Tangled up in the West

by

David Haskell

When grandpa cleared the sage a hundred years ago,
He said it was harder to train cows back then.
So he used 4-point wire on all the fences,
To keep the cows out and to keep'em in.

Then the winds blew and the sand moved in.
Buried the fences and almost their dreams.
Through the Depression what keep them going,
Was the grass along a perennial stream.

The deep wells were dug during the War,
When farm prices were finally good.
And when the best ground was planted to hay.
We uncovered the wire where the fences once stood.

Now I know barbed wire helped win the West.
But now days we are just trying to get untangled from the mess.

Once I took a short-cut across a back pasture.
Then I found out a little too late.
I had also taken ten feet of wire with me,
For a ride, out on the interstate.

When those 4-points finally grabbed ahold,
Chunks starting coming out of my rear tire.
With pieces flying and the tread a flappin.
"My God, I must be on fire!"

When the rear end spun around to greet me,
I thought, this might be the end?
But then the skidding stopped and the dust settled.
The sand and sagebrush had saved me again.

It's true barbed wire helped win the West.
But now days we just want to stay untangled from the mess.

Now I know my bales are usually heavier than most.
Good farmin keeps the alfalfa weed-free.
And my cows are gainin, but moving awfully slow.
I called the vet, "What could the problem be?"

He drove out to the ranch to take a look.
"This trip better be worth my gasoline!"
Then he told me, "You've got hardware disease!
Its the worse case I have ever seen!"

"These cows got anvils floating in their eyes,
And they are looking pretty obscene.
And if you sell them for slaughter now,
they'll have to cut them up with acetylene."

Yep, the "Devil's Rope" did help us tame the West.
But now days folks are wondering how to get untangled from the mess.

Now when I break open a piece of new ground,
I have nightmares the night before.
Grandpa's wire is waiting there for me.
I feel like I am marching off to war.

The disc digs it up and cuts it into pieces,
Spreading shrapnel across the new hay field.
To jam the drill and dull the swather,
I feel like I am working in a battlefield.

The shards have taken out the swather's teeth.
I'm headed back to the tractor dealer again.
"Your ranch has got the hardware disease."
The parts man says with a sarcastic grin.

I know barbed wire helped win the West.
But God help me please get untangled from this mess.

YOU CAN'T FARM WITH AN AEROSTAR

Well, I bought this piece of ground ten years ago,
To build some city boy dreams.
I cleared the sage and planted the seeds.
This farming, it can't be as hard as it seems.
And I got the name of a local farmer,
Someone I might try to befriend.
To answer all my crazy questions,
And the things I couldn't comprehend.

Now he always acts surprised,
Every time that I drive up.
Because everybody he knows,
Drives a pickup truck.
So he hides out in his shop,
Hoping I will just drive away.
Until he realizes it's me,
And not some tourist from the highway.

When he finally offered me some neighborly advice,
He didn't mean me any harm.
"David, buy the pickup first!
Then start the farm".

Well, I prayed for the snow and the spring rain.
I learned that water is precious indeed.
And I learned that a farmer has to experiment,
If he is ever going to succeed.
But after four years of worry and sweat,
I am going to have to concede.
The only crop I can seem to grow,
Is a new kind of jackrabbit feed.

So I asked him, "What am I doin wrong?
Is there something I cannot see?"
He stared at the ground, took a deep breath,
And then he told me.
"IT'S THE CAR!
YOU CAN'T FARM WITH AN AEROSTAR!"

"Now you better stay off the highways,
When those cold winds start to blow.
Because that's a California car.
It doesn't like the snow.
Or always carry your tire chains,
Flashlight and poncho.
Unless you like driving sideways,
Where ever you try to go."

"And I know that sliding door opens wide,
And those seats, they do come out.
And you can just fit a pair of calves inside,
From the tail to the snout.
But if you desecrate the family car,
Your wife is going to shout.
And you better not drive in the carpool,
Until all that poop dries out."

"And when you take those rear seats out,
There is plenty of room in back.
For your tools, pesticide cans,
And your handyman jack.
But, you better pray the Lord is with you,
If you ever get in a wreck.
Because that load you have been a carryin,
You will be wearing around your neck!"

"So you had better hire a good lawyer.
And write a brand new will.
Because if your tools don't getcha,
That 2,4-D will!"

"Ah tell ya, IT'S THE CAR!
YOU CAN'T FARM WITH AN AEROSTAR!"

Stewardship for Roundup Ready® Bentgrass

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Introduction:
The development of Roundup Ready Bentgrass for use on golf courses may lead to new opportunities and responsibilities for golf course superintendents across the United States. Upon commercialization, the opportunities would include the simplification of weed management and improved playability in golf, while the responsibility would include implementation of 'Best Management Practices' appropriate to these new Roundup Ready Bentgrass cultivars.

Background:
Scott's Co. and Monsanto Co. have joined together to address the technical issues surrounding the introduction of Roundup Ready Bentgrass. Through this effort, lab, growth chamber, and field-research studies have been completed across the United States at the companies' research facilities, selected golf courses, and at a number of land grant universities. Results of these studies have provided data and information needed to understand specific safeguards needed to ensure that this emerging technology can be safely used, and stewardship issues can be effectively managed.

Currently, APHIS is evaluating technical and environmental data submitted by Scott's Co. and Monsanto Co. Once reviews are completed, and questions have been adequately addressed, it is anticipated that Roundup Ready Bentgrass will be given '*Non-Regulated*' status, and Monsanto and Scott's plan to proceed with the commercialization of the product. ***Use Guidelines*** and ***Best Management Practices*** are being developed to insure that the technology is used properly and performs to the expectations of customers.

To provide helpful guidance to turfgrass professionals on the use of Roundup Ready Bentgrass, a number of production practices have been implemented. Numerous research studies have also been conducted to determine the impact to the environment of various maintenance activities and cultural/mechanical practices commonly found on golf courses, and to determine the potential impact of movement of plants or pollen from golf courses that could affect crops or native habitats.

Best Management Practices:

1) <u>Controlled Seed Production Area</u>

The first area of 'Best Management Practices' is centered on the location and production practices defining where and how Roundup Ready Bentgrass seed is produced and how seed are handled post-harvest. Significant research was conducted to define the parameters required to adequately safeguard the environment from the unintentional release of Roundup Ready Bentgrass. With this information and USDA/APHIS concurrence, the State of Oregon approved and issued permits for Roundup Ready Bentgrass to be grown for seed in a small area in eastern Oregon. Strict guidelines for the production of seed have been employed. Among the precautionary measures undertaken was the establishment of a Control Area Order under the laws of the State of Oregon that includes stipulations that:

1) Only varieties of bentgrass that have been developed through the techniques of modern biotechnology may be planted, grown, cleaned, conditioned or handled in the control area. Conventionally bred bentgrass varieties may not be planted, grown, cleaned, conditioned or handled within the control area.

2) Bentgrass seed produced within the control area must be processed at a seed cleaning and packaging facility located within the control area. No conventionally bred varieties of grass seed of any type shall be cleaned or packaged at this facility.

3) Bentgrass seed produced within the control area must be transported from the field to the cleaning and packaging facility in enclosed containers. Processed bentgrass seed produced in the control area may not leave the control area except in sealed commercial containers.

4) Combines used to harvest bentgrass in the control area must not be used for any other crop. Dedicated combines no longer being used to harvest bentgrass in the control area must be fumigated to devitalize all bentgrass seed and thoroughly cleaned before leaving the control area. Containers such as poly bags used to transport unprocessed bentgrass seed and straw must not be used for other agricultural commodities or must be thoroughly cleaned before being used for other agricultural commodities to avoid contamination of other seed sources.

2) Control Alternatives

Roundup® agricultural herbicides have often been the preferred tool for the control, removal, and conversion of bentgrass production fields, and in areas where bentgrass turf control/conversion was desired. With the development of Roundup Ready Bentgrass, alternate control methods needed to be identified. A series of studies designed to screen potential herbicides that could be used to kill Roundup Ready Bentgrass identified several effective commercial products. (Table I.)

Table I. Herbicides that have activity on Agrostis spp. based upon herbicide sensitivity studies.

Herbicide	Active Ingredient	Use Pattern
Roundup Pro	Glyphosate	POST
Fusilade II or DX	Fluazifop	POST
Outrider	Sulfosulfuron	PRE/POST
Arsenal	Imazapyr	PRE/POST
Eptam 7-E	*S*-ethyl dipropylthiocarbamate	PPI
Direx	Diuron	PRE/POST
Sinbar	Terbacil	PRE/POST
Casoron	Dichlobenil	PRE
Envoy	Clethodim	POST
Finale, Rely	Glufosinate	POST
Goal 2XL	Oxyfluorfen	PRE/POST
Select	Clethodim	POST
Basamid	Thiadiazine	FUMIGANT
Poast	Sethoxydim	POST
Vapam HL	Methyldithiocarbamate	FUMIGANT
Assure II	Quizalofop	POST
GramoxoneMax	Paraquat	POST

Tillage practices and hand roguing or mechanical removal used alone, or in combination with effective herbicides have confirmed that alternate control recommendations are available. (Not all of the active herbicides listed in the table above are currently registered for this use. It is a violation of federal law to promote an unregistered herbicide use.)

3) Use Practices

A. Weed control

The use of Roundup PRO® herbicide simplifies common agronomic and cultural issues regarding maintenance and quality of bentgrass varieties used on golf courses. Roundup Ready Bentgrass has shown outstanding tolerance to Roundup PRO applications and offers significant value compared to current practices in non-Roundup Ready Bentgrass situations. The need for complicated approaches using fumigants, herbicides and plant growth regulators for weed management may be eliminated or significantly reduced. Control of annual bluegrass (*Poa annua*) and roughstalk bluegrass (*Poa trivialis*) has been demonstrated through timely in-season applications. Applications can occur throughout the growing season.

B. Tracking

A series of tracking studies have been conducted over the past two years to determine the impacts of mechanical tracking across Roundup PRO treated areas onto untreated, conventional turfgrass. Studies were conducted on a broad range of turfgrass species and at various cutting heights ranging from green-cuts to un-mowed roughs. Tracking methods of: 1) walking (measuring footprint impressions), 2) motorized, and 3) pull-cart traffic (measuring wheel-track markings) were imposed in various timed events of 2-5 minutes, 20 minutes, 60 minutes, and 24 hours following Roundup PRO applications to adjacent 10 foot strips of conventional turf. Applications were made in the presence and absence of dew. Impacts of relative humidity and temperature were also measured as variables.

Results from these studies have shown limited evidence of tracking even under conditions that would favor tracking. Even when tracking injury occurred within 5 minutes of the Roundup PRO application, no long-term turf injury occurred. Tracking damage consistently became less evident with time and the turf recovered fully. Injury was not observed at any location beyond 21 days of the tracking event. Under practical conditions, tracking should not be a commercial concern beyond 5 minutes after application.

C. Use and disposition of plugs arising from core aeration

The practice of core aeration on greens and fairways offers the potential for Roundup Ready Bentgrass to move from the golf course to areas outside the intended use area. Burial, composting, and burning, where allowed after drying, represent viable options for effectively devitalizing these propagules. Golf courses that adopt Roundup Ready Bentgrass will follow a set of 'Best Management Practices' that will not allow plugs and viable plant parts to be removed from the golf course property.

D. Clipping management

The handling of clippings of Roundup Ready Bentgrass has been evaluated. Preliminary greenhouse data from University of Nebraska showed that clippings taken from Roundup PRO treated bentgrass then spread over Kentucky bluegrass and perennial ryegrass resulted in injury symptoms when applied within 3 days of spraying. Herbicide symptoms were not seen after mowing was delayed for more than three days after application. Since plants grown under greenhouse conditions are often more susceptible than those grown under field conditions, evaluation of this effect is needed under practical conditions in the field. Complete composting and/or returning clippings onto Roundup Ready Bentgrass would seem reasonable alternatives until more defined research can be completed.

4) Escapes

Agrostis species are generally not considered invasive weeds. Invasive weeds are characterized by both their ability to aggressively spread and their ability to occupy a biome to the exclusion of many other native species. Movement of bentgrasses into natural areas is a rare event. Bentgrasses tend to develop or establish themselves more readily in disturbed soils rather than expanding into undisturbed sites. Should Roundup Ready Bentgrass escape from golf courses, a number of grass herbicides, as well as mechanical removal and other cultural practices, are very effective in controlling bentgrasses. In established stands and under golf course management practices, seedhead development is not expected to occur.

5) Weed Management Issues

The development of weed resistance to glyphosate is much less common than most herbicides. Glyphosate resistance has been confirmed by Monsanto in only two weed species in the U.S. (and four globally) after almost three decades of use. Neither U.S. species is common in golf course turf. The primary weed of interest to golf course superintendents in bentgrass turf is *Poa annua*. Glyphosate has been used to control *Poa annua* in dormant bermudagrass turf in the southeastern U.S. for more than 20 years without resistance development. Weed management programs should be developed on a case-by-case basis considering the nature of the active ingredient, the agronomics of the crop, the biology of the target weed species and the available tools for control. Sponsored research is underway that will refine appropriate weed management programs for reducing the potential for weed resistance in herbicide tolerant turf.

Based on current knowledge, the following is a typical weed management plan for Roundup Ready Bentgrass in golf course turf:

- Renovation practices for fairways and greens will be employed to eliminate all existing *Poa annua* plants, including perennial biotypes, that may be present in the target site.

- The maximum labeled Roundup PRO rate of 3 qts/A will be required one time per year to avoid any lower rate selection of tolerant biotypes.

- Fall applications of Roundup PRO will be made as mixtures with a preemergence herbicide. (eg. Dimension, Barricade or equivalent)

- Aggressive monitoring and follow-up will occur (as is practiced in other Roundup Ready crops) with any performance problems.

- Continued investigation of new postemergence herbicide candidates such as Velocity for fit in *Poa annua* management in Roundup Ready Bentgrass.

Detecting Herbicide Injury on Turfgrasses

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Turfgrass managers use various pre-emergence and post-emergence herbicides to control weeds on their courses. Herbicides applied according to instructions specified by the manufacturer are intended to kill undesirable weeds, however misapplication of herbicides can cause injury to desirable plant species. Herbicide injury can happen due to a single factor or a combination of various factors like herbicide residues in soil, carry over from a previous application, spray drift during an application, tank-mix compatibility problems. The general symptoms of herbicide injury are yellowing, curling of leaves, bronzing, stunting of growth of plants etc. These symptoms vary with the different types of herbicides used, application rate, carrier volume, or adjuvants used along with the herbicide.

Biochemical diagnostic tools are being made available to superintendents and custom applicators to identify the herbicide, which caused the injury. Knowledge about the herbicide's mode of action and mechanism of action are very helpful in identifying the injury. Herbicides use different biochemical pathways to act on plants. The mode-of-action refers to the overall manner in which an herbicide affects the plant at the tissue or cellular level. Herbicides with the same mode-of- action will have the same translocation (movement) pattern and produce similar injury symptoms. Selectivity on crops and weeds, behavior in the soil and use patterns are less predictable, but are often similar for herbicides with the same mode-of-action (Ross and Childs 1996).

Plants are complex organisms with well-defined structures in which multitudes of vital (living) processes take place in well-ordered and integrated sequences. Plants are made up of organs (root, stem, leaf, and flower); organs consist of tissues (meristems) and tissues are made up of cells. Plant cells contain subunits including walls, membrane systems (golgi, plasma membrane, nuclear membrane, endoplasmic reticulum) and organelles (mitochondria, nucleus, chloroplasts), and undifferentiated cytoplasm. Some vital metabolic plant processes include photosynthesis (capture of light energy and carbohydrate synthesis), amino acid and protein synthesis, fat (lipid) synthesis, pigment synthesis, nucleic acid synthesis (RNA - DNA essential to information storage and transfer), respiration (oxidation of carbohydrate to provide CO_2 and usable energy), energy transfer (nucleic acids) and maintenance of membrane integrity. Other vital processes include growth and differentiation, mitosis (cell division) in plant meristems, meiosis (division resulting in gamete and seed formation), uptake of ions and molecules, translocation of ions and molecules, and transpiration. One or more of the vital processes must be disrupted in order for an herbicide to kill a weed (Ross and Childs 1996).

Factors Contributing to Herbicide Injury

There are various factors, which can contribute to herbicide injury.

1. **Soil Residues.** Some pre-emergence soil applied herbicides may persist in the soil for months after application. The amount of herbicide sorbed on the soil particles in governed by soil texture and organic matter content. In sandy soils the rate of application should be lower than the rates in finer texture soils (more clay content). In sandy soils the majority of the herbicide is present in the soil solution since sand is an inert material and does not adsorb any herbicide molecule. Clay and organic matter bind the herbicide molecules on their surface. Most herbicides are organic molecules and are attracted to negative sites on clay or organic matter. Strongly bound herbicides do not pose a potential threat to sensitive plants, but herbicides, which are not strongly bound may desorb into the soil solution. The amount of herbicides that are actually present in the soil solution are responsible for herbicide injury. Roots of sensitive plants when exposed to the herbicide molecule will affect them physiologically resulting in herbicide injury. The roots of younger plants are more prone to damage. Hence, often it is recommended to wait a minimum time period before planting or sodding after an herbicide application. Superintendents should be careful when they are doing a renovation job since they often use a post-emergence non-selective herbicide to kill the turf and weeds.

2. **Soil pH.** Soil pH is a very important factor influencing herbicide persistence. Herbicides often breakdown to different chemical compounds in the soil. The chemical breakdown or metabolization of a herbicide is governed by soil pH. Some actual herbicide molecules are not toxic to plants, but their metabolites are. Hence the breakdown of a particular herbicide plays a very important role. Certain herbicides are adsorbed more at lower pH, which makes them unsafe to use in soils with high pH. For eg. the herbicide Balance® (isoxafultole) is adsorbed more at lower soil pH (Mitra et al. 2000). An applicator has to be careful when they are applying Balance® in a sandy soil with low organic matter and high soil pH.

3. **Weather.** The weather conditions play an important role in herbicide injury to plants. Herbicides applied on a very warm day can injury the turf, since the turf will be growing rapidly and might take up larger amounts of herbicide. Certain plants do have the capability to detoxify herbicides by forming conjugates with other molecules in the plant (eg. Atrazine®) or they metabolize the herbicide molecule into non-phytotoxic substances. If the plants absorb a larger amount than they can handle physiologically it will lead to an injury. Cool-season turf is prone to herbicide injury on a warm day due to the heat and drought stress. Stressed plants are more susceptible to herbicide injury than non-stressed plants.

4. **Spary drift.** Spray drift is the major contributing factor to off-target injury. Herbicides applied under windy conditions may be carried over to adjoining areas and might cause damage to sensitive plants. Herbicides applied at high pressure tend to produce finer droplet size and are

more prone to spray drift. Superintendents can use drift retardants to reduce spray drift and should apply herbicides either early in the morning or in the late afternoon.

5. Rate of application. Selective herbicides are formulated by manufacturers to be safe to non-target plants only at specified rates. Hence, herbicides applied at higher than recommended rates result in injury. Over application can result due to faulty spray equipment, wrong calibration, uneven pressure along the boom, excess overlap or faulty nozzles.

6. Contamination. Spray tanks should be triple rinsed every time after applying any pesticide. Herbicide injury caused due to contamination is evident when symptoms are observed where the spraying starts and then slowly the symptoms become less noticeable. The water source is also a source of contamination. Water sources containing excess bicarbonates and other cations might react with the herbicide. Superintendents should be careful when they use Roundup® (glyphosate) with a contaminated water source.

7. Tank-mix compatibility. Turf Managers should be careful and follow label directions while mixing different pesticides. Some herbicides cannot be tank mixed with other herbicides or other pesticides. It is always advisable to do a jar shaker test before actually mixing any chemicals. The jar shaker test is a quick and easy test in which a solution is made with the chemicals in question and the water to be used. The jar should be shaken and observed for any precipitates. If any precipitate is observed then the chemicals should not be mixed.

MATERIAL AND METHODS

Experiments were conducted at the Center for Turf Irrigation and Landscape Technology (C-TILT) at California State University, Pomona.

Treatments

Different glyphosate based herbicide formulations were applied on a creeping bentgrass putting green. QuikPro® powered by Roundup®, and Roundup ProDry® were applied at three rates (5, 5.88, and 6.8 kg ae/ha). All the treatments were compared to an untreated check and a Finale® 2SC (glufosinate) treatment applied at 1.7 kg ae/ha.

Extraction of Shikimate

Shikimate was extracted using following Singh and Shaner's (1998) method. Plant material was ground in liquid nitrogen in a mortar pestle and then further ground in 0.25 N HCl in the same mortar. Leaves were ground in a 1:3 ratio of tissue weight in g/volume of 0.25 N HCl in ml. The extract was centrifuged at 15,000 *g* for 15 min. The supernatant was collected and used directly for the shikimate assay.

Determination of Shikimate

Shikimate was determined according to a modification of the method of Gaitonde and Gordon (1958). An aliquot of the test sample (50 µl) was mixed with 0.5 ml of a 1% solution of periodic acid to oxidize shikimic acid. After 3 h, the sample was mixed with 0.5 ml of 1 N NaOH, and 0.3 ml of 0.1 M glycine was added. The solution was then thoroughly mixed and the optical density at 380 nm was measured immediately. The concentration of shikimate was presented on a fresh weight basis.

RESULTS AND DISCUSSION

The mode-of-action of an herbicide offers a clue in identifying herbicide damage. Various biochemical pathways are used by herbicides to act on plants. The herbicides produce different metabolites or derivatives, which can be used to positively identify the herbicide. For eg. Roundup® (glyphosate) acts on the shikimic acid pathway in plants. Glyphosate inhibits the 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase, which produces EPSP from shikimate-3-phosphate and phosphoenolpyruvate in the shikimic acid biosynthetic pathway (Amrhein et al. 1980). EPSP inihibition leads to the depletion of the aromatic amino acids phenylalanine, tyrosine and tryptophan, all needed for protein synthesis in plants (Ahrens 1994). As a result of the herbicide application there is an accumulation of a particular chemical in plants called, shikimate. Scientists have used chemical methods to identify and quantify the amount of shikimate from Roundup® treated plants.

Problems Associated with using Biochemical Methods

Generally plant samples are collected after a long time has lapsed since the injury was first observed. Since the biochemical tests have to be conducted when the plant tissue is still alive sometimes it is too late to conduct a test. Turf managers should send samples out for biochemical analysis as soon as they observe any visual signs of herbicide damage. The symptoms of herbicide injury resemble other kinds of damage or injury. Stunting, twisted leaves or death of growing points are some of the general symptoms of herbicide damage. Herbicide residue in affected plant tissues is often quite difficult to detect and the presence of certain metabolites is not always definitive.

Shikimate Content

Within 48 hrs after treatment Roundup ProDry resulted in significantly higher amount of shikimate in the plant tissues compared to the untreated check and the QuikPro powered by Roundup treatments. After 72 hrs there was no difference in the amount of shikimate in the plant tissues between the different glyphosate formulations (Fig. 1). A spike in the amount of shikimate content in the herbicide treated plant tissues confirms that the plant was affected by a glyphosate based herbicide. There are also some differences between the different glyphosate based herbicide formulations in the amount of shikimate present in plant tissues, but the differences are observed very early (within 48 hrs after application). As the plant starts to die the tissues start to accumulate high levels of shikimate irrespective of the herbicide formulation and once the tissues die it is very difficult to extract shikimate from the plant tissues. Hence using these biochemical methods we can detect the amount of shikimate present in plant tissues and can positively identify glyphosate injury to plants.

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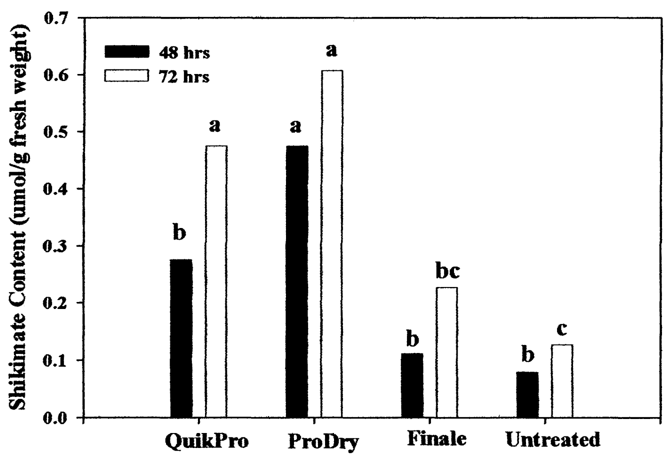

Fig. 1. Amount of shikimate in plant tissues as observed at 48 hrs and 72 hrs after treatment. Each column with a letter in common are not significantly different at p = 0.05 level. Means were separated by Duncan's New Multiple Range Test.

Breeding Turf Varieties To Resist Weeds

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Breeding turfgrasses for weed resistance has traditionally taken a backseat to breeding for other pests. Great strides have been made over the past 50 years in developing cultivars with resistance to diseases and insects. Nonetheless, research suggests a potential for developing turfgrasses with improved resistance to weeds as well.

The National Turfgrass Evaluation Program (www.ntep.org) regularly evaluates cool- and warm-season cultivars for a number of indigenous pests, at 20+ test locations across North America. On occasion, evaluators have uncovered differences among cultivars in resistance to annual bluegrass (*Poa annua* L.), crabgrass (*Digitaria* spp.), and other weeds in Kentucky bluegrass (*P. pratensis* L.), perennial ryegrass (*Lolium perenne* L.), and bermudagrass (*Cynodon* spp.). Weed reductions as great as 80% have been found in some resistant cultivars.

How do certain cultivars resist weeds? The underlying mechanism is still a matter of speculation and debate. Several explanations are tenable:

- The leading hypothesis is that vigorous cultivars are able to reproduce vegetative tissue more rapidly than can weeds. As a result, after a given time interval, the stand of a resistant cultivar is composed more of turf than of weed. Added vigor may be the result of better genetics, superior physiology, or possibly an offshoot of a plant's resistance to diseases or insects.
- Another hypothesis is that certain cultivars are able to "crowd out" weeds by physical competition for space. But as Brede and Duich (A.D. Brede and J.M. Duich. 1982. Cultivar and seeding rate effects on several physical characteristics of Kentucky bluegrass turf. Agron. J. 74:865-870) explain, physical crowding in a lawn is unlikely: "Considering the mean sheath width [of a turf shoot is] 1.1 mm, the sheath of an average bluegrass tiller would occupy less than 0.9 mm^2 of ground space. At a [typical] density of 300 tillers dm^{-2}, less than 3% of the total ground surface would be occupied by tiller bases."
- Surface shading and rapid germination are prime factors in weed competition. Weed seeds are light induced. A cultivar that effectively shades the ground will reduce weed seed germination. Likewise, a fast germinating cultivar will minimize proliferation of weed seedlings in a new stand.
- Allelopathy is defined as the effect of plant A on plant B as the result of a chemical produced by plant A. Although sporadic examples can be found in the literature of allelopathy in grasses, it is unlikely allelopathy plays a major role in lawns.

Modern breeding programs, such as the one at Jacklin Seed, are discovering genetic resistance to annual bluegrass in perennial ryegrass and other turfgrasses. This is important because chemical control of annual bluegrass is ineffective or prohibitively expensive for most lawn and sports turf. In the trial results below, perennial ryegrass cultivars were screened for resistance to annual bluegrass. Results show that breeding for annual bluegrass resistance is practical. Reductions in annual bluegrass populations of 40 to 50% can be seen over common-type cultivars such as Linn.

Cultivars with high turf quality tend to have the least *P. annua* encroachment. This phenomenon can be seen in a 1999 Kentucky bluegrass turf trial in Idaho. A significant inverse correlation was found between turf quality and annual bluegrass population: correlation *r*-values were -0.21, -0.23, -0.48, and -0.63 in yearly 2000, 2001, 2002, and 2003 means, respectively, indicating an accelerating trend for cultivars with higher turf quality to have the lowest percent annual bluegrass.

Annual bluegrass encroachment into two perennial ryegrass turf trials in Post Falls, ID. The first trial (left columns) was planted in 2002 and the second (right columns) in 2001. Trials were mowed at 1¼ inch, watered to minimize stress, and evaluated monthly. Experimental breeding populations are designated with a number.

Cultivar	% *Poa annua*
02-8011	5
Gator 3	5
Kokomo	7
Prelude III	7
Amazing	8
Caddieshack	8
Palmer III	8
Pizzazz	8
Admire	10
All*Star 2	10
Brightstar II	10
Goalkeeper	10
Monterey II	10
Radiant	10
Top Gun	10
Accent	12
Calypso II	12
Excel	12
Extreme	12
Paragon	12
Repel III	12
ASAP	13

Cultivar	% *Poa annua*
01-8014	0
01-8004	5
Laredo	5
Secretariat	5
Admire	7
ASAP	7
Caliente II	7
Goalkeeper	7
Caddieshack	8
Paragon	8
SR 4200	8
Accent	10
Pizzazz	10
Wizard	10
Cathedral II	12
Extreme	12
Monterey	12
Monterey II	12
Omega III	12
Pennant II	12
Top Gun	12
Brightstar II	13
JR-147	13
Prelude III	13

Manhattan 3	13
MardiGras	13
Prowler	13
Secretariat	13
Seville II	13
Phantom	17
Premier II	17
SR4420	17
Imagine	18
Pennant II	18
Linn	50
$LSD_{0.05}$	12

Radiant	13
Repel III	15
Saturn II	15
Line Drive	17
Phantom	18
Advent	20
Prowler	20
APM	30
Palmer III	30
B7E	40
Linn	40
$LSD_{0.05}$	27

Weed Management Strategies for Maintaining Good Quality Turfgrasses: Economic Impact

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Turfgrass offers Californians a number of benefits. For one, it is aesthetically pleasing and adds value to the home or office. Turfgrasses help cool the surrounding environments, dampen noise, provide oxygen, and act as a great filtration system as materials pass through its fibrous root zone.

The lawn is an investment both at the onset and ongoing as it is maintained. Initially, there is the cost of site preparation and installation. When done wisely, a solid foundation is set to maintain the site over the years. Economically, it is less expensive to maintain the investment with good cultural practices including proper watering, mowing height and frequency, and good nutrition. Cultural practices plus good scouting for potentially damaging weed, insect, or disease pest can extend the lifetime of your lawn.

Knowledge is valuable. Knowing the turfgrass type, its strengths and weaknesses, and potential damaging pest problems will help one plan better. Some grasses thrive in the summer heat, while others barely hang on. Knowing the historical pest problems for the area will also be key in planning and prevention. When turf density diminishes following a given stress event (disease, insect, under-watering, scalping, etc.) an opportunity arises for weed invasion. As time passes, the surrounding environment will change overtime as the landscape plantings mature and produce more shade over the lawn.

Initially, site selection and planting materials will determine what potentially difficult weeds are present in the landscape. Nutsedge is notorious for sneaking into sites that had no prior history of the noxious weed. Bermudagrass can also spring up in a tall fescue or bluegrass lawn because the old plant material was not killed out first or the incoming soil and plant materiel was contaminated.

A healthy, dense lawn will have fewer weed problems. Weeds are often present because the density decreased following a cultural or pest related damaging event. In the case of crabgrass, good turf density helps, but is not sufficient in keeping out unwanted tufts of crabgrass. Economically it is much better to place a pre-emergent down in February to prevent successful establishment of the weed than to go out with multiple applications of MSMA in the summer to selectively remove it out of the grass. Keep in mind that the turf may also become discolored temporarily with the post crabgrass treatments. When the turf does become thin, aeration followed by reseeding or resodding can help shore up the turf quality and density.

A turfgrass manager can save time and money by knowing his/her site, plant materials, environmental conditions, local pest history, and cultural activities that favor the establishment and continued vigor of the turfgrass over the competing elements. Planning and proper execution will determine the success and longevity of the turfgrass stand.

Implementation of Air Quality Laws and the Effects On Cultivation and Weed Management in Agronomic Crops

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The San Joaquin Valley has become one of the poorest air quality regions in the nation. The valley becomes a collecting basin for poor air because of its natural mountain barriers, inflow of air from cities further up the valley and San Francisco Bay area, and from its own local sources. With our rapidly expanding population and ever increasing numbers of cars and trucks on valley roads, the valley is not meeting air quality standards. Because of this poor air quality, health experts relate air pollution to increasing respiratory problems. Automobiles are the cause for the bulk of the valleys pollution but the district has little power over regulation which comes under Federal authority. Air officials suggest the farming plays a significant role in contributing to air pollution. Agriculture is not given proper credit for what it contributes such as the effect that crop production plays on filtering dust and carbon dioxide. Nevertheless the agriculture industry has worked with local air officials in compiling a list of cleanup ideas that farmers can use soon.

Senator Dean Flores from Shafter introduced the SB700 bill that will cause hardships and some changes in production agriculture. The perceived benefits from SB700 include some of the following:

- Less tillage, compaction, P.M. emissions
- Reductions in Nox, VOCs, CO2, erosion, and fuel usage
- Maintains residue
- Increases organic matter and fuel efficiency
- Improves soil and water conservation
- Enhances nutrient management
- Improves vegetation for wildlife and creates beneficial insect habitat
- Public benefit of electricity and soil structure
- Power efficient water delivery

A "Conservation Management Plan" will be required by the Air Pollution Control District for farms greater than 100 acres As part an effort to reduce PM10 emissions, California Cotton Growers and Ginners Association Roger Isom said "new air quality district rules will go into effect July 1 which requires that farmers adopt at least <u>5 conservation mgt. practices</u> to reduce emissions and file these plans with the local Air Quality Control office". "Two of these practices must involve field operations and harvesting; two involving unpaved and equipment yards and one to reduce burning of agricultural residue".

The following is a list of many practices that will qualify under this bill.

I. Land Prep/Cultivation

Category	Examples
1. Equipment changes	Increased size, modified equipment including combines, cotton pickers, tilling and harvesting equipment, landplaning/land leveling
2. Combined operations	Multiple cultivation, operations/pass
3. Conservation tillage/non-till	Reduced/eliminate soil disturbance/passes
4. Precision farming	Fertilizer management, selective area treatment, using satellite navigation to calculate position in the field
5. Land set aside	Temporary/permanent removal of land from cultivation
6. Row spacing	Used in combination with other practices
7. Night farming	Where practical, utilize increased humidity/ decreased wind velocity through night operations
8. Shuttle system	Multiple bin/trailer transportation, e.g. Cotton Module Builder

II. Cultural Activities

1. Technological Improvements	Innovative farming practices
2. Integrated Pest Management	Utilizing all available resources including organic, conventional, biological farming practices
3. Irrigation conservation Drip/sprinkler/flood Buried line/lateral move system	Using appropriate techniques for water management

4. Row spacing and overhead system	Increasing plant density/canopy through row width reduction, overhead vineyard production systems
5. Compact, low volume, Concentrate spray equipment	Micro-heads, infrared spot-sprayer (image recognition) Aerial applications
6. Field crop rotation	When possible, rotating to low till crop
III. Agriculture Burning	
1. Biomass	Utilize grindings, chips and crop residue for generating electricity
2. Grain/Corn/Safflower Non-burning	Incorporation of stubble residue
IV. Road Maintenance	
1. Approved practices for unpaved roads, staging areas, equipment yards	Water, oil, other approved control methods, limit access, speed reduction, commuting program
V. Organic Farming Practices	Biological control methods
VII. Irrigation Power Units	Cleaner burning engines, new electric motors, pumping efficiency

Agricultural producers have implemented many of these practices in an effort to control high labor costs and to reduce energy costs. A few examples include using larger plantings, tillage, and harvesting equipment which uses less passes across the field. Several growers already are using one pass tillage systems that contain several tillage operations in one pass.

No-till systems have been used for several years in California dryland grain. Several thousand acres are planted in no-till corn in the San Joaquin Valley. Results of this system is mixed. Results vary from grower to grower, with some negative and many positive. One study conducted by Carol Frate in Tulare County compared no-till with strip till, and conventional tillage. Strip tillage worked better than no-till. It reduced the amount of variability, resulted in a more uniform seed bed, allowed for manure applications, and solved the compaction problem. Stand counts were less in no-till, no-till used more water and required more labor for irrigation during a time of when there is less water available, as pumps are running continuously in the middle of summer when growers are trying to move water from crop to crop. This no-till system required borders which took out an additional 6 acres out of an 80 acre field. Even though there may have been a cost saving due to less tillage with no-till, the grower lost $50-$100/A in total crop yields.

Reduced tillage study in silage corn. Carol Frate, Tulare County.

Treatments	Sandy Loam Soil		Clay Loam Soil	
	Tons/A @70% H20	Tons per field acre	Tons/A @ 70% H20	Tons per field acre
Conventional	35.9	35.9	34.6	34.6
Strip-till	36.7	33.0	33.2	29.9
Light disk	35.9	31.8	33.5	30.2
No-till	33.8	30.4	33.0	29.7

Many growers are using Global Position Satellite systems with different equipment. With this system you make less passes and eliminate overlaps. There is an opportunity to reduce chemicals and fertilizer in some cases. Since these GPS systems also work at night and in the fog this provides an opportunity to keep tractors and tillage running during periods of higher humidity creating less dust.

Some growers have evaluated narrow row systems. Results are quite variable from farm to farm. Generally about 1/3 of the studies have show a slight loss of yield compared to conventional 30 or 38 inch row systems, 1/3 with the same yield results, and 1/3 with a yield increase from 1 to 10 percent.

One of the reasons that so much tillage is done in cotton is because of "plow down" regulations which destroy over wintering sites for Pink Bollworm. An exemption in the San Joaquin Valley has been made in reduced tillage operations. Permits for reduced tillage system are required in districts 2, 3, and 4 to use this. Native pink bollworm (PBW) cannot have been detected within the described boundary of a government section (township-range) and immediate adjoining sections (a total nine square miles) the current crop year. Cotton stalks and debris shall be shredded by a power driven shredding device. The county Agricultural Commissioner must be notified a minimum of ten (10) days prior. Following shredding as required, cotton plant roots must be dislodged from the soil which ensures that cotton plant regrowth will not occur in the reduced tillage system. Roots, plant stubs, shredding debris, and trash remaining from harvesting or clean-up operations are not required to be mixed with surface soil in this reduced tillage system.

Cost-share assistance is available when applying dust control to unpaved roads, or implementing conservation tillage, which reduces the number of trips a tractor makes across a field. The funds are being offered by U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) through its Environment Quality Incentives Program (EQIP). EQIP is voluntary conservation program that assists agriculture producers install conservation practices that minimize air quality emissions. The deadline to sign up for 2004 EQIP funds in most counties was January 30th. Agricultural producers interested in participating in the EQIP air quality program should contact their local NRCS office. In Fresno County the deadline was January 15, 2004.

In summary this was a poorly written bill. It is obvious from reviewing some of the management options for growers that most of the practices that make both economic and agronomic sense are already being practiced by growers but confusion remains since it appears that this bill does not want to give them credit for it. Eliminating all agricultural burning puts an extreme financial burden on the agricultural community and will dramatically raise costs of farming particularly with the permanent crops.

Implementing this Air Quality Law will have to be done through several changes in production practices. These changes can and must maintain weed control by incorporating resistance management strategies that include all of our weed management approaches that utilize crop rotation, herbicide rotation, and control of weed escapes by tillage or hand. This presentation highlighted the key components of this new law for San Joaquin Valley growers and interested people should look at the website: www.valleyair.org for more complete information.

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Air quality Control District information. Website: www.valleyair.org.

EFFECTS OF TILLAGE PRACTICES ON WEED SPECIES IN ROTATIONAL CROPS

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Tillage has been an essential component of traditional agricultural systems. Broadly defined, tillage is the mechanical manipulation of the soil and residue to prepare a seedbed for crop planting. The benefits of tillage are multifaceted; it loosens soil, enhances the release of nutrients from the soil for crop growth, kills weeds and regulates the circulation of water and air within the soil (Reicosky and Allmaras, 2003). However, intensive tillage has been found to adversely affect soil structure and cause excessive breakdown of aggregates leading to soil erosion. Further, intensive tillage can negatively impact environmental quality by accelerating soil carbon loss and greenhouse gas emissions (Reicosky and Allmaras, 2003). Such concerns have led to the search for tillage systems that minimize negative impacts to the environment while maintaining sustained, economic crop productivity. The tillage systems being developed and studied to address these concerns can be broadly termed 'conservation tillage'.

Conservation tillage (CT) is an 'umbrella term' that encompasses many types of tillage and residue management systems (Reicosky and Allmaras, 2003). There are several definitions for 'CT'. For example, Allmaras and Dowdy (1985) define it as a combination of cultural practices that result in the protection of soil resources while crops are grown. The Conservation Technology Information Center (CTIC) defines CT as any tillage and planting system that leaves at least 30 percent of the soil surface covered by residue after planting. Several states in the US have been exploring for innovative tillage systems that conserve soil and residue. In California, CT is still in a stage of infancy compared to other states because of climatic and soil factors. CTIC (2002) estimates show that only 16% (964, 064 acres) of the cultivated crop land is under some form of CT in California. This includes 12692 acres under no-till, 43 acres under ridge-till and 951,329 acres under mulch-till.

The development of CT systems has far reaching implications to weed management because tillage has been a major tool for weed management. Tillage affects weeds by: uprooting, dismembering, and burying them to depths too deep for emergence; changing the soil environment and promoting or inhibiting their germination and establishment; and moving their seeds vertically and horizontally. CT is considered as an important change that has taken place in the development of sustainable agricultural systems. However, concerns about weed species shifts and associated crop yield losses have restricted its widespread adoption (Buhler et al., 1994; Derksen et al., 1993).

Some common concerns about weed management under CT include emergence from recently produced seeds that are not being buried deep, prevalence of annual grasses and weed species shifts, interference of surface residue with herbicides, lack of disruption of perennial rootstocks, and a bigger 'window' for weed emergence. Stahl et al. (1999) suggested that a shift in tillage system causes changes in weed seedling microsites and thus affects the weed community composition. However observations on these concerns, especially weed species shifts have been contradictory. For example, Cussans (1976) reported greater abundance of some dicot weeds with increasing levels of cultivation. On the other hand, Wrucke and Arnold (1985) reported similar distribution of broad-leaved weeds in CT and conventional tillage systems. Pollard et al. (1982) reported that most weeds showed no consistent response to tillage. Swanton et al. (1999) found that tillage was an important factor affecting weed compositions. Derksen et al. (1993) suggested that changes in weed communities were influenced more by environmental factors (location and year) than by tillage systems. Shrestha et al. (2002) concluded that long-term changes in weed flora are driven by interaction of tillage, environment, crop rotation, crop type and timing and type of weed management practice. Similarly, the timing of weed emergence also seems to be species dependant. For example, Bullied et al. (2003) found that species such as common lambsquarters (*Chenopodium album* L.), field pennycress (*Thlaspi arvense* L.), green foxtail (*Setaria viridis* (L.) Beauv.), wild buckwheat (*Polygonum convolvulus* L.), and wild oat (*Avena fatua* L.) emerged earlier in CT than in conventional tillage system. However, redroot pigweed (*Amaranthus retroflexus* L.) and wild mustard (*Sinapis arvensis* L.) emerged earlier in the conventional than in the CT system.

For successful implementation of a CT system, it is important to understand how the ecology of weeds is affected. Seeds shed by annual weeds are not buried deep in CT systems. So, initial weed densities may be high if effective weed control is not maintained. On the other hand, weed seeds that are placed deeper in the soil profile are not being brought to the soil surface any more because of lack of soil inverting mechanisms by tillage. Therefore, in CT, we may be dealing with the weed seed bank in the top few inches. So, minimizing seed return can be an important tool for weed management in CT. Lack of tillage and presence of residue may influence soil temperature and moisture thus influencing weed seed germination and emergence. This may make the 'window of weed emergence' bigger or sporadic. Therefore, timing of weed control may have to be altered.

The reproductive structures of perennial weeds may no longer be buried deep or killed in CT systems as in conventional systems. Most perennial weeds are found in patches, so monitoring of weed patches will be essential in CT systems. Soil surface residue can interfere with herbicides so there is a greater likelihood of weed escapes if residue is not managed properly or herbicide application timings or rates are not adjusted.

Prediction of weed populations and weed species shifts would also help in designing weed management systems in CT. Similarly, information on the effect of crop rotation on weeds may be helpful because crop rotation has been critical for managing problem weeds in CT. There are very few reports on experiences in weed community dynamics under CT systems. Some personal experiences on these aspects from elsewhere and California are shared as follows:

i. A 9-year study in Ontario, Canada comparing the weed flora in continuous corn (*Zea mays* L.) under CT (no-till) and conventional tillage with or without a rye (*Secale cereale* L.) cover crop under varying levels of nitrogen showed that tillage was the most important factor influencing weed compositions. Cover crops and nitrogen rates had no influence on the weed species composition. Species like redroot pigweed and common lambsquarters were associated with conventional tillage systems whereas, large crabgrass (*Digitaria sanguinalis* (L.) Scop.), and common purslane (*Portulaca oleraceae* L.) were associated with CT systems (Swanton et al., 1999).

ii. Nine-year evaluations of three weed management systems under a CT corn-soybean (*Glycine max* (L.) Merr.)-winter wheat (*Triticum aestivum* L.) rotation was conducted in Ontario, Canada. The three weed management systems were: minimum (preplant application of glyphosate + mechanical control), integrated (preplant application of glyphosate + band application of preemergence herbicides + mechanical control), and conventional (preplant application of glyphosate + broadcast application of preemergence herbicides). It was found that, weed densities were greater in the minimum compared to the integrated and conventional systems. Weed densities in the integrated and conventional systems did not differ. There was no apparent 'buildup' of weed density with time in the rotation resulting from weed escapes. This study challenged the current thinking that weed densities increase with time if weed escapes are allowed to go to seed (Swanton et al., 2002). The study also saw distinct differences in weed species composition between the three weed management systems. Further, the weed species composition in wheat differed from that in corn and soybean within a weed management system. Species like common ragweed (*Ambrosia aretemisiifolia* L.), annual sowthistle (*Sonchus oleraceus* L.) were associated with the minimum system in general whereas, common lambsquarters was associated with corn and soybean in the minimum system. Wild buckwheat (*Polygonum convolvulus* L.) was associated with wheat in the integrated system. Similarly, dandelion (*Taraxacum officinale* Weber in Wiggers) was associated with wheat in the conventional system and yellow foxtail (*Setaria glauca* L. Beauv.) was associated with corn and soybean in the conventional system. This study showed that weed communities were associated with the type of crop in the rotation and the type of weed management system even within a CT system.

iii. From a California perspective, initial assessments of weed population dynamics under CT in a small grain (wheat, barley, and oats) – blackeye bean (*Phaseolus* sp.) rotation were made in 2003 at Denair, CA. The weed densities and biomass in both small grains and beans were lower in the CT compared to the conventional system. The dominant weed in the rotation was wild radish (*Raphanus raphanistrum* L.). There was a high occurrence of wild radish in the conventional tillage plots compared to the CT plots. It seems that wild radish prefers disturbance and hence showed a preference for conventional tillage system. Similarly, in the beans, weed density and biomass were greater in the conventional than in the CT plots. Again, the major weed species were similar as in the small grain plots with additional summer weeds like hairy nightshade (*Solanum sarrachoides* Sendtner), large crabgrass, and puncturevine (*Tribulus terrestris* L.) (Shrestha et al., 2003).

From these experiences, it appears that it is difficult to generalize that weed densities will be greater in CT compared to conventional tillage systems. It may also be difficult to generalize weed population shifts and time of weed emergence. Types of crops in the rotation, weed management, and location (e.g., soil, environment) will determine weed communities. However, it can be concluded that, in general, weed communities and species will be influenced by tillage systems; type of crop in the rotation will influence weed communities; and although there may not be more weeds in CT systems, the species present will most likely differ from those in conventional tillage systems. Monitoring these changes and minimizing weed seed return can be an important strategy for the success of CT systems. Similarly, residue management will be important for the success of weed management in CT systems. Failure to adapt to these changes may result in a failure of CT systems.

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Defoliation - Efficacy on Cotton and Effects on Late Season Weeds

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INTRODUCTION

Although it is one of the last management decisions in the cotton production cycle, defoliation timing and application are critical to producing a profitable crop. Improper timing will compromise both seed cotton yield and quality. In light of the premiums and discounts for fiber quality brought about with High Volume Instrumentation (HVI) measurements, proper choice and timing of harvest aid chemicals are of paramount importance. Ideally, the proper harvest aid materials should defoliate the entire plant within 14 days after application with minimal desiccation. However, plant maturity, moisture status, nitrogen status and environmental conditions dictate this response. The tight economics of cotton production today dictate that grower's do all that is possible to properly set up the crop for effective, reduced-cost defoliation that still protects lint quality and price. The best conditions for effective defoliation include the following: 1) Air temperatures from moderate to high (day time - >10^{B}C; 2) Relatively low plant and soil nitrogen levels; 3) Moderate soil water levels (plants can't be water stressed); 4) uniform crop development with crop at cutout; 5) Weeds, insect and disease under control; 6) Complete defoliant coverage with good penetration within the canopy.

IMPORTANCE OF PROPER TIMING FOR HARVEST AID APPLICATIONS

Defoliation decisions have to be made on a field-by-field basis due to the wide range of crop maturities experienced within and across fields, and the impacts of weather and crop conditions that prevail at the time when the crop is acceptably mature for harvest preparation. Fields that have gone through a relatively even vegetative cutout and have a good boll load will be much easier to defoliate than fields with a non-uniform fruit set (for example, early and late bolls and a poor middle crop) or where there is substantial late vegetative growth due to factors such as late plantings, late irrigations or high late season soil nitrogen.

Timing and techniques for determining boll maturity

Generalizations. Understanding of the sequence of boll maturation and knowledge of how to assess boll
maturity are necessary in order to effectively use any of the following approaches to assess proper timing
for harvest aid applications. The standard recommendation is to apply defoliation treatments when 95% of green bolls are mature or when 65% of expected harvestable bolls are open. A mature green boll cannot be easily cut with a sharp knife. The seed coat of seeds within mature bolls also has a tan color as opposed to the milky white color in immature bolls. In California, counting nodes above cracked bolls (NACB) is the recommended technique to determine the proper application timing. If defoliation is delayed until the recommended NACB, fiber quality and yield will not be affected

Specific Factors to Consider. Different approaches to the assessment of boll maturity and crop readiness for harvest aid applications will be reviewed in the following discussion. In the late-season, not all green bolls will have the right conditions and adequate time to mature and open prior to harvest aid applications, so it is important to be able to assess both boll maturity and the amount of time and heat units required to finish out and open mature bolls. Mature harvestable bolls have the following general characteristics:

- Difficult to slice boll open across the suture lines of the boll wall even with a sharp knife
- Hard to "dent" or depress the boll wall with your fingers when pressing on it
- Seed coats range from yellowish to tan, even dark tan in color (in mature bolls, no seeds will have the milky-white seed coat color seen in immature bolls)
- When boll is cut open, lint can begin to string out rather than feeling wet
- Gelatinous material around seeds is mostly or completely gone

Percent Open/Assessment of Mature Bolls:

This approach has been in use for many years across the U.S. cotton belt, and it involves specific percentages of (a) mature green bolls; or (b) open bolls for harvest aid applications:

- 90 to 95 percent of the green bolls are "mature" as defined above
- 60 to 65 percent of the expected harvestable bolls are open is used as a target for defoliant application
- 80 to 85 percent of the expected harvestable bolls are open is used as a target for desiccant applications

There are advantages and disadvantages to use of this approach. Examples can be used to identify problems with this approach, including the following two examples: (1) a crop set over an extremely long time period; versus