county; however, knapweed plant densities have not yet decreased (Joley et al. 2001).

Squarrose knapweed (*Centaurea virgata* ssp. *squarrosa*). CDFA has released two seedhead weevils (*Larinus minutus* and *Bangasternus fausti*) on squarrose knapweed to see if they would attack it. Seedhead weevil (*L. minutus*) populations rapidly increased, and after 3 years, they are attacking over 90% of the seedheads (Woods and Popescu 2001).

Other targets for foreign exploration

Other weeds recently added to the list of targets for foreign exploration include: perennial pepperweed (*Lepidium latifolium*), teasel (*Dipsacus sativus*), and medusahead (*Taeniatherum caput-medusae*).

Two older projects have recently been suspended because of delays in receiving feedback from the U.S. Fish and Wildlife Service on the acceptability of proposed agents: Houndstongue (*Cynoglossum officinale*) and Sulfur cinquefoil (*Potentilla recta*) (J. Story, personal communicaton). Canadians are continuing to support the search for new agents of Canada thistle (*Cirsium arvense*) in central Asia. In 2000 & 2001 the planthopper, *Prokelisia marginata*, was introduced into Willapa Bay, Washington for biological control of Salt marsh cordgrass (*Spartina alterniflora*). It is established, and its spread and impact are being studied.

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USE OF IMAZAPYR FOR WOODY VEGETATION CONTROL

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Introduction

Woody vegetation control is an important facet of any vegetation management program. Woody vegetation may compete with desirable vegetation for light, nutrients and water. Many woody species may also be noxious or invasive pests that need to be controlled to keep from dominating local plant communities.

Control of unwanted species may consist of manual, cultural or chemical methods. In the case of woody plants, manual and cultural treatments tend to be difficult to implement on anything other than small scale projects and are usually less effective and more costly than chemical control methods. Re-sprouting of woody vegetation is the main deterrent to manual treatments such as cutting, grubbing or mulching. Results are usually short term before the vegetation reoccupies a site and the need for repeat treatments becomes necessary.

Chemical methods are extremely effective, efficient and safe. However, not all chemicals have the same ability to control woody vegetation. Growth regulator herbicides in some instances will cause excessive damage to the translocating tissue in the plant hindering the ability of the chemical to work effectively. Initial results may look good but the plants may soon re-sprout and continue to grow vigorously. Some systemic products are effective on certain species but not others. This demonstrates the need to know your targets and what chemicals fit your needs.

One of the most effective compounds for controlling woody vegetation is imazapyr. Imazapyr is a highly systemic phloem mobile compound that inhibits the ability of the plant to produce three essential amino acids valine, leucine and isoleucine. Imazapyr provides broad spectrum control of many woody species. It is also suited to a variety of application methods and techniques and is an extremely safe product having LD-50's greater than 5000mg/kg.

Application Techniques and Methods

Imazapyr is available in several formulations. There are water soluble formulations such as Arsenal®, Arsenal AC® and Habitat® and formulations which are bi-phasal amines soluble in both water and oil such as Chopper® and Stalker®. Each formulation lends itself to certain types of applications and targets. The oil soluble products are best suited for foliar applications to evergreen brush species whereas, the water soluble formulations are more suited for foliar applications to deciduous brush or injection treatments.

Broadcast Applications

Imazapyr can be used effectively for woody vegetation control as a broadcast site preparation treatment. It is critical to emphasize the applications are for site preparation and not release as most western conifers have little tolerance for imazapyr (Fredrickson & DiTomaso, 1999)(Cole & Newton, 1990).

The choice of product depends on the target species. Evergreen brush is particularly difficult to control compared to deciduous species due to the thick waxy cuticle associated with these species. The cuticles of such species as tanoak, golden chinqapin and snowbrush are highly hydrophobic and difficult to penetrate with water soluble compounds (Newton & Fredrickson, 1998). Therefore, the oil soluble formulations should be used. Even with the oil-soluble formulations, an additional penetrant can improve the performance in the field. Tests of a variety of adjuvants with Chopper® on tanoak showed that the esterified vegetable oil Hasten® was superior to non-ionic or silicone based surfactants (Fredrickson & DiTomaso, unpublished data)(Figure 1).

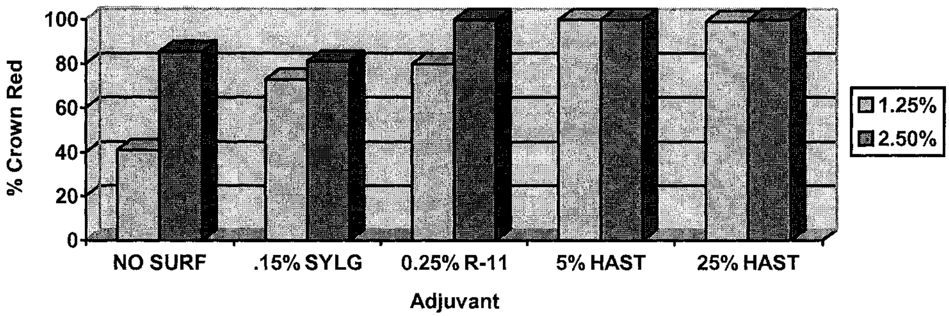


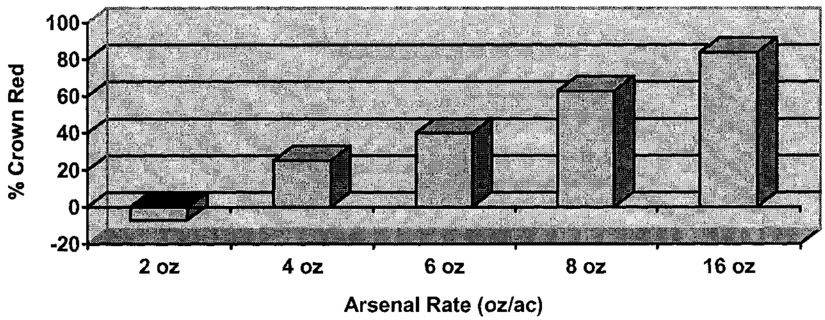
Figure 1. Tanoak percent crown reduction three years after directed treatments with 1.25 and 2.5 percent Chopper with and without Sylgard 309, R-11 and Hasten adjuvants.

Rates of Chopper® may vary by species but in general, rates between 24 and 32 ounces per acre will provide good control of golden chinqapin, madrone, tanoak and snowbrush with chinqapin being the most susceptible and snowbrush being the least. Imazapyr is not the chemical of choice for manzanita. All applications should have the addition of an esterified vegetable oil as the adjuvant. Treatments to date on evergreen brush show better results with spring treatments than later in the year.

Deciduous species tend to be easier to control than evergreens. However, there are differences in control between woody brush and woody tree species, especially for broadcast applications. Deciduous woody vegetation can be controlled with either the water soluble or oil soluble formulation of imazapyr. As with the oil soluble products an adjuvant is also required with the water soluble products (Fredrickson & DiTomaso, 1999). With water soluble products such as Arsenal AC, non-ionic or silicone based surfactants work equally as well. From an economic standpoint, treatments with the oil soluble formulation are slightly cheaper, and also slightly more effective.

Deciduous brush such as deerbrush, whitethorn, cherry and snowberry can be readily controlled with fairly low rates of imazapyr. Eight to ten ounces per acre of Arsenal AC® or sixteen to twenty ounces of Chopper® is usually adequate. Rates can be lowered even further if imazapyr is tank mixed with glyphosate. Treatments in late summer to fall before senescence occurs are best.

Re-sprouting hardwoods are slightly more difficult to control. In this instance, application techniques other than broadcast methods should be utilized. Adequate suppression of re-sprouting species such as black oak can be achieved with maximum rates of Arsenal and a non-ionic or silicone based surfactant, but cost is a factor (Figure 2). Maximum rates of Chopper



with

Firgure 2. Black oak percent crown reduction three years after broadcast treatments with Arsenal AC plus 0.25% R-11 non-ionic surfactant.

an esterified vegetable oil provide slightly better control. Usually, the established root systems of cut stumps require more volume and better coverage to the clumps than what can be obtained with a broadcast application.

<u>Directed Applications</u>

One of the most effective control methods for woody brush and stump sprouting trees is directed applications of imazapyr. Directed applications allow the applicator to obtain even coverage across the foliage as well as have better control over the volume applied. The main difference between imazapyr directed applications and that of other chemicals is the amount of volume used per clump. Imazapyr applications are extremely low volume compared to other types of herbicides. Typical volumes per acre ranges from three to ten gallons per acre for woody brush with imazapyr and two to five gallons for sprouting hardwoods. This allows for a decrease in labor costs compared to other chemical applications that put out two to three times the amount of solution.

Directed applications are the most effective means for controlling short evergreen brush. Long-term control of species such as golden chinqapin, tanoak, snowbrush and madrone can be achieved with rates of Chopper® as low as one to two percent solution in combination with an esterified vegetable oil (Fredrickson & DiTomaso, unpublished data) (Figure 1). The water soluble formulations of imazapyr should not be used for evergreen directed applications (Fredrickson & Newton, 1998).

The water soluble formulations of imazapyr are best suited for directed applications to deciduous hardwoods. In combination with a non-ionic or silicone based surfactant, rates of one to two percent of Arsenal AC® provide long-term control of re-sprouting hardwoods such as California black oak (Fredrickson& DiTomaso, 1999)(Figure 3). Again as with the broadcast treatments, the oil-soluble formulation could also be used on deciduous hardwoods.

Timing typically varies by treatment. Early results indicate slightly better performance on evergreen brush with Chopper® in the spring compared to later in the year. However, with the water soluble formulations on deciduous species late summer to fall is best.

One opportunity for treatment which has become increasingly popular over the last few years has been that of pre-harvest site preparation. An application for which Chopper® or Arsenal® have a perfect fit due to the broad spectrum control. This application method has several advantages in that a person has the ability to treat understory vegetation in an undisturbed state at least a year prior to planting. This allows adequate time for any residual effects of the herbicide to dissipate before the new seedlings go into the ground. Directed applications usually have the best fit in these circumstances due to the amount of understory vegetation which can cause excessive interception and shadowing. However, in instances where there is little residual conifer in the understory broadcast applications using the waving wand technique are feasible.

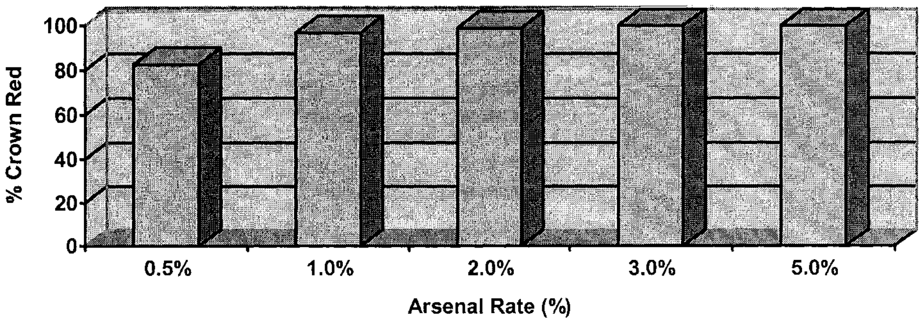


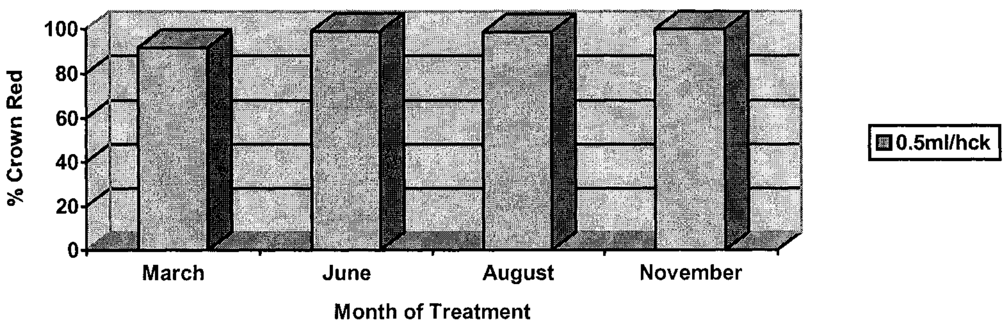
Figure 3. Black oak percent crown reduction four years after directed treatments with Arsenal AC plus 0.15% Sylgard 309 silicone based surfactant.

Hack & Squirt Applications

One of the most useful applications is the hack and squirt method. Hack and squirt applications consist of making a cut into the cambium and injecting a measured amount of Arsenal AC®. For these applications the water soluble formulation should be used.

In forestry, the hack and squirt method has several advantages. First, it allows the land manager to treat their ground either prior to or after harvest. Applications prior to harvest are usually more effective and reduce the need for future treatments once the plantations are established. This considerably reduces the risks involved regarding conifer tolerance of young plantation trees. Second, the land manager has the ability to release established young to mid-rotation conifer stands from hardwood competition. Third, in existing plantations, hack and squirt applications reduce the risks of conifer damage from drift, although there is still some risk involved from soil uptake. Fourth, by injecting it directly into the tree or brush, worker exposure is minimized while maximizing efficiency of chemical use. Finally, the manager has the ability to treat large brush and trees that would otherwise be untreatable with directed or broadcast applications.

Rates of application are based on the diameter of the stems being treated. For deciduous hardwoods, usually one injection of 0.5 milliliters pure Arsenal AC® per 3 inches of diameter at breast height is adequate for control of most species (Fredrickson & DiTomaso, 1999)(Figure 4). Evergreen hardwoods are slightly more difficult to control and a full milliliter of undiluted product should be used. Fall to mid-winter is the most optimal time of year to treat. Where treating near desirable hardwoods, a buffer should be left between treated and untreated trees as



imazapyr will readily translocate through root grafts into neighboring trees.

Figure 4. Tree black oak percent crown reduction 3 years after hack and squirt treatment with 0.5 mls of undiluted Arsenal AC at one hack per every three inches diameter at breast height.

Conclusions

In the realm of herbicides, imazapyr is a powerful and effective tool for any vegetation management program. Its versatility and broad spectrum control lend itself to a variety of applications. The chemistry is arguably the best around for long-term control of woody vegetation. Caution must be given regarding the residual activity of the product, especially around desirable conifer and hardwood species. However, timing, treatment method, buffers and awareness of the sensitivity of crop species can alleviate the majority of these concerns. Overall, imazapyr will be a very important tool in the future of vegetation management.

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Sandea – A New Herbicide for Vegetable Crops
A Technical Review

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CWSS Jan 15, 2002

Sandea is the trade name for a new soil residual selective sulfonylurea herbicide which will be registered for selective weed control in certain vegetable crops such as asparagus, cucumbers, cantaloupes, tomatoes, winter squash, and possibly beans, and watermelons.

Sulfonylurea herbicides were first patented in 1977 by the Du Pont Co. By the mid 1980's 14 agrichemical companies had S U patents and there were 230 patents in the U.S. alone. These new low use rate soil residual and foliar absorbed herbicides did have Pre and Post activity with medium to long soil persistence.

These herbicides are classified by their mode of action and they are all inhibitors of the (ALS) aceto lactate synthase enzyme system inside plants. There are four families of herbicides which have this same mode of action: sulfonylureas, imidazolinones, pyrmidinylthiobenzoates, and thiazolopyrimidines. That is to say that each herbicide which inhibits the (ALS) system works to control weeds in the same way but may have very different levels of activity on specific weeds or crop plants. Examples of these herbicides in the four families are:

<u>Sulfonylureas</u>; chlorsulfuron (Glean,Telar), chlorimuron (Classic), bensulfuron (Londax), rimsulfuron (Shadeout, Matrix), ethametsulfuron, (Muster), metsulfuron, (Escort, Ally), sulfometuron (Oust), triflusulfuron, (UpBeet), triasulfuron, (Amber), thifensulfuron, (Pinnacle), nicosulfuron, (Accent, Muster,Steadfast), halosulfuron, (Permit, Manage, Sempra CA, Sandea), prosulfuron, (Peak), primisulfuron, (Beacon), and thiameturon, (Hamony)

<u>Imidazolinones;</u> imazamethabenz, (Assert), imazapyr, (Arsenal), imazaquin, (Scepter), imazethapyr, (Pursuit),

Pyrimidinylthiobenzoates; pyrithiobac sodium, (Staple),

<u>Thiazolopyrimidines</u>; clopyralid, (Broadstrike. Stinger).

Plant selectivity is primarily due to rapid degradation within certain crops which can tolerate these chemicals and little ability to degrade the herbicides in weeds which are controlled.

Plants have an (ALS) aceto lactate synthase enzyme system which helps the plant manufacture three key amino acids: valine, leucine, and isoleucine which are needed by the plant to build proteins to support development of cells and general plant growth.

When this enzyme system is inhibited or shut down by the presence of halosulfuron inside the plant, the plant is retarted or stopped in its ability to continue manufacturing the needed amino acids. And, when there is an interruption in the necessary amino acids plant cell development slows down or stops where the concentration remains high enough in the plant tissue. Thus, the

first symptoms normally seen following an application of halosulfuron or other ALS inhibiting herbicides is stunting of new plant growth at the meristematic cell areas of plants in the developing root tips or new shoot growth. Then other symptoms such as mild chlorosis will follow for a period of 7-14 days.

For plants which do not have the ability to metabolize halosulfuron you can expect extended plant stunting or death of younger more susceptible plants. For crop plants in the grass family like corn and sorghum and cereals there is normally little effect from halosulfuron as these plants have a strong system of (MFO) mixed function oxidases which breakdown the herbicide molecule to acid metabolite forms which are 1/30th to 1/50th as toxic to plants and these crops and weeds return to normal growth in a very short time after an application of halosulfuron.

Vegetable crops have moderate to low levels of (MFO) present inside the plant to help breakdown the herbicidal action of halosulfuron and there lies the challenge of finding just the right rate of exposure which each crop can tolerate and metabolize effectively and return to normal growth. Common experience is to see a vegetable crop show some degree of stunting for 7-14 days after an application of halosulfuron and then return to normal growth once the herbicide has been degraded sufficiently. Under most conditions the vegetable crops on which Sandea will be registered for use will return to normal growth in 14-21 days after an application.

Halosulfuron is absorbed by roots, shoots and especially new foliage of weeds and crop plants. The herbicide is absorbed in approximately 4 hours under good growing conditions so that the effects will not be washed off by rain or irrigation. Then the active ingredient is translocated first into the xylem and then through the phloem where it can accumulate in the apical buds at the tips of roots, in shoots, and leaf axils and reproductive structures including below ground nutlets of nutsedge plants.

Even though halosulfuron inhibits plant growth, seed germination is generally not affected. However, growth inhibition of new cells is very rapid and secondary symptoms of yellowing and sometimes reddening can be seen in 7 - 10 days after an application.

For crops which have a very active (MFO) system to breakdown the herbicide there will very few symptoms of crop injury for a short period of time. Then the crop will return to normal active growth. There are many things that a grower can do to help crops tolerate an application of halosulfuron and return to normal growth. The best way to overcome the herbicidal activity is to manage the crop in the best way to help it grow. Give the crop water, air to the roots, fertilizer or other treatments to encourage return to good vigor.

The half-life of halosulfuron is stated to be 9-14 days in the soil but that depends upon the pH of the soil, soil type, temperature, soil moisture, and general health of the soil. Microbial degredation is one of the most effective means of degrading the herbicide in soils followed by chemical hydrolysis. The herbicide will remain active longer in cold wet soils than hot wet soils. The herbicide will hydrolize more rapidly in soils where the pH is < 4.5 or > 7.5.

Some vegetable crops are very sensitive to small amounts of halosulfuron in the soil so plantback studies have been conducted to indicate safe recroping time intervals.
There are a number of field crops which can be planted back with safety after only a few months and these crops should be considered prior to use of halosulfuron.

Safe time intervals in months after an application of halosulfuron to a soil for specific crops have been determined which will allow for germination and good crop growth. These time intervals are listed on the product label and should be referred to prior to use of any S U herbicide and then followed after use.

One other point needs to be made relative to use of Sandea and that is proper spray equipment clean-out procedure. There are specific directions on the label for proper clean-out of spray equipment which should be followed in order to prevent unintended crop injury in subsequent uses of that equipment.

With all the above information, Sandea can be used effectively and safely for selective broadleaf and nutsedge control when the proper rates, timing and method of application, PPPE, POST, POST-DIR or with Crop Row Shields or Row Middle sprays, to provide excellent weed control and good crop safety. The product will not fit for use in all vegetable crops but can be used safely on certain crops as listed above.

Role of Conservation Tillage in Vegetable Production

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The term "conservation tillage" (CT) technically denotes a variety of crop production alternatives that minimize primary tillage operations such as disking, plowing, ripping and chiseling and as a result, typically leave a minimum of 30% of the soil surface covered by residues from previous crops. While CT practices have traditionally been applied to the production of agronomic crops, there has been a dramatic increase over the last 5 years in interest and innovation related to reduced tillage alternatives in several of California's very diverse cropping systems that include vegetable crops. Currently, however, less than 1% of row crop acreage in California is farmed using CT practices. Effective and efficient approaches for managing weeds are a critical and compelling requirement in CT vegetable rotations. Recent research in the Central San Joaquin Valley indicated that even heavy residue cover crop surface mulches typically permit over 25% of incoming photosynthetically active radiation to reach the soil surface and thus necessitate the use of specially-adapted high residue cultivators that allow residues to "flow" and avoid damage to crop plants, hand weeding, herbicides, or combinations of these interventions. A number of short-term studies have demonstrated the potential of CT processing tomato and melon production variants to match standard tillage systems in terms of yields and to reduce estimated diesel fuel use per acre. Longer term implications of these reduced till regimes in terms of soil compaction, water use, profitability, soil carbon sequestration, insects, diseases and weed seed banks are currently under evaluation.

Crop Management with Information from Digital Satellite Imagery

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Introduction

Innovators and early adopters of new and emerging technologies involved in farming provided a surge of interest in production agriculture due to considerable media coverage. While the word revolution implies a sudden or complete change, the use of information technologies in horticultural crop production has been somewhat of a slower evolution as innovators searched for practical applications for farm management. As a suite of technologies became available, a new strategy that combined information with decision-making became known as precision agriculture (National Research Council, 1997). This concept has also been referred to as site-specific crop management. High-resolution satellite imagery from digital sensors provides information for analysis and interpretation of crop growth and offers valuable in-season progress reports. Fierce competition and strict confidentiality are expected in fresh market vegetable crop production. While possession of information may infer more knowledge, the real power of information lies in knowing how to use it to manage more effectively. Satellite imagery offers an ability to extend the vision of what can be seen by humans and provides end-users with an opportunity to acquire visual information that can be used in crop management. Numerous practical applications of remote sensing technology for crop management of high value fruits and vegetables, including fertility and water management, have been previously identified (LeBoeuf, 2000).

Technology Shift from Public Sector to Private Sector

The Land Remote Sensing Policy Act of 1992 brought about significant changes as applicants from the private sector were allowed to obtain licenses to operate in satellite technology (KMPG Peat Marwick LLP, 1998). This action prompted a quick surge of interest in 1993 as remote sensors were evaluated on aerial platforms in the San Joaquin Valley in California. It was also in 1993 that the global positioning system (GPS) became fully operational with 24 h a day coverage providing latitude, longitude, elevation, and time of day information (National Research Council, 1995). Interest in satellite technology was also shifted from the public sector into the private sector with the 1994 Presidential Directive by President William Clinton when he decided to allow commercial companies to acquire and market one-meter spatial resolution imagery. Applicants from the private sector were allowed to obtain licenses to operate satellites through the United States Department of Commerce. By 1994, numerous foreign countries such as India, France, Russia and Japan had started to create medium to high spatial resolution imagery for commercial use.

Low Spatial Resolution Satellites

Prior to the development of high-resolution imagery, low or coarse resolution satellite imagery of 10 to 30-m spatial resolution offered a look at in-field crop situations. The use of 10-m (32.8-ft) resolution imagery provided nine times more pixels than 30-m (98.4-ft) resolution imagery which is typical of U.S. Landsat imagery (Verbyla, 1995). SPOT (Le Systeme Pour l'Observation de la Terre) satellite imagery operated by the French Space Agency has 10-m panchromatic imagery along with 20-m (65.6-ft) color imagery. SPOT Image (Reston, VA) markets imagery from the SPOT-4 satellite, which was launched in 1998 and expects to handle imagery from SPOT-5, which is scheduled for launch in 2002. SPOT-4 does not have a blue band (450 to 520 nm) so true color images are not available. True color images are made up by combining the three additive primary colors of blue, green (520 to 600 nm), and red (630 to 690 nm) bands, which make up the visible range of the electromagnetic spectrum. False color images are made from near infrared (760 to 900 nm), red, and green bands. Information on the satellite constellation operated by SPOT can be found at: http://www.spot.com.

All of the coarse spatial resolution satellites offer 8-bit digital data that corresponds to 256 levels of gray scale (2 to the 8th power) which allows for image classification from 0-255.

High Spatial Resolution Satellites

The first successful launch by a United States private sector company of a high-resolution satellite was achieved by Space Imaging (Thornton, CO) on September 24th, 1999. Their IKONOS (Greek word that means picture) satellite offers 1-m (3.28-ft) spatial resolution imagery in panchromatic (black and white) and 4-m (13.1-ft) resolution in multi-spectral color (blue, green, red, and infrared). The IKONOS satellite is in orbit at an altitude of 680-km (Gerlach, 2002). The global connection for satellite imagery can be seen by the team of investors involved with IKONOS satellites: Lockheed Martin Corporation, Raytheon, Inc., Mitsubishi Corporation, Singapore's Van Der Horst Ltd., Korea's Hyundai Space & Aircraft, Europe's Remote Sensing Affiliates, the Swedish Space Corporation, and Thailand's Loxley Public Company Ltd. Information on the satellite constellation operated by Space Imaging can be found at: http://www.spaceimaging.com. DigitalGlobe (Longmont, CO) operates the world's highest spatial resolution satellite. DigitalGlobe was formerly known as EarthWatch, which was a merger between EarthWatch Incorporated, Ball Aerospace, and WorldView. DigitalGlobe's QuickBird satellite was successfully launched on October 18, 2001. QuickBird offers 61-cm (2-ft) resolution at nadir (looking straight down from the satellite) in panchromatic and 2.44-m (8-ft) in multispectral color. DigitalGlobe operates the QuickBird satellite in a sun-synchronous orbit of 450-km around Earth that is significantly lower than that of the IKONOS satellite, thereby achieving higher spatial resolution (Lindgren, 2001). Key investors of DigitalGlobe include Ball Aerospace, Hitachi Ltd., ITT Industries, Inc. and Morgan Stanley Dean Witter. QuickBird imagery is expected to be available for commercial use in spring of 2002 depending on national security issues due to the terrorist's attack on America in September of 2001. As soon as QuickBird was successfully launched, Space Imaging lowered their prices for high-resolution satellite imagery. So competition has helped cut the costs of imagery to end-users. Information on the satellite constellation operated by:
DigitalGlobe can be found at: http://digitalglobe.com.

Both IKONOS and QuickBird satellites offer 11-bit digital data that corresponds to 2,048 levels of gray scale (2 to the 11^{th} power) which allows for image classification in areas such as shadows for more powerful image enhancement compared to the 8-bit data from other satellite systems. This is what is meant by the term higher radiometric resolution.

A network of authorized resellers of satellite imagery is in place to help end-users in selecting the appropriate imagery and they can be found listed in the web sites of the satellite companies. Some network partners such as AgriDataSensing of Fresno, CA offer value-added services such as spectral analysis of original data files for the various sensors along with image classification.

Mapping Accuracy Standards

There are numerous satellite products available for use in crop management, which should be matched up with the end-user's applications. Horizontal accuracy statistics may be shown as 12-m CE90 which would mean that any point within the satellite image is within 12-m horizontally of its true Earth's position on the surface 90% of the time as CE stands for circular error. Vertical accuracy is usually shown as linear error or LE.

Imagery can also be identified by scale with United States National Map Accuracy Standards (NMAS) such as 1:4800 which means that one cm on the image represents 4800 cm on the ground. It is important to remember that image scale is not the same as spatial resolution as scale is totally independent of the pixel size. It is also important to know what the accuracy standards are when an end-user wishes to stack maps for analysis of different layers of information. Quadrangle maps from the U.S. Geological Survey are usually published with a NMAS statement.

Supervised Classification versus Unsupervised Classification

The difference between supervised and unsupervised classification of digital satellite imagery is basically knowing the different cover types that will be used in the classification before the analysis is performed. An unsupervised classification requires no knowledge of the grouping of pixels into classes. The use of a histogram to look at the range of pixel values can be an indicator of spectral signatures when crops are known in the image, especially if the fields are of large acreage. Spectral analysis can be performed with upper-end computer software packages such as geographic information systems (GIS). Individual pixel values can be identified for the various sensors and crop identification can be achieved with adequate ground truthing to verify what is in the field compared to what is being identified in the image. The higher the image resolution, the more data there is to classify and identify, process, and store in databases. Ground truthing is also important when a crop is under attack from insects, plant disease, or subjected to competition from weed species.

Raw Data Sets versus Pretty Pictures

When imagery is acquired with the digital data files, statistical analyses can be performed to extract valuable information for crop management. This type of analysis requires image processing software and upper end computer hardware. Time is involved in the data analysis but potential information relevant to crop production and weed management makes the effort worth a lot more than just getting a pretty picture from a technology provider. Areas with extensive weed pressure can change the reflectance characteristics of a crop. Mapping of perennial weed species such as *Convolvulus arvensis* L (field bindweed) has been used by the author to direct spot treatments with ground applications of glyphosate (Roundup) instead of sending a tractor across a large field looking for areas to be treated with the herbicide. Perennial weeds typically grow in concentrated areas and management efforts can be targeted to spots identified in digital imagery. This has been seen with *Cyperus esculentus* L.(yellow nutsedge) which appears in sandy, light soils. Digital imagery combined with GIS and GPS equipment allows for specific mapping that also aids in site-specific weed management of annual weeds such as *Avena fatua* (wild oats) (Hanson et al., 1995).

Crop Management and Decision-Making

Recent developments in technology have shown that the cornerstone to successful farming is information. Innovative producers are often looking for a competitive advantage when they choose to use new visual information based technologies such as satellite imagery. The use of digital imagery in high value vegetable crops in California has been beneficial when ground truthing activities were performed to verify what was depicted. Satellite sensors provide information about crop health and identify plant stress. Imagery provides for effective crop monitoring if timely processing, analysis, and delivery is achieved. Ground truthing enhances diagnosis and meaningful information can then be applied to a management response that is site-specific. The examples identified from horticultural production in California have the potential to be applied to other commodities in various growing regions. As site-specific weed management becomes adapted in other crop production regions, the decision making process used by farmers and ranch managers will be enhanced. Numerous other benefits of satellite imagery will ultimately be discovered.

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Seasonal Fluctuations In Weed Emergence On The Central Coast

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Lack of progress in developing new vegetable herbicides coupled with the potential loss of old ones (Bell et al. 2000) has prompted an urgent need for the development of integrated weed management strategies for vegetable crops. The development of these strategies requires knowledge of weed biology. One approach in this direction is to study seasonal variations in weed emergence so that weed management inputs can be optimized according to the timing and severity of likely weed emergence. To study seasonal variations in weed emergence and seed germinability, permanent quadrats were set up in vegetable fields near Salinas, California. At intervals of 1.5 months, i.e., half-season, from September 21, 1999 to September 20, 2000, field weed emergence was counted and soil core samples were taken. Soils were placed into trays and incubated in growth chambers at approximated 5 cm soil temperatures for 1.5 mo (Table 1). At the end of this period, remaining ungerminated seeds were extracted using methods described in Ball and Miller (1989). The total number of seedlings that germinated in the growth chamber and the number of viable seed extracted from the soil cores were used to determine seasonal variations in seed germinability. Germinability is defined as the potential for a seed population to germinate. Results indicated that some weed species emerged in specific seasons, while other species emerged all year. Annual blue grass (*Poa annua*), and southern brassbuttons (*Cotula australis*) germinated primarily in the fall and winter (Table 2). In contrast, hairy nightshade (*Solanum sarrachoides*), and common purslane (*Portulaca oleracea*) germinated at the highest levels during the late spring and summer months. At least some fraction of the burning nettle (*Urtica urens*), common chickweed (*Stellaria media*), common groundsel (*Senecio vulgaris*), henbit (*Lamium amplexicaule*), and shepherdspurse (*Capsella bursa-pastoris*) seedbank population was able to germinate during each half-season of the year.

Typically weeds fall into categories of summer and winter annuals (Alrich and Kremer, 1997). However, we have observed a class of continuously germinating weed species that includes burning nettle, common chickweed, common groundsel, henbit, and shepherdspurse. Crops such as broccoli, cauliflower, lettuce and spinach are planted throughout much of the year on the central coast of California. It would appear that central coast vegetable fields harbor well-adapted weed species that are capable of emerging in any month that crops are planted. Knowledge of weed emergence cycles may aid in the development of improved weed management systems for vegetables. For example the development of season-specific weed management recommendations may result in better herbicide selection based on the expected weed spectrum by season. Season-specific weed management systems may result in increased herbicide use efficiency and production cost savings.

Acknowledgement

We thank the California Department of Pesticide Regulation for financial support.

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Table 1. Photoperiods and mean daily maximum and minimum half-season 5 cm soil temperatures in arable lands at Salinas, California.

Half-season	Photoperiod[1]	Temperature (°C) [2]	
		day	night
21 Sep-5 Nov (early fall)	7:00-18:30	25	6
6 Nov-20 Dec (late fall)	7:00-17:00	20	5
21 Dec-3 Feb (early winter)	7:00-17:00	20	-1
4 Feb-20 Mar (late winter)	6:30-18:00	20	2
21 Mar-5 May (early spring)	6:30-20:00	25	3
6 May-20 Jun (later spring)	6:00-20:00	25	9
21 Jun-5 Aug (early summer)	6:00-20:00	28	14
6 Aug-20 Sep (late summer)	6:30-19:30	28	14

[1] coinciding with daylength at Salinas, California, of the median date of the period covered (i.e., 14 October, 29 November, 14 January, 28 February, 14 April, 29 May, 14 July, and 29 August for early fall, late fall, early winter, late winter, early spring, late spring, early summer and late summer, respectively)

[2] based on temperature data recorded by HOBO Pro Series at 5 cm depth in soil for the duration from 1 July 1998 through 20 September 1999 in arable lands at Salinas, California

Table 2. Seasonal distribution of seedling emergence at two field sites in the Salinas valley from September 21, 1999 to September 20, 2000.

	Emergence percentage by half-season [1]							
Species	Early fall	Late fall	Early winter	Late winter	Early spring	Late spring	Early summer	Late summer
Annual bluegrass	29	4	37	16	0	0	5	9
Burning nettle	10	3	32	2	23	5	20	5
Common chickweed	19	6	34	5	11	3	19	3
Common groundsel	5	8	19	1	24	13	11	19
Common purslane	0	0	0	0	17	18	45	20
Hairy nightshade	4	1	0	0	28	18	48	1
Henbit	8	6	24	1	6	15	31	9
Shepherdspurse	13	4	22	6	25	4	24	2
Southern brassbuttons	12	0	69	13	0	0	0	6

[1] The eight half-season germination percentages sum to 100%, i.e., the total annual germination percentage of each species

Machine Vision Applications in Weed Control

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Machine vision technology has the potential to produce precision weed maps for use in weed targeted herbicide application. Machine vision can be used to distinguish crop plants from weeds using leaf or whole plant shape, and leaf color. When coupled with microspray technology, machine vision has the potential for spot spraying of individual weed leaves. The concept of a machine vision based microsprayer is shown in figure 1a. The spray map shown in figure 1b was produced by a machine vision system that distinguished nutsedge weeds from cotton plants using the distance from the margin to the center of the leaf. Spray results based upon the machine vision map are shown in figure 1c. This method could distinguish broadleaf plants from narrow leaf plants with an average accuracy of 87% in commercial cotton fields[1].

[1] Lamm, R. 2000. Robotic Weed Control for Cotton. Ph.D. Dissertation. UC Davis.

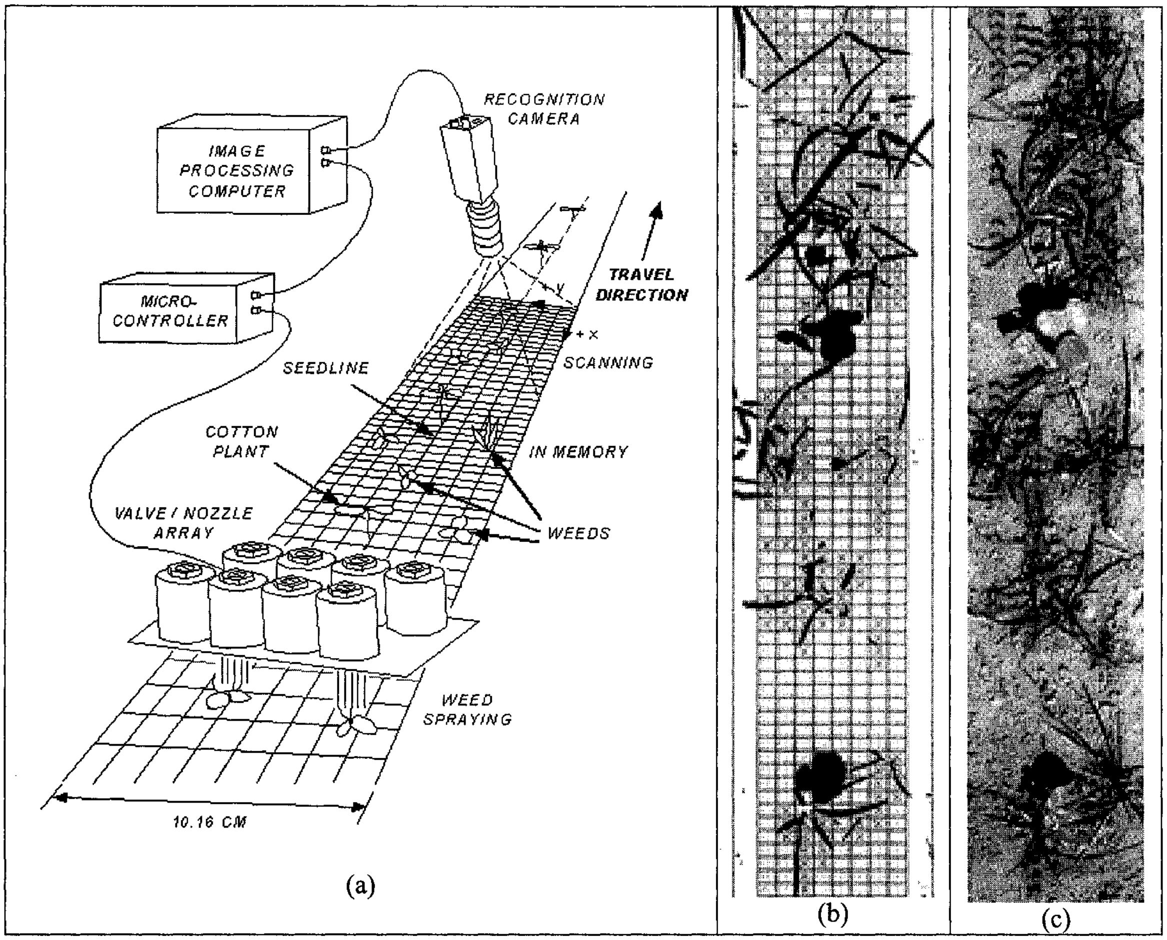

Figure 1. a) Concept diagram of machine vision system and precision microsprayer[2], b) machine vision produced spray map of cotton and nutsedge. X=cells to be sprayed, c) photograph of microspray deposition (in black).

[2] Lee, WS, DC Slaughter & DK Giles. 1999. Robotic weed control system for tomatoes. Precision Ag. 1(1):95-113.

THE MONTEREY COUNTY WATER RECYCLING PROJECTS

-- over 7 billion gallons sold!

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SUMMARY

The Monterey County Water Recycling Project (MCWRP) is a joint effort between two public agencies that are helping to slow seawater intrusion in Northern Monterey County. Since beginning operating in 1998, over 7 ***billion*** gallons of recycled water have been used for irrigation of food crops. The initial concerns over waterborne pathogens, food safety, and public perception have not turned out to be pressing problems at this juncture. Instead, water quality (salts) has been the key concern. Various strategies have been employed to anticipate and/or mitigate potential disruptions in order to maintain the project's overall success.

BACKGROUND

Northern Monterey County is one of the most productive agricultural areas in California. However, it has also been plagued by seawater intrusion for decades. Thus, in the late 70's, the concept of substituting recycled water for crop irrigation was proposed as a way to reduce groundwater pumping. However, there were lots of questions about the safety of using recycled water on food crops that might be consumed without cooking. A study would be needed to confirm that the new water would be suitable.

With that charge, the Monterey Wastewater Reclamation Study for Agriculture (MWRSA) was initiated in 1978. This 11-year study included five years of field tests. Various crops were irrigated including artichokes, head lettuce, celery, broccoli, and cauliflower. Using side-by-side comparisons with well water, the yield and quality of the produce was measured. The recycled water and produce were also examined to verify that no pathogens were present. At the end of five years, a summary report was published indicating that the water was safe. It was found that produce yields and quality were as good as, and in some cases, better using recycled water. Subsequently, approvals for using this water were obtained in 1988 from both the state and county.

Based on the above affirmations, conceptual and pre-design reports were prepared in order to prepare environmental documentation and to obtain funding support. Eventually, Bureau of Reclamation and California low-interest loans were obtained for the $75 million project. In order to proceed, a partnership was created between the Monterey County Water Resources Agency (the water planning agency for Monterey County) and MRWPCA (the regional wastewater agency).

KEY OBSTACLES

A. Long-Term Loans

The key funding instruments were the Bureau of Reclamation loans. These loans (one for construction of the treatment plant and another for the distribution system) were very low interest with 40-year terms. However, because the Bureau was limited on current funding, the loans were disbursed over eight years. Since project construction would be completed in 2½ years, short-term bonds were used as a cash flow "bridge." Unfortunately, this increased both overall project costs, as well as initial annual operating costs (debt service).

B. Signage

The project area encompassed 12,000 acres of rural agricultural land in Northern Monterey County. So, it was a major concern when our draft permit indicated that we'd need to post large (3' x 3') "Recycled Water – Do Not Drink" signs every 100' along the perimeter and interior roads of the project. Fortunately, after extensive discussions, we were able to revise the requirements to signs every 1/3 mile since most of the sites were fenced and on private property. And, wording on the signs was changed to "Irrigation Water – Do Not Drink" or "No Trespassing."

C. Customer Concerns

The main grower issues were related to food safety (pathogens), marketability of the produce, public perceptions, and water quality. The concern over water safety was understandable since there had been many recent incidents nationwide related to "emerging pathogens." While the MWRSA testing in the 1980's looked at viruses and general pathogens, it didn't address some of the new ones, such as E-coli (157:H7), cryptosporidium, cyclospora, giardia, and legionella. In order to address these concerns, a short food safety study was conducted prior to actual operation of the recycling plant. The results verified that the water was of very high quality, free of viable pathogens, and thus suitable for food crop irrigation.

Marketability and public perception issues were of particular importance since the produce would need to be sold in the open market. Because recycled water quality is similar to that of other water sources, there is **no** labeling of the produce to indicate that it's grown with recycled water. To address perceptions and marketing issues, a communications company was hired to develop an overall plan that considered both education and crisis planning. Materials generated were used to prepare local produce sellers and growers for any questions regarding the safety of recycled water and the produce grown with it.

OPERATIONS

A. Production

The first year of operation was geared towards starting slow and achieving a very high level of water quality and safety. Extra testing was conducted to assure that the water was pathogen free. As with any new venture, there were also the usual O&M issues during the first year. Even so, about 5,000 acre feet (AF) of recycled water was produced during calendar year 1998. For 1999, production problems were much reduced. Consequently, 10,000 AF of recycled water was distributed to the growers. And for the year 2000, expected production should be about 10,500 AF.

B. Water Quality Questions

The project was designed to supply water for about 12,000 acres of food crops. Based on about 1.75 acre feet of water per irrigated acre, about 21,000 AF of water would eventually be needed per year. However, most of this water is supplied during the peak growing months of May through August. Since the recycling plant has a current output of nearly 21 MGD (about 1,900 AF per month), supplemental well water is added to make up the difference. For example, in June 2000, 1,790 AF of recycled water was added to 1,050 AF of well water in order to meet the grower demand.

Even with the added well water, some growers still had a concern about the long-term impact of high salts. Since the system was not designed to achieve uniform blending of recycled and supplemental well water, the salt level received by a grower depended on their location, plus which wells were operated. Currently, the salt level of 100% recycled water, as measured by the sodium absorption ratio (SAR) is about 4.7. In contrast, good quality well water averages about 1.8. Overall grower water consumption in 1999 was 15,300 AF (10,050 AF recycled and 5,250 AF well). Thus, the overall SAR was about 3.9.

The question of how high the SAR can be over the long term without significant yield and soil permeability impacts is not known at this time. Thus, a multi-year soil salt monitoring program has been initiated to better understand this issue. In the interim, MRWPCA has embarked on a source control effort to limit salts from commercial and residential customers from entering the wastewater system.

LESSIONS LEARNED

Although it took 20 years before the project became a reality, the MCWRP has been a tremendous success by providing a new source of water for the area. Persistence and ongoing dialogue with the customers (growers, regulatory agencies, etc.) has proven to be the keys for negotiating the obstacles expected for a large-scale and innovative project.

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Summer Fallow management Changes Soil Temperature and the Diversity of Weed Populations in Desert Lettuce

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Introduction

The desert valleys of Coachella and Imperial produce a diverse array of vegetables. These are frequently grown in rotations of two crops per year that receive extensive inputs of fertilizers and pesticides. Weed infestation and high soil temperatures in early fall are some of the major problems facing lettuce growers in the desert (Coachella). The weed suppression action of cover crops is well-documented (Hutchinson and McGiffen 2000; Liebman and Davis 2000; Teasdale 1998). However, vegetable crops have received little attention. Reducing weed populations in vegetable through appropriate use of cover crops will reduce the amount of inputs required for weed control (Hutchinson and McGiffen 2000). Cover crops have also been shown to affect soil temperature (Teasdal and Abdul-Baki 1995; Teasdal and Mohler 1993), but little work has been conducted in the hot desert environment. If soil temperatures were reduced in Coachella, it may be possible to extend the growing season and allow produce to reach the market when costs are higher. The extended season would also give growers additional flexibility in crop selection and timing of field operations.

This research was conducted to: (1) determine if cowpea cover crop grown in the summer and incorporated into the soil or used as mulch could provide non-chemical weed control in fall planted vegetables; (2) evaluate the potential of cowpea mulch to improve soil temperature regime in early fall.

Materials and Methods

Field experiments were conducted at Caochella Valley, California during summer and fall of 1999 and 2000. Cowpea (var. Iron Clay) cover crop was grown in the summer, and lettuce (var. Shining Star) was grown in the fall.

The experiment had three treatments replicated four times. Treatments included:

1. Cowpea mulch (CM) -- cowpea residues were left on the soil surface as mulch prior to lettuce transplanting
2. Cowpea incorporated (CI) -- cowpea residues were incorporated into the soil prior to lettuce transplanting
3. Bare ground (BG) -- the soil was fallow during the summer prior to lettuce transplanting.

To study the effect of cowpea mulch on soil temperature, a data logger was installed in the field to monitor the soil temperature in the CM and BG treatments. Thermocouples were placed at 6.5 cm in the soil and temperature was recorded every hour for the first three weeks of the growing season.

The data collected included the density of each weed species, soil temperature, and lettuce marketable yield.

Results

Summer cowpea cover crop decreased the number of weeds in fall planted lettuce throughout the entire growing season. The weed control effect of summer cowpea cover crop was more pronounced when cowpea residues were used as mulch rather than when the residues were incorporated into the soil (Figure 1). In addition to decreasing total weed population, summer cowpea cover crop decreased the number of weed species in fall planted lettuce. Reduction of weed species was greater in cowpea mulch plots (Figure 2).

Soil temperature regime was improved when summer cowpea residues were used as mulch in the fall compared to when the ground was bare in the summer. Cowpea mulch acted as a temperature buffer (Figure 3):

- Night temperatures were increased in cowpea mulch plots
- Temperature rise in the morning was delayed by cowpea mulch
- Maximum temperature was slightly decreased and the duration of the daily peak was shorter in cowpea mulch plots.

Summer cowpea cover crop increased fall planted lettuce yield when the residues were incorporated into the soil. (Figure 4).

Reduction of weed population and diversity by summer cowpea cover crop will reduce the need for herbicide and labor inputs for vegetable production in the fall. In the Coachella Valley, the buffering effect of cowpea mulch on soil temperature may have the added advantage of allowing grower to plant earlier. Early planting will ensure supply of the produce at a time when there is less competition on the market and better prices.

In our study, we are also investigating the combined effect of summer cowpea cover crop and crop management system on weed population, insect population, soil organic matter content and lettuce growth parameters. These data will be analyzed and available later this year.

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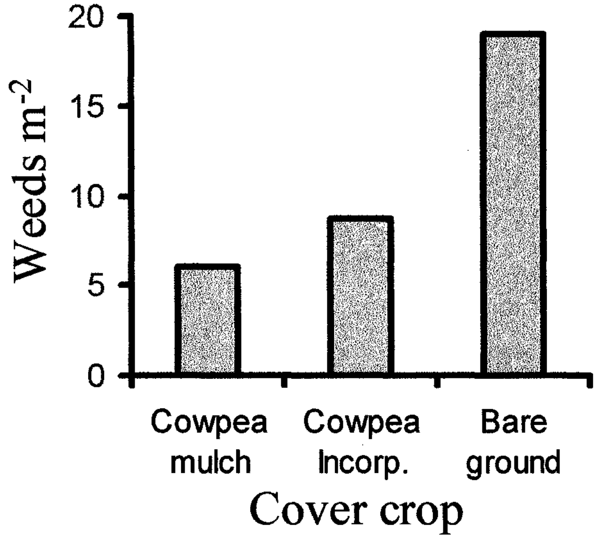

Figure 1. Weed population response to different summer cover crops.

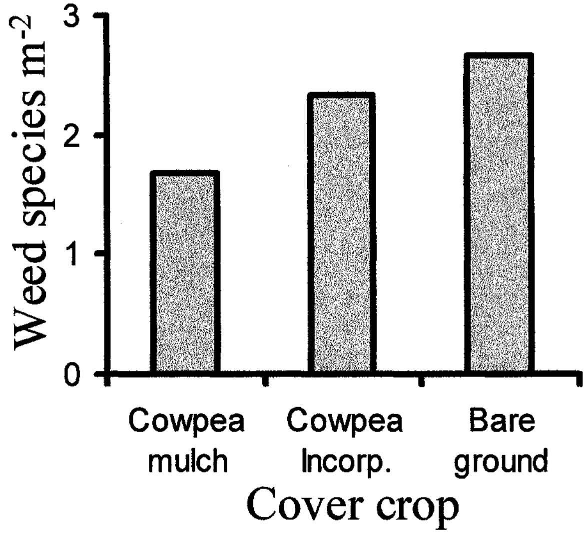

Figure 2. Weed species response to different summer cover crops.

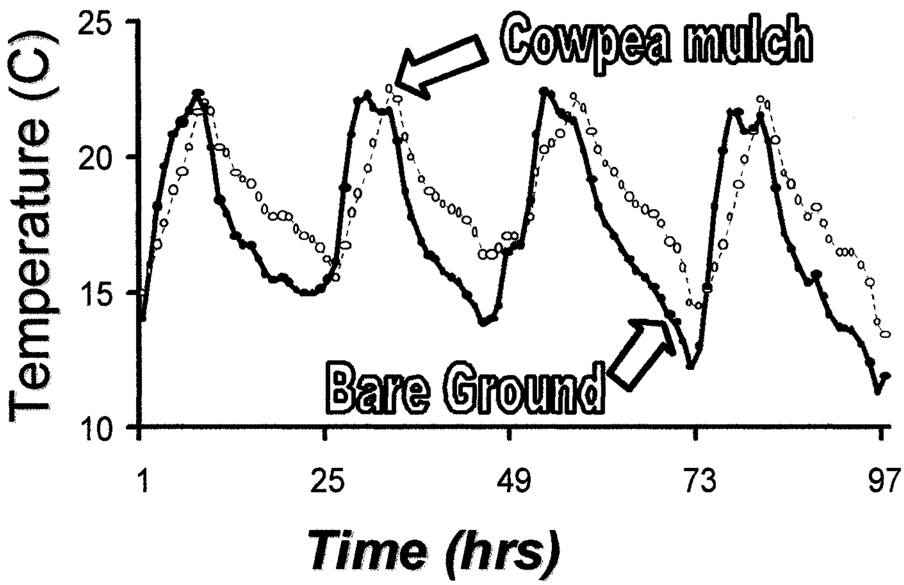

Figure 3. Effect of cowpea mulch on soil temperature.

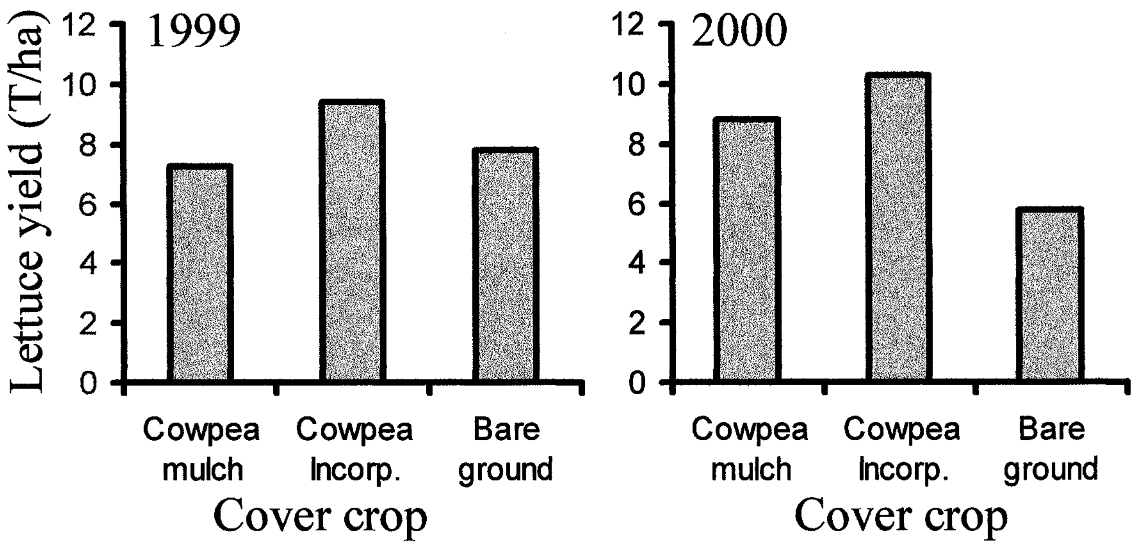

Figure 4. Fall lettuce yield response to different summer cover crops.

Non Chemical Weed Control in Specialty Crops - Solarization and Plastic Mulches

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Growing specialty crops is a big challenge. Not only is there limited expertise because of the uniqueness of the crops, but there are also fewer pesticides registered for combating insects, diseases, and weed problems. This means that alternative pest controls are extremely important to the specialty crop grower.

Whereas, the California DPR database for tomatoes, lettuce, potatoes, and onions shows 5-11 registered preemergent herbicide active ingredients, the same database shows specialty vegetables such as cilantro, daikon, and Chinese longbeans have none. Other crops such as eggplant have 4; parsley, Chinese broccoli, and basil have 2; and tomatillos have 1. When one considers that planting, cultural, and harvest costs are between $2,000-6,000 per acre for many specialty crops, a tremendous investment is placed on these crops that have limited people and pest management resources.

This discussion will look at two alternatives in particular - soil solarization, and plastic mulches.

Soil Solarization:

An excellent discussion of the topic is presented in a University of California publication titled Soil Solarization (publication # 21377). A compilation of papers presented at an international conference is found in Soil solarization and integrated management of soilborne pests, a document distributed by the Food and Agriculture Organization of the United Nations (FAO), paper #147, 1998.

Considering that the solarization process kills diseases, insects, and weeds, and also changes soil physical and chemical properties to enhance plant growth, it is an alternative that certainly merits consideration. It requires no chemical purchase or permits, and can be easily done by the farmer

Solarization is most effective in areas where summer temperatures are highest. However, solarization can still be fairly effective in only moderately warm regions as well. Generally the months of June, July, August, and part of September are reserved for solarization.

The process includes preparing the soil for planting and making the beds. The beds are then covered with clear 1-1.25 mil plastic. Thicker plastic can be used, but this increases the cost per acre, and also actually reduces the total heating. The edges of the plastic should be covered or buried to prevent heat from escaping. The soil is either prewetted and covered at about 70% field capacity, or if drip irrigation is used, the soil can be wetted after the plastic is in place. Usually only the initial irrigation is required. The plastic is left in place for at least 4-6 weeks. The longer the soil is covered, the better, but some growers have had some success after only 3 weeks of solarization.

In trials conducted in the San Joaquin Valley in 1997, temperatures as high as 142 F. were obtained at 5 cm. depth, while the highest temperature at 15 cm. was 124 F. The following graph shows temperature fluctuation over forty-eight hours at 5, 15, and 30-cm. depth. The highest temperatures at 5 cm. were recorded on August 7, 8,and 9 (60.7, 60.5, 60.3 respectively). Warmest temperatures were always recorded around 4 p.m.

During this time period, the following "solarization heat units" (over 43 C/ 110 F) were recorded.

'solarization heat units' over 43 C.

		highest temperature
5 cm. depth	156 hours	61 C (141.8 F)
15 cm. depth	125 hours	51 C (123.8 F)
30 cm. depth	0 hours	42 C (107.6 F)

Weed control can be enhanced when solarization is used in combination with other soil fumigants such as methyl bromide/chloropicrin (mbc) or metam sodium. The table below shows treatment means and estimated costs per acre to hand weed strawberry beds in a 1997 trial. In this trial, weed control was as good or better than with mb or metam alone. The same weeds escaping solarization were also missed by both fumigants.

'Man-hours to hand weed treatments'

TREATMENT	**minutes Treatment means**		**cost /acre**
4. solarization + Vapam	7.550	A	$ 74.00
3. solarization	8.890	A	88.00
1. solarization + mbc	12.880	A	126.00
2. mbc	13.403	A	131.00
5. metam sodium	14.100	A	137.00
6. untreated check	26.900	B	264.00
LSD	.01		
CV	22.10		

Plastic Mulches:

Embossed 1 mil black plastic is widely used for weed control in many different specialty crops with excellent results. Eggplants, squash (winter and summer), tomatoes, cucumbers, tomatillos, and many Asian crops such as bittermelon, opo, sinqua, and moqua use black plastic extensively. The middles, or furrows, are either sprayed with pre or post emergent herbicides, or simply cultivated. Nutsedge is one of the few weeds not controlled with plastic mulch. Where the plastic is stretched tightly over the bed, the nutsedge is more easily able to penetrate the plastic. If the plastic is a looser fit, many of the plants grow and simply bend over under the plastic. Their growth is less vigorous and less competitive with the crop. Black plastic provides moderate soil heating.

Several years have been spent evaluating the different colors of plastic mulches that will provide weed control and possibly enhance crop growth, yield, quality, or warm the soil. Other advantages include water conservation, reduced leaching of fertilizer nutrients, and enhanced soil fumigation. Most of the colored mulches control weeds almost as well as the black, though there is still some spindly weed growth under the plastic. Soil warming is most effective with clear plastic mulches, but clear plastic also encourages weed growth in the greenhouse-like environment.

When using colored plastics it is important to consider the time of the year, the crop, the type of plastic, and additional benefits besides weed control. For example, besides providing weed control, reflective or silver mulches also help to repel insects (aphids, etc.) and significantly reduce the incidence of viruses in such crops as squash and melons. Yields in these crops, as well as eggplant, corn and others, have doubled or tripled. However, reflective mulches applied in strawberries during the spring result in cooler soil temperatures, delaying the crop by 1-2 weeks.

Green and brown colors also control weeds quite effectively and can warm the soil more than black to result in earliness. In testing 6 different colored mulches applied to Black Bell eggplants in the summer of 2000, there was no significant difference in marketable yield or fruit quality. Green, white, silver, and black mulch yields ranked consistently at the top, while red and brown were consistently at the bottom There was some weed growth under the different colors, but none under the black.

In a strawberry trial evaluating plastic colors during the spring of 1999, the clear and green resulted in higher yields for the first 5 harvests (soil warming=earliness). The overall 4-month resultant heat accumulation compared to black was as follows:

clear=	+2.6 F.
green=	+ .6
black=	0 reference temperature
red on brown=	- .8
brown=	- .8
reflective=	- 1.2
white on black=	- 2.6

In conclusion, solarization can be very effective in controlling weeds alone, and in combination with soil fumigants such as mbc and metam. It is most effective in inland areas where temperatures are in excess of 100° F., however, some benefits can be realized in certain coastal or low mountain areas where temperatures are in the 90's. Colored plastics provide good to excellent weed control and in some cases result in earlier harvests. Additional benefits include insect/disease control, water conservation, enhance soil fumigation, and reduced leaching of fertilizers. Costs for black embossed plastic mulches in eggplants planted on 60" centers is $150-200 per acre.

The Windows CE Environment for GPS/GIS Field Data Collection

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As budgets shrink and workloads increase, employees are expected to be more efficient and multi-task in the workplace. Why should we not expect the same of our Windows CE software/hardware? The Windows CE environment allows a CE device to do many things: from doing GPS, editing shapefiles, working with spreadsheets and even emailing data, wirelessly. Gone are the days of purchasing a GPS unit that allows only for GPS field data collection.

ESRI's ArcPad, Tripod Data System's Solo CE and Trimble's TerraSync software are three software packages that run in a Windows CE environment. Some commonalities of these products, as well as key differences, will be discussed. One software package might be better than another based upon what needs to be accomplished in the field.

ArcPad is a lightweight GIS product for mobile computing. This software features low cost, portability, and a similarity in look and feel to ArcView, and an ability to work with GPS for navigation and data capture/data update in the field. ESRI has positioned this product as a 'field-based extension to your desktop or enterprise GIS.' It supports a multi layer environment with industry-standard vector map and raster image themes, similar to ArcView. It works directly in shapefile format and allows one to use customized data entry forms designed in Arc Pad Studio. If multiple background layers are required for use in field data collection, ArcPad is the right choice for the job.

Trimble's TerraSync for Windows CE is a full-featured data collection and data maintenance software package designed to work seamlessly with Trimble's ProXR/XRS, Pro XL, Pocket and Power receivers, along with Pathfinder Office. This product supports laser rangefinder input when performing GPS offsets of trees, utility poles, etc. Time saving tools such as repeating features, collecting line and point features at the same time and log now/log later, will make you more efficient out in the field. If full functional GPS is a field data collection requirement, then TerraSync is the answer.

Tripod Data System's Solo CE is a versatile GIS/mapping software application capable of gathering accurate position data and creating customized data collection forms with no additional software required. With Solo CE you can use GPS or a laser rangefinder to collect position data or simply select a position on your touch screen. User defined symbology is also supported by Solo CE, as well as user defined menu, toolbar, and map display options. Additional tools such as enhanced grid generation make Solo CE an excellent choice for field computing. If data collection done solely by laser rangefinder is needed, when GPS isn't necessary, then Solo CE should be used for the task.

Not only are there many Windows CE software packages available, there are many Windows CE hardware options, ranging from rugged to non-rugged. Again, the tasks that need to be accomplished in the field will dictate the kind of Windows CE hardware/software that are suitable to use. The beauty of Windows CE is just that - choice. One Windows CE software product can be used or, a combination of different Windows CE hardware and software packages used together, to aid in field data collection. So, the choice is yours. Will you continue to use one device to do one job or will you use Windows CE?

New Molecular Targets for Herbicide Discovery

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Current herbicide use is dominated by active ingredients with only a few modes-of-action, including PS II inhibitors, ALS inhibitors, an EPSP synthase inhibitor and auxins (1). New herbicide target sites are needed to control weeds resistant to existing herbicides, protect the usefulness of existing herbicides, enhance efficiency and add value. Of the more than 280 registered herbicidal active ingredients, only 19 modes-of-action are known. Among the 19, only 12 have been characterized at the molecular level (Table) (2).

New target site discovery can be approached fundamentally by two means, chemical probes or genomics (Figure 1). In the former, natural products or organic chemicals are screened against whole plants and active lead compounds pursued for target site identification. The organic chemicals may be derived from traditional linear synthesis or combinatory chemistry, in which pools of compounds are prepared around a common scaffold. A number of new tools are available to help with the screening process, including high-throughput automation technologies for sample and data handling. Molecular genetics is increasing the approach to target site identification. Resistant plants can be obtained directly by screening. Alternatively, the expression level of specific enzymes can be increased which also leads to resistance. In both cases the resistance can be traced to the genetic level and the target site identified. Other new genetic approaches for mode-of-action determination include the use of microarrays to match the mRNA response of treated plants to a database of known responses, or matching the small molecule profile of treated plants to a known metabolite library. These techniques are useful for distinguishing new modes-of-action from known, and for initial direction in new target site discovery.

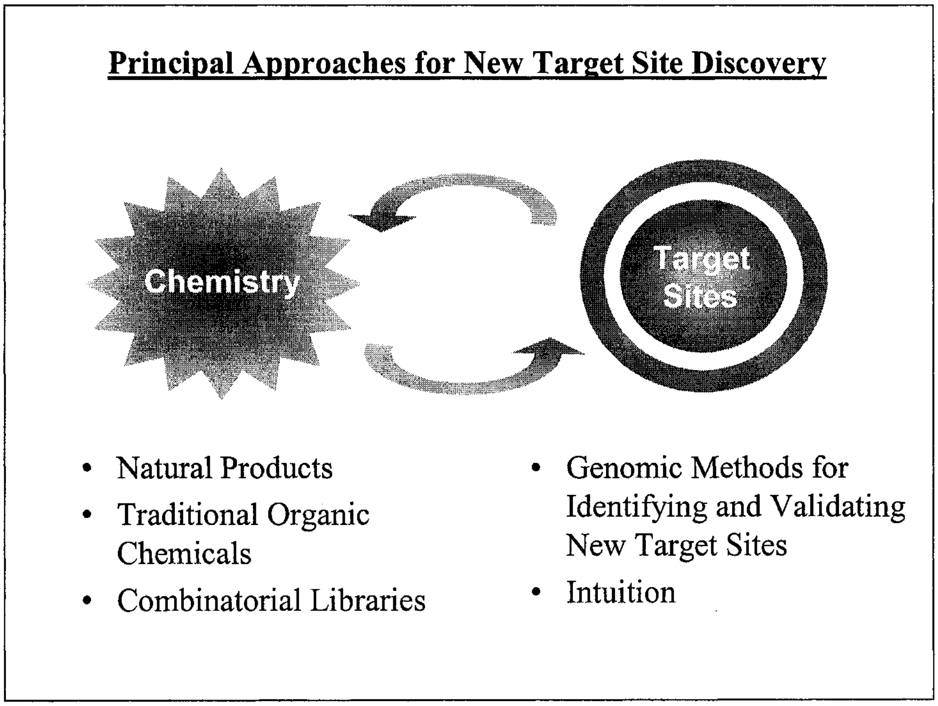
An alternative approach to target site discovery is genomics. Plants are known to have ~30,000 genes and each gene encodes a specific protein. Only a few of these proteins will be effective as herbicide target sites and these can be identified by molecular techniques, such as decreasing the expression level of a specific gene and noting the response. If slight decreases in the level of a specific protein cause significant effects on plant growth, the protein may represent a good herbicide target. Finding an inhibitor for this target site that can function as an actual herbicide may require high-throughput *in vitro* screening, molecular design technologies, or both.

New target site discovery is increasingly the focus of herbicide discovery research groups around the world. Whether the research starts with a chemical probe or the genome, molecular biology is providing the tools for identification. Despite the wealth of new technologies available in genomics, automation, and molecular design, the success of the discovery effort ultimately hinges on the initiative and curiosity of the discovery scientist.

Known Molecular Target Sites of Commercial Herbicides

Commercial Herbicide Example	Molecular Target Site
diuron	Photosystem II
diclosulam	Acetolactate synthase
oxyfluorfen	Protoporphyrinogen oxidase
haloxyfop	Acetyl CoA carboxylase
trifluralin	Tubulin
fluridone	Phytoene desaturase
sulcotrione	Hydroxyphenylpyruvate dioxygenase
glyphosate	Enolpyruvateshikimate phosphate synthase
asulam	Dihydropteroate synthetase
glufosinate	Glutamine synthetase
amitrole	Lycopene cyclase
cinmethylin	Asparagine synthetase

Figure 1: Complementary Approaches to Target Site Discovery



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1. D. Cole, K. Pallett, and M. Rodgers, Pesticide Outlook. 11(6), 223-229 (2000).
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The Impact of Generics on Weed Management

James R. Bone, Jr., Griffin L.L.C.

In a presentation to the 2001 annual meeting of the Weed Science Society of America, it was said, Awhen considering the role of a generic product it is important to understand that few herbicides are discontinued due to lack of efficacy. Newer products with a different spectrum of activity or more favorable environmental/toxicological properties replace some, but others fade for economic reasons B they no longer meet the commercial expectations of the registrant.@ While this very much remains the same, the case is being tempered by declining success from discovery and commercialization of new molecules.

To better understand the impact of generics, present and future, on weed management, it is important to consider factors having given rise to this group of products. It must always be remembered that Agenerics@ are a commercial and not a technical evolution. Generic herbicides are not the result of a targeted development activity, but economic necessity.

World wide, agriculture is in recession with free market desires entangled with a variety of national and international subsidies. As a result, farmers in most areas are unable to maintain profitability considering the breadth of the gap between income and expense. As a result, in 2000, the Crop Protection Chemical (CPC) industry experienced a 12 to 15% reduction in value; in 2001, it may have been nearer a 25% loss of value. Keep in mind this loss was only partially due to reduced CPC product utilization, but more significantly due to reduced prices. With greater than 70% of currently registered CPC products off patent, pressure will continue to assure that competition drives pricing; but the big question is will this result in costs that are sustainable? Products will be lost forever once the threshold is crossed whereby value received will not sustain expenses required to maintain registrations and provide reasonable shareholder financial return. Other factors impacting the rise of generic herbicides include:

1) Cost of discovery of new CPC products increasing sharply as the rate of commercialization of new molecules declines.
2) All sections in the CPC industry are attempting to rationalize costs to deal with reduced profitability through consolidation at all levels.
3) Global manufacturing/supply is in change characterized by over capacity in regard to production.
4) Reduced CPC profitability is impacting funding available to support public research efforts.
5) Biotechnology has given rise to a variety of before unknown agricultural tools impacting the use of CPC products.

With these factors giving rise to significant change, what is this thing called a Ageneric herbicide?"

1) A product without an established trade name or a representative of a class.
2) A product with patent protection expired.
3) A commercially proven product remaining biologically active.
4) A product often presenting opportunity for modification of presentation form (e.g. Formulation).

Key to acceptance of a generic herbicide has been user or customer reaction. While acceptance of newly introduced products can be long and costly, generics are seen by users as a way to influence supply/demand by supporting the presence of competition within the market place. Generics are generally considered more cost effective than patented proprietary offerings. There is also concern among some users in regard to tactics employed by original suppliers when products were under patent protection. There is continuing concern as to the way prices decline so rapidly upon the entry of generic supplier(s). Utmost among factors causing users to accept generic products is Aconfidence@ based on use history. This is an interesting representation of selective memory as this knowledge is the direct result of activity funded while sold under patent protection.

To have generic herbicides, there must be a means by which they can be made available. While it is becoming more common for a generic supplier to have manufacturing capacity, excess manufacturing capacity around the world allows toll/contract market entry. Once supply is obtained, a product must be proven Asubstantially@ similar to currently/previously registered products to qualify for data citation in the registration process. While some specific data are required for any generic CPC product, proving substantial similarity, assures the opportunity to cite the data of other registrants under the FIFRA provision regarding Adata compensation." This all done, the public domain presents data relating to the product performance which serves to substantiate generic performance in creation of a use label.

Now we have created an opportunity to market a generic herbicide. Those who have registered generics have a huge challenge that may be new to most of them. It is becoming more common for the generic producer to become the primary registrant for a product with attendant responsibilities. Often there is a void in regard to adequacy of current environmental and toxicological data leading to the need for expensive testing. To complicate product issues in a very competitive business environment, it is not uncommon for the Arumored@ issues to have a greater impact on data requirements than the Aknown."

Now that we have some appreciation for what a Ageneric@ is, how it comes to be, and the factors that influence, what will a generic herbicide do? Technically, nothing that it did not do as a patented product, but economics have changed! The largest generic product in the USA is glyphosate; at a cost of $3 to $4 per acre, its use brought about by biotechnology has humbled pre-plant and pre-emergence herbicide use. The applied cost of this one product has set a pattern where low cost product delivery is more important than service and to a degree quality. Declining prices have been experienced across most major classes of herbicides with the trend expected to continue as other classes of products come off patent.

It was reported at the 2001 Brighton Conference that the following five herbicides make up over 75% of generic herbicide sales:

Rank	Product	2000 Sales (Est. $ Million)
1	Glyhposate	3,100
2	Paraquat	470
4	Atrazine	320
5	Metolachlor	305
7	2,4-D	265

Further, a ranking of generic producers was given at Brighton:

Company	2000 Sales (Est. $ Million)
Makhteshim-Agan	734
Nufarm	498
Griffin	406
Cheminova	255
Sipcam Oxon	229

Interestingly the two largest generic producers, Monsanto and Syngenta, were considered basic manufacturers for the purposes of the Brighton report.

What will a generic herbicide do for weed management? The cost reductions brought about by the rise of generic herbicides have created an opportunity for users to employ products/mixtures previously not cost effective. Generics have removed cost as a controlling factor in most herbicide management systems!

METHYL BROMIDE SUBSTITUTES

Regulatory Status of Possible Methyl Bromide Replacements

Ralph E. Shields
California Department of Pesticide Regulation
Sacramento, California

TWO POSSIBLE ALTERNATIVES
- Iodomethane (methyl iodide)
- Propargyl bromide

IODOMETHANE
- Manufactured by Tomen Agro, Inc.
- Plan to submit to U.S. EPA and California in January 2002
- Hope to have registered in California in early 2003

PROPOSED USES
- Pre-plant Soil (Strawberries and Tomatoes)
- Non-food (Strawberry Nurseries, Cut Flowers and Bulbs)
- Crop Replant (Orchards and Vines)

IODOMETHANE BENEFITS
- Much lower volatility than Methyl Bromide
- Not a threat to stratospheric ozone layer

REGISTRATION CHALLENGES
- Mandatory Chronic Health Effects studies will not be submitted until mid 2004
- Is on the Prop 65 list (Carcinogen)

PROPARGYL BROMIDE
- In early stages of experimental use
- Is explosive in high concentrations
- May have an odor problem (stinks)

Registered Alternatives for Methyl Bromide

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As the cost of methyl bromide, both in dollars and regulatory burden, goes up there is increased interest in alternatives. Considerable resources are being spent on the search for alternatives, but that is for someone else to cover. I am going to discuss the main options available today.

There are basically three options. They are all fumigants and they are all restricted materials. They can only be used by or under the direct supervision of a certified private or commercial applicator. In addition, all three require a permit from the county agricultural commissioner for possession or use. They are:

1,3-D (Telone)
metam sodium (and other MITC producing compounds)
chloropicrin

1,3-D is currently regulated by registration and permit condition in addition to labeling requirements. There are currently no specific regulatory requirements on this pesticide. The most rcent permit conditions are found in ENF 01-40. You can get a copy from your county agricultural commissioner.

Probably the biggest impacting factor is the township cap. This requirement is to mitigate excessive offsite exposure. It is implemented as a negotiated product stewardship condition of registration and marketing of the product in California. It is managed by the registrant with overview by DPR. Basically it limits application in a township to about 34,000 adjusted pounds in each of January and December of each year and 90,000 adjusted pounds annually. DPR does not allocate the pounds to growers. It is up to the industry to make that distribution.

If you are a greenhouse grower, you are out of luck. Our recommendation to the commissioners is that no permits for greenhouse use be issued.

Other requirements touch on buffer zones and reentry. The minimum buffer zone recommendation from DPR to the commissioners for permit conditioning is 100 feet. Some labels have greater buffer zones and some do exempt certain situations from buffer zone requirements altogether. The suggested permit conditions for REIs are a little stricter that standard REI requirements. During the seven day REI only pesticide handlers may enter. No other work may be done, including what would normally be allowed during a normal REI.

Metam sodium and other MITC generating compounds (Dazomet and metam potassium) are also regulated by permit condition. In addition to the label requirements and permit conditions, there is a Technical Information Bulletin. Unfortunately there is sometimes confusion among the three. This is because they were all written an different times, by different people with a different perspective. If faced with confusion, my suggestion would be to let your commissioner be the referee.

Metam sodium has what are probably the most complex requirements of any of the methyl bromide alternatives. There are site monitoring plans. Monitoring hourly is required when applied within 1500 feet of an occupied structure. There is also a general 500 foot buffer to "sensitive sites". The commissioner gets to make this determination but in general they will be based on the presence of people and will likely include most occupied structures. The monitoring extends for up to 12 hours after the completion of the application but is reduced to every two hours.

Another thing you get involved with is the, so called, water sealing, or soil capping. The addition of water (irrigation) seems to reduce, at least the rate, if not the overall amount, of off gassing so there are requirements for adding water when odor is detected during the monitoring.

The primary methods of application are shank injection, sprinkler, flood, and by rotary tiller. By far, the most troubling to DPR, from a regulatory standpoint, is sprinkler. Most of the incidents and complaints we received resulted from sprinkler applications. There are a number of equipment specifications for all types of applications, so, again, I would recommend that if you are looking at metam sodium as your methyl bromide alternative get a copy of ENF 2000-044 from your commissioner.

Chloropicrin has the least restrictions on it at the moment. You must, of course, follow the labeling. There are no specific regulations or DPR suggested permit conditions. Chloropicrin is currently undergoing reevaluation and development of a risk assessment. The general suspicion is that the eventual outcome will be that additional restrictions, probably similar to the other fumigants, are put in place.

Those are your current choices. My recommendation is that you mix and match, applying the most appropriate to each situation. The whole fumigant situation is in a state of flux. Nothing is assured except change.

Water Quality Control Permits for Aquatic Herbicides

California State Water Resources Control Board[1]
with minor modifications by
Rudy J. Schnagl and Emily C. Alejandrino,
Central Valley Regional Water Quality Control Board

On March 12, 2001, the Ninth Circuit Court of Appeals decided that discharges of pollutants from the use of aquatic pesticides (for example herbicides, algaecides and insecticides) to waters of the United States require coverage under an NPDES permit, (Headwaters, Inc. v. Talent Irrigation District). The Talent decision was issued just prior to the major season for applying aquatic pesticides. Because of the serious public health, safety, and economic implications of delay in such applications, the State Water Resources Control Board (SWRCB) adopted the *Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Discharges of Aquatic Pesticides to Waters of the United States* (General Permit) on an emergency basis on 19 July 2001. This Permit provides coverage for broad categories of aquatic pesticide use in California, but does not provide coverage for private operations.

Coverage under the General Permit is available to public entities for discharges of pollutants to waters of the United States ("water bodies") associated with the application of aquatic pesticides for resource or pest management. This limitation to "public entities" is based on the provisions of the SWRCB's *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* (the State Implementation Policy, or SIP) allowing categorical exceptions from meeting priority pollutant criteria/objectives for resource or pest management control measures conducted by "public entities." "Public Entity" is defined in the SIP to include "the federal government or state, county, city and county, city, district, public authority, or public agency." The categorical exception provision also gives examples of management programs that such public entities may conduct: vector or weed control, pest eradication, or fishery management. The entities that conduct such programs vary in legal structure, but all have in common a public role of protecting waterways and/or the public health from harmful organisms. The General Permit is available to all such entities regardless of legal structure, including mutual water companies, public water purveyors, investor-owned utilities, and homeowners' associations.

The SIP further provides that the categorical exception is for resource or pest management conducted by public entities "to fulfill statutory requirements, including, but not limited to, those in the California Fish and Game, Food and Agriculture, Health and Safety, and Harbors and

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[1] This paper primarily consists of the cited reference. Minor modifications have been made to reduce the length of the document and to provide information on how to obtain additional information.

Navigation codes." This General Permit **does not** cover indirect or non-point source discharges from agricultural or other applications of pesticides to land that may be conveyed in storm water or irrigation runoff.

The General Permit **does not** cover applications of pesticides that are **not registered for use on aquatic sites**. The General Permit **does** cover the uses of properly registered and applied aquatic pesticides that constitute discharges of "pollutants" to waters of the United States.

The aquatic pesticides covered by the General Permit will be applied directly into the water body, and/or directly to organisms in the water or on the water surface with the purpose and intent of killing the target aquatic organisms. The impacts of these chemicals may not be limited to the target organisms – other plants and aquatic life in the treatment area may be impacted. Due to water movement at the treatment locations, the residual pesticides can be carried to adjacent areas while concentrations in the water are still high enough to cause adverse impacts not only to aquatic organisms but also to other beneficial uses, such as irrigation, municipal water supplies and recreation (such as swimming). As part of the pesticide registration process conducted by the U.S. Environmental Protection Agency (USEPA) and Department of Pesticide Regulation (DPR), adverse impacts relevant to these beneficial uses have been evaluated and determined not to be unreasonable. A purpose of the General Permit is to minimize the areal extent and duration of adverse impacts to beneficial uses of water bodies treated with aquatic pesticides.

To qualify for coverage under this General Permit, dischargers must meet the following criteria:

1. The discharger must submit a fully completed Notice of Intent (NOI), a project map, and first annual fee.
2. The discharger must be a public entity.
3. Dischargers must be licensed by DPR or Department of Health Services (DHS) if such licensing is required for such public entities, to apply aquatic pesticides.

The basic requirements of this General Permit include:

1. The discharger must follow all pesticide label instructions and any Use Permits issued by a County Agricultural Commissioner.
2. The discharger must implement best management practices (BMPs).
3. The discharger must comply with monitoring requirements.

Waters of the United States

This General Permit regulates the addition of pollutants associated with the application of aquatic pesticides to navigable waters. "Navigable waters," means waters of the United States.

"Waters of the United States" include all waters currently used, used in the past, or susceptible to use in interstate commerce; all interstate waters; all other waters the use, degradation, or destruction of which would or could affect interstate or foreign commerce. Waters of the United States include waters used by interstate or foreign travelers for recreation, waters from which fish or shellfish are taken and sold in interstate or foreign commerce, impoundments of and tributaries to waters of the United States, and wetlands adjacent to waters of the United States. For instance, irrigation canals that exchange water with natural streams and lakes are waters of the United States.

Emergency Conditions

The General Permit was issued under emergency conditions. On March 12, 2001, the Ninth Circuit Court of Appeals in Headwaters, Inc. v. Talent Irrigation District determined that discharges of aquatic pesticides to waters of the United States require coverage under an NPDES permit. The public entities covered by the General Permit conduct resource or pest management programs in order to fulfill statutory requirements and to protect beneficial uses of water and the public health. Many of the public entities would be unwilling to perform the activities prior to issuance of an NPDES permit because of the substantial liability they could incur for discharging aquatic pesticides in violation of the Clean Water Act (CWA).

Because of the emergency nature of this General Permit, many of the actions that would normally occur prior to issuance of a permit granting a categorical exception to priority pollutant objectives/criteria have not yet occurred. The General Permit was issued as a limited term permit, and it will expire January 31, 2004. During the term of the General Permit, activities will occur that will provide the basis for a full-term permit in the future. The public entities subject to the General Permit will complete necessary California Environmental Quality Act (CEQA) documents to justify the categorical exception. The public entities will develop monitoring plans that will be the basis of monitoring requirements in the next permit. The SWRCB will consider issuing future permits that are more limited in nature as to specific pesticides, types of resource and pest management programs, or areas of the State. The future permits will be based on the submittals received during the term of the General Permit, will specify whether categorical exceptions are warranted, and will ensure that other applicable water quality standards, including the antidegradation policy, are achieved.

Related Pesticide Regulations

DPR and the County Agricultural Commissioners (CACs) regulate the sale and use of pesticides in California. Pesticide applications subject to the General Permit must be consistent with the pesticide label instructions and any Use Permits issued by the CACs.

Water Quality Standards

USEPA established water quality criteria for priority pollutants in the National Toxics Rule and the California Toxics Rule, and Regional Water Quality Control Boards (RWQCBs) establish water quality objectives for priority pollutants in basin plans. The SWRCB has adopted the SIP that contains implementation provisions for these water quality criteria and objectives. The SIP provides that categorical exceptions may be granted to allow short-term or seasonal exceptions from meeting the priority pollutant criteria/objectives if "necessary to implement control measures ... for resource or pest management conducted by public entities to fulfill statutory requirements." The SIP specifically refers to vector or weed control, pest eradication, and fishery management as bases for categorical exceptions. The General Permit grants a categorical exception from water quality criteria and objectives for priority pollutants for the application of aquatic pesticides by public entities in the exercise of resource or pest management powers authorized by State statute. The SWRCB recognizes that the discharges of pollutants may also cause or contribute to exceedance of water quality standards for parameters or constituents that are not priority pollutants. The General Permit does not require immediate compliance with such water quality standards, but requires that the dischargers implement additional BMPs to eliminate or reduce the pollutants that are causing or contributing to exceedance. As a condition to retaining the categorical exception, dischargers must comply with conditions that are included in the General Permit. Further, consistent with the SIP exception, dischargers are allocated a temporal zone of impact on beneficial uses of water within which there may be a temporary exceedance of criteria, but the resulting impact must be transient, and must allow for full restoration of water quality and protection of beneficial uses upon project completion. The SIP exception applies only to water quality criteria/objectives for priority pollutants and not to other water quality standards, such as the antidegradation policy.

For parameters or constituents that are not priority pollutants, dischargers must implement appropriate BMPs to achieve compliance with other applicable water quality standards contained in a Statewide Water Quality Control Plan or in a RWQCB Basin Plan. If the discharges of any non-priority pollutants cause or contribute to exceedance of water quality standards, the dischargers are required to develop and implement improved BMPs to prevent or reduce such pollutants.

Effluent Limitations

NPDES permits for discharges to surface waters must meet all applicable provisions of Sections 301 and 402 of the CWA. These provisions require controls of pollutant discharges that utilize best available technology economically achievable (BAT) and best conventional pollutant control technology (BCT) to reduce pollutants and any more stringent controls necessary to meet water quality standards.

The General Order does not contain numeric effluent limitations for pollutants in discharges associated with aquatic pesticide applications. Establishment of numeric effluent limitations for pollutants was not feasible because: (1) aquatic pesticide applications are made directly to the water body and/or to organisms in the water or on the water surface, (2) there may be numerous short duration intermittent pesticide releases to surface waters from many different locations, and (3) there are numerous pesticides used, including many inert ingredients, and the SWRCB does not have the ability to establish numeric effluent limitations for each of these constituents. Therefore, pursuant to Title 40, Code of Federal Regulations (CFR) Section 122.44(k), the effluent limitations contained in this General Permit are narrative and include requirements to implement appropriate BMPs, including compliance with all pesticide label instructions. The required BMPs constitute BAT and BCT, and they will be implemented to minimize the areal extent and duration of impacts caused by the discharge of pollutants and to allow for full restoration of water quality and protection of beneficial uses of the receiving waters following completion of resource or pest management projects.

Best Management Practices (BMPs)

The development of BMPs provides the flexibility necessary to establish controls to minimize the areal extent and duration of impacts caused by the discharge of pollutants and to allow for full restoration of water quality and protection of beneficial uses of the receiving waters following completion of resource or pest management projects. This flexibility allows dischargers to implement different BMPs for different types of applications and different types of waters.

Much of the BMP development has been incorporated in the pesticide regulation process by the USEPA, DPR, DHS, and CACs. As discussed above, the dischargers must be licensed by DPR or DHS if such licensing is required for the aquatic pesticide application project. The General Permit requires that the dischargers must comply with all pesticide label instructions, DPR and DHS regulations, and any Use Permits issued by the CACs. The General Permit also specifies the steps that will be followed to identify and implement appropriate BMPs that are designed to maximize efficacy of control efforts and minimize adverse impacts to the environment. These steps are:

1. *Preliminary site evaluations.* The discharger will conduct a site inspection to verify the need for treatment, options to treatment (including non-toxic and less toxic alternatives), and suitability of the site for treatment.
2. *Alternative Control Measures.* The discharger will evaluate other available BMPs and alternative control measures to determine if there are feasible alternatives to the selected aquatic pesticide application project that could reduce potential water quality impacts.
3. *Secondary site evaluations and pre-treatment monitoring.* The discharger will determine the type and intensity of treatment needed. This evaluation will include measurement and

analysis of indicators to provide information on potential efficacy and water quality impacts.

4. *Treatment.* Immediately prior to treatment, the discharger will examine a series of indicators and modify treatment plans accordingly. These indicators may include day length, precipitation, recreational activity, sunlight, tidal water exchange, water depth, water flows, water turbidity, and wind. If this examination indicates a potential for reduced control efficacy and/or heightened water quality impacts, the treatment will be rescheduled.
5. *Post-treatment.* The discharger will assess control efficacy and water quality impacts. The results of this assessment will be evaluated by the discharger to refine project operations through an adaptive management process.

The selection of control measures that use non-toxic and less toxic alternatives is an example of an effective BMP. For example, Mosquito Control Districts and other vector control agencies can select larvicides for mosquito control in some situations that have very low toxicity and pose very little or no threat to the environment. Specifically, (a) for microbial larvicides (e.g., Bacillus thuringiensis israelensis, Bacillus sphaericus), USEPA has concluded that they do not pose risks to wildlife, non-target species, or the environment; and (b) for methoprene, USEPA has concluded that, as used in mosquito control programs, it does not pose unreasonable risks to wildlife or the environment. Thin film larvicides (e.g., Agnique) also have low inherent toxicity.

The General Permit includes requirements for the dischargers to identify and implement additional BMPs and alternative control measures where such additional BMPs and measures will prevent or reduce impacts to water quality.

Monitoring Requirements

The General Permit requires that the dischargers comply with the Monitoring and Reporting Program (MRP) that is incorporated as Attachment B of the General Permit. Dischargers are also required to submit technical and monitoring reports as directed by the appropriate RWQCB's Executive Officer. The MRP requires that the dischargers develop and implement Monitoring Plan (Plans) to:

1. Document compliance with the requirements of the General Permit;
2. Support the development, implementation, and effectiveness of BMPs; and
3. Demonstrate the full restoration of water quality and protection of beneficial uses of the receiving waters following completion of resource or pest management projects.
4. Identify and characterize aquatic pesticide application projects conducted by the discharger.
5. Assure that projects are monitored that are representative of all pesticides and application methods used by the discharger.

Dischargers must comply with these requirements either individually or by joining with other dischargers to participate in one or more Regional Pesticide Monitoring Program(s) (RPMPs). The establishment of the RPMPs by groups of dischargers that use similar pesticides and application methods provides an opportunity for dischargers to cost-effectively comply with the MRP. By combining resources and selecting a limited number of representative projects, the RPMPs will be able to conduct monitoring efforts that are comprehensive and technically sound.

Each Discharger will submit a Plan to the appropriate RWQCB(s) **by March 1, 2002** for approval. Plans developed by RPMPs must be provided to both the SWRCB and each RWQCB. The Plan submitted by a discharger should describe any individual monitoring activities and incorporate by reference the RPMP Plans that have been prepared by RPMPs in which the discharger is participating. The Plan must include monitoring of a representative project for each pesticide used by the discharger. The MRP lists six monitoring elements that must be incorporated in all monitoring plans except for some plans for vector control projects. The dischargers and RPMPs shall implement the Plans **by July 1, 2002** in accordance with any modifications required by the RWQCB.

The MRP requires the dischargers to submit a monthly report to the RWQCB documenting specific information for each aquatic pesticide treatment site. The discharger is also required to submit a calendar-year annual report to the RWQCB by January 31 of the following year (beginning January 2003). The report shall include a summary for the previous year including but not limited to (1) objectives of the monitoring program(s); (2) results; and (3) interpretation of data in relation to frequency, duration, and magnitude of impacts to beneficial uses.

Notification Requirements

To obtain coverage under this General Permit, an NOI and the first annual fee ($400.00) must be submitted. A separate enrollment is required for discharges located within more than one RWQCB's boundary, as defined in Section 13200 of the California Water Code. Each enrollment will cover all discharges occurring within the boundaries of that RWQCB. Only one annual fee must be submitted to the SWRCB for all covered discharges from one entity.

Signing the certification on the NOI signifies that the discharger intends to comply with the provisions of this General Permit. Dischargers are authorized to discharge upon submission of a complete and accurate NOI application for coverage. The NOI Form A is included as Attachment A within this General Permit package. The fully completed NOI, a project map, and first annual fee constitute a complete application for coverage under the General Permit. An NOI must be signed to be valid.

The RWQCB may determine that a discharger submitting an NOI is not eligible for coverage under the General Permit and may require submittal of an application for an individual permit. Individual application forms will be provided by the appropriate RWQCB.

The General Permit will expire on January 31, 2004. Enrollees who are covered under this General Permit must obtain coverage under another general permit for aquatic pesticide applications or an individual NPDES permit.

Copies of the General Permit may be obtained by going to the Water Quality section of the SWRCB's web site (www.swrcb.ca.gov), or by contacting the Regional Board for your area.

Reference

California State Water Resources Control Board, Fact Sheet for Water Quality Order No. 2001-12-DWQ Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Discharges of Aquatic Pesticides to Waters of the United States, General Permit No. CAG990003

Travel With a Full Set of Tools

Poems by David Haskell

5UD2

Now my uncle-in-law was a generous man,
He gave us a tractor when he passed away.
A crawler they bought back in "51".
The year of my wife's first birthday.

I was excited as a boy on Christmas Day,
A real Tonka Toy I could say was mine.
A piece of equipment from the old ranch,
With only 6800 hours of working time.

I consulted with the office mechanics,
Their knowledge was questioned by few.
Retired growers and Iowa farm boys.
For free advice, it was the best I could do.

There are 24 steps for starting a D2,
One remembered from a Cal Poly exam.
But he was a Ag Business major,
And he hated getting grease on my hands.

They warned me that diesel tractor won't start,
With just the turn of an ignition key.
There was a pony motor you had to deal with.
A foreign concept for a city boy like me.

Check the electrical and fuel system first,
That's usually what goes wrong.
And don't call for a diesel mechanic,
Or else your money will soon be gone.

If the diesel smells funny, better drain the tank,
And the filter and the injectors too.
Then you have to re-prime the fuel system.
A task that is not easy to do.

They said “go easy” with the starting fluid,
Even though it could be a sure start.
The cylinders could fire too early.
And that pony could come flying apart.
So we primed the spark plugs with gasoline,
And I pulled on that flywheel rope.
To bring that tractor back to life,
on a mixture of ether and hope.

We keep feeding her shots of gasoline,
until a plug wire finally broke.
And a spark arched through that ether cloud.
I almost lost my partner in a puff of smoke.

The carburetor was impossible to adjust,
Maybe it was a sign to leave it alone.
Uncle had set it from past experience,
And I couldn’t just call him on the phone.

The throttle and choke knobs were side by side,
Entwined with a spark plug wire.
One time I shuck hands with the magneto.
And I sounded like a Hallelujah Choir.

She’s just an overgrown mower motor.
How could starting her be so hard?
I’ve seem these old tractors running.
Did they drag-start them back at the yard?

We ran crying to the local Cat. dealer,
With our tale of frustrated woe.
But a customer in line behind us,
Tipped us a secret a parts man wouldn’t know.

Give her four spark plug shots of gasoline,
In each cylinder before you give it a pull.
With a spritz of ether in the air filter,
She should start and that’s no bull.

The pony motor finally came to life,
With a sound that pounded our ears.

My God, we had finally done it.
We traded cheers and had another beer.

Well, the pony started with the choke in or out,
But what worked better I could never tell.
And it started better in the afternoon.
She was a piece of mechanical hell.

The bleeder valves for the injector pumps,
Were designed by an engineer with a grudge.
They say he caught his wife in bed with a mechanic,
And he turned meaner than a Mississippi judge.

The tractor's manual Uncle left was helpful,
The instructions were simple and clear.
Use the pony motor to prime the diesel.
It's easy and there's nothing to fear.

We bled the filter, we bled the pumps,
Until all the bubbles disappeared.
And we cranked the diesel against compression,
To generate heat, it seemed kinda weird.

But when I opened the injector pumps,
She gulped the diesel down without a burp.
Or even a reassuring puff of smoke.
More frustration, I was ready to desert.

5UD2,
I've had it with you.
I know once you were Peoria's pride.
But Uncle's last wish,
Has only brought anguish,
And it might end in a suicide.

Travel With A Full Set of Tools

My father was a backyard mechanic,
But it wasn't to make money on the side.
It was more of a financial necessity,
Mixed in with his New England pride.

I started off holding the flashlight,
When the repairs lasted into the night.
And searching for nuts in the coffee cans,
When the original had bounced out of sight.

We repaired the Volkswagens together.
I was the reluctant member of the team.
A teenager with more important things to do,
Than wash wheel bearings with gasoline.

"Pump it up three times and hold it",
"And don't relax till I tell you to".
And he bled the air from the brake lines.
Another brake job was almost through.

He showed me you can fix almost anything,
With the right tools, patience and care.
And keep your temper in the tool box,
Or you'll damage what you are trying to repair.

He said travel with a full set of tools,
And with experience you'll learn what to do.
And the key to success in your life,
Is how you use the tools that you carry with you.

The crescent wrench is strong and adjustable,
It can be your most versatile tool.
It's strength comes from your set of values,
That can be flexible when you set the rules.

The vicegrips can hold almost anything,
Sometimes, that's all you can do.
And with your tenacity alone,
Break the rust and bring the solution through.

Those box and open-end wrenches,
Are forged with American made steel.
Don't torque your values down too tightly,
Time may change the way that you feel.

He showed me the leverage in a screw driver,
Turn it with a firm and steady hand.
With discipline you can change behavior,
Or strip the head with too many demands.

Your temper can be the strongest hammer,
With enough pounding you can break hardened steel.
Or flatten the threads in a relationship,
Leaving cross threads that will never heal.

A sense of humor is the best grease,
To lubricate relationships in life.
To keep those ball-joints turning,
With your family, friends and wife.

So travel with a full set of tools,
And remember this "rule of thumb".
Its easy to take something apart.
The hard part is yet to be done.

Weed Mapping for Site Specific Herbicide Application

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Introduction

Site specific weed management deals with precise application of chemicals only to infested areas of the field and with relation to weed infestation densities. Benefits of this technology include decreased usage of herbicides, reduction in the volume of spray and the cost of herbicide, reduced soil compaction, less non-target spraying, reduction of potential environmental risks, and more flexibility in timeliness of operations (Felton, 1995). Site specific herbicide application may be a very effective tactic in dealing with herbicide resistant weeds since a whole field herbicide application is likely to encourage herbicide resistance (Maxwell, 1992). The ability to manage weed infestations in a spatially precise manner relies on efficient methods of obtaining information about weed distributions (Colliver et al. 1996). Accurately recorded weed infestation and spatial analysis of weed populations precedes the development of weed maps. Prescription of herbicide rates is based on interpolated weed map and is loaded into on-board computer of a variable rate applicator before the site specific treatment.

Materials and Methods

Weed populations were sampled in two following years, in commercial fields with processing tomatoes. Weeds were sampled at seedling stage in spring and in mature stage in the time of the crop harvest. Weed densities were recorded by field sampling using a hand held data logger with a Differential Global Positioning System. Methods of spatial statistics (geostatistics) have been developed to describe variation, create maps, and improve sampling of weed populations. Reclassified weed maps were used for developing herbicide treatment maps for the experiment to evaluate the effectiveness of the variable rate application of the preemergence herbicide. A portion of the field was selected where the greatest gradient in weed infestation was observed and a split-plot experiment was set up. The main effect was the type of the weed sampling used to create a treatment map (two levels: a map based on seedling counts and a map based on mature weeds), and the secondary effect being the herbicide rate - zero, half, and full dose of the recommended rate of ethalfluralin (Sonalan, 360 g ai/L), full dose = 1.5 lb ai/a. A prototype variable rate applicator traveled at the speed of 8 km/h. The application rate was varied by changing the duty cycle of the nozzles with the response time of about 0.1 second.
The variable rate herbicide application was evaluated by density measurements of weeds that survived the treatment. Initial measurements were made two weeks after the application, and twice more at two weeks intervals. Measurements included estimation of the total weed cover for each subplot and weed seedling counts in a 0.25 m^2 placed randomly ten times per herbicide level in each replication.

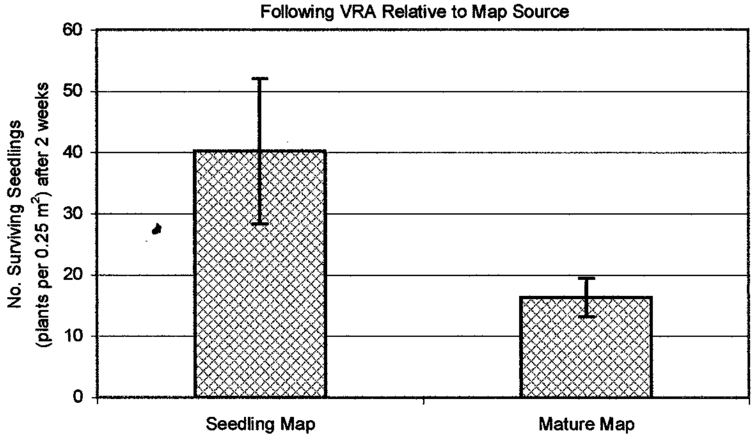
Results and Discussion

Two weed species accounted for approximately 80 % of the total weed counts in both years 1998 and 1999. More abundant species are less aggregated and their spatial pattern approaches the random distribution. Within high density areas the plants were spatially related within 60 ft. At larger scale, within the range of 650 ft, 85 % variation in weed density could be explained by the distance between points. The area of weed-free sites reached 30 % in 1998 and

40 % in 1999. About 50 % of the field had less than 10 weed plants per square meter in both years. About 17 % of the field had no weeds in both subsequent years.

Based on seedling emergence two weeks after application, overall weed control was significantly better when maps were based on mature weeds than on seedlings (Fig. 1). Weed control was significantly better when treatments were based on a mature weed map for the zero and 0.75 lb/a herbicide rate. There was no significant difference between map source for the high 1.5 lb/a herbicide rate treatment. Weed cover averaged less than 10% for both maps two weeks after the application. After four weeks, weed cover in plots where the seedling map approach was used exceeded 10 %. Six weeks after the application there was no significant difference in weed control between the map source, weed cover exceeded 10% for both sources.

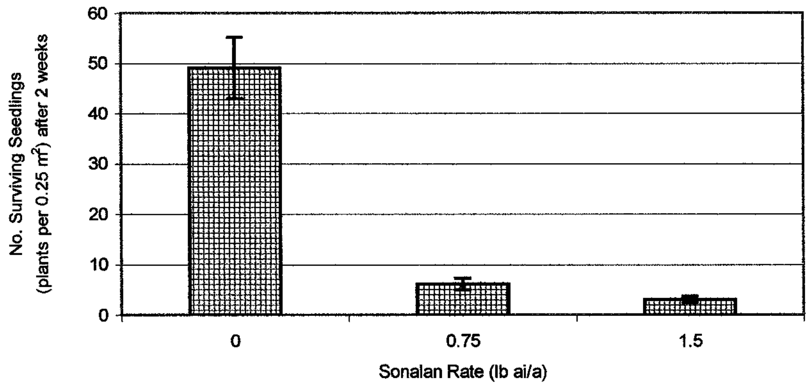
Fig. 1 Mean Number of Surviving Seedlings (plants per 0.25 m^2) Following VRA Relative to Map Source



There was a significant difference in weed control after each herbicide rate (Fig. 2). In plots receiving application of reduced rates, there was higher survival of weed seedlings compare to full rate. A significant difference in numbers of surviving seedlings after zero and medium treatment was observed. The zero herbicide plots had the highest number of seedlings, in average 49 plants per 0.25 m^2 two weeks after the treatment. The average of surviving seedlings in the medium rate plots was significantly lower, 6.2 plants per 0.25 m^2. All plots receiving medium or high herbicide rates had weed seedling weed cover below 10 % 2 to 6 weeks after application.

A 48 % reduction in herbicide use was achieved with the seedling map approach when compared to a uniform full-rate application. Reduced rates were applied to 79 % of the experimental area. A 36 % reduction in herbicide use was achieved with the variable rate application based on a mature plant weed map when compared to a uniform full-rate application and 50 % of the experimental site received a reduced herbicide treatment.

Fig. 2 Mean Number of Surviving Seedlings (plants per 0.25 m^2) Following VRA



Conclusion

Fields can be separated into site with no weed infestation and sites with related weed densities. The edges of the fields are more weedy than areas inside the field under conventional herbicide treatments. The results from this experiment documented a decrease in the total amount herbicide use. Weed control was comparable with the grower standard uniform application for the medium and high herbicide rates. Map-based site specific weed control with three rates performed better with mature weed map. Reduced herbicide rates gave the same weed control at most of the sites as the uniform one rate.

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Clopyralid Drift Following Aerial Application at Fort Hunter Liggett, Monterey County, California

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An herbicide drift study was conducted during a clopyralid application for yellow starthistle (*Centaurea solstitialis*) control at Fort Hunter Liggett, Monterey County, California. This study provided the opportunity to closely monitor an application with high potential for drift of clopyralid into adjacent vernal pool and stream sites. A 30-m buffer was established along Stony Creek and around vernal pools not supporting larval salamanders, while a 200-m buffer was established around pools supporting salamander larvae. Using ArcView® GIS software, sites were mapped into shape files for use with on-aircraft Trimble® navigational GPS to help the helicopter pilot identify buffer zones.Both land-based (inside both treatment and buffered areas) and water samples were collected for drift analysis. Clopyralid was not detectable in any of the water samples taken in Stony Creek. Within the treatment zone the average amount of clopyralid detected on a filter disk was 7.8 µg (equivalent to 172 $\mu g/m^2$). 30 m from the stream, clopyralid was found at 93% of the rate found in the treatment zone. The rate of clopyralid had dropped to 8% of the treated area 10 m away from the border. At the stream edge (30 m from the treatment zone) the rate of clopyralid was only 0.6% of that found in the treatment zone. Clopyralid was not detectable in vernal pools 1 and 4. In vernal pools 3 and 5, clopyralid was at the lowest detection limit (0.05 ppb), equivalent to 0.6% of the amount of herbicide in the adjacent treatment zone. Only vernal pool 2 had a significant amount of detectable clopyralid (3.2% of the treatment zone).Pilot error led to treatment of the downwind buffer of pool 2 and the buffer zone of pool 5, thus accounting for the detection of clopyralid. In general, drift potential for clopyralid was minimal even with aerial application and a slight breeze (<5 mph). Buffers of 30 m provided adequate drift safety. Nevertheless, it is important to minimize application error, particularly accidental encroachment into buffer zones, to ensure that movement of herbicide to water sources is minimized.

Effect of Glyphosate and Sulfosate on Weeds and Roundup Ready Cotton

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Abstract

Weeds present major problems for cotton culture. Studies were conducted in Riata cotton with glyphosate and sulfosate to evaluate control of field bindweed *(Convolvulus arvensis)*, yellow nutsedge (*Cypres exculentus*), and redroot pigweed (*Amaranthus retroflexus*). Cotton injury related to timing and type of herbicides was also evaluated. Early broadcast applications of glyphosate or sulfosate provides good to excellent control of weeds. Sulfosate can produce major injury to the cotton. Later applications of glyphosate enhances weed control but adversely affects yield.

Introduction

Weeds can present a major problem in cotton culture by competing with the crop and increasing cost to the grower. Transgenic cotton such as Riata have been developed to allow treatment over the top of cotton for control of broadleaf and other weeds. The ability to apply herbicides at an early stage can greatly enhance control of problem weeds.

Materials and Methods

Uniform fields of Acala Riata cotton planted in April, 2001 were divided into four replications of 5 to 12 treatments in a randomized complete block design (RCBD). Treatments were applied over the top of the cotton at 2, 4, 6, 8 and 12 nodes with a backpack or tractor pulled sprayer. Weed control and cotton injury were evaluated during the season. Trials were hand and machine harvested for yield.

Results

Glyphosate Timing Study

There was slight injury with the glyphosate tank mixes with either Goal (oxyfluorfen) or Staple (pyrithiobac sodium) at the directed application which was no longer evident at harvest time. All treatments provided good to excellent control of field bindweed at harvest except the 1 lb ai/A at 2 node treatment. Applications of glyphosate beyond four nodes significantly reduced yield up to 2400 lbs of seed cotton/Acre (Table 1).

Nutsedge Control Study

At 14 days after treatment (DAT), MSMA exhibited the greatest control of yellow nutsedge. At 35 DAT, sulfosate at 2 lb at 2 and 4 nodes exhibited the greatest nutsedge control. However, this sulfosate treatment also exhibited the greatest injury to the cotton and the greatest reduction in yield. Glyphosate effectively controlled nutsedge and did not cause any significant injury to the cotton at any time (Table 2).

Annual Weed Control Study

The only cotton injury at all evaluations was in the sulfosate treatments. There was no indication of injury to the cotton by any application of glyphosate. All treatments provided complete control of pigweed at 7 DAT. There were not enough weeds to evaluate later in the season (Table 3).

Conclusions

Early applications of glyphosate over the top of glyphosate tolerant cotton can provide good to excellent control of a variety of weeds. Later applications of glyphosate while enhancing weed control, also adversely affect boll retention and yield. Sulfosate can provide excellent weed control, however, it can produce major injury to the cotton even if the cotton is a glyphosate resistant variety. This will result in major reductions in crop yield.

Table 1. Glyphosate Timing Study

Treatment	Rate lb ai/A	Timing TL	Cotton Phyto		Field Bindweed Control		lb/A Seed cotton
			7 DAT	21 DAT	21DAT	147 DAT	
1. RUM	1/2	2/6	0	0 c	89 ab	100 a	5335 ab
2. RUM	1/2	2/8	0	0 c	82 bcd	100 a	4842 bc
3. RUM	1/1.5[2]	2/4/8	0	0 c	82 bcd	95 ab	4884 bc
4. RUM	1/1.5[2]	2/6/12	0	0 c	85 bcd	96 a	3265 d
5. RUM	1.5	4/8	0	0 c	80 de	95 ab	4437 c
6. RUM	2	4/8	0	0 c	82 bcd	96 a	4609 c
7. RUM	1.5	4/6/8	0	0 c	81 cd	95 ab	4862 bc
8. RUM	1.5	4/6/12	0	0 c	88 abc	98 a	3628 d
9. RUM B. RUM + Goal	1.5 1.5 + 1.5	2 Dir	0	25 a	94 a	95 ab	5719 a
10. RUM B. RUM + Staple	1.5 1.5 + 1oz	2 Dir	0	15 b	82 bcd	85 ab	5649 a
11. TD IQ	1	2	0	0 c	82 bcd	66 c	5507 ab
12. TD IQ	1	4	0	0 c	74 e	80 bc	5714 a

Table 2. Nutsedge Control Study

Treatment	Rate lb ai/A	Timing	Cotton Phyto	Nutsedge Control		lb/A Seed Cotton
			35 DAT	20 DAT	35 DAT	
1. TD5	1	2	8 d	55 de	55 cde	4645 ab
2. TD5	1	2/4	14 d	49 e	66 abcde	4203 abc
3. TD5 + AMS	1 + 10	2	11 d	52 de	54 de	4348 abc
4. TD5 + AMS	1 + 10	2/4	41 c	78 abc	75 abc	3693 bcd
5. RUM	1	2	0 d	50 e	48 e	4793 a
6. RUM	1	2/4	0 d	65 bcde	65 bcd	4048 abc
7. RUM	1	2	0 d	70 abcd	71 abcd	4145 abc
8. RUM	1	2/4	11 d	80 ab	78 ab	4103 abc
9. TD5	2	2	58 b	60 cde	50 e	4110 abc
10. TD5	2	2/4	90 a	86 a	86 a	2925 d
11. MSMA	1.5	2	11 d	62 bcd	56 cde	3848abcd
12. MSMA + RUM	1.5 + 1	2	4 d	76 abc	65 bcde	3508 cd

Table 3 Annual Weed Control Study

Treatment	Rate lb ai/A	Cotton Phyto				Pigweed	Seed Cotton lb/A
			Days After Treatment				
		SOG	8/1	12/5	21/14	8/1	
1. TD5	1	2	59 a	52 b	35 bc	100	5058 cd
2. TD5	1	2/4	51 a	81 a	59 a	100	4728d
3. TD5 + AMS	1 + 5	2	45 a	45 b	22 c	100	5405 abc
4. TD5 + AMS	1 + 5	2/4	44 a	75 a	50 ab	100	5128 bcd
5. RUM	1	2	0 b	0 c	0 d	100	5661 a
6. RUM	1	2/4	0 b	0 c	0 d	100	5670 a
7. RUM + AMS	1 + 5	2	0 b	0 c	0 d	100	5558 ab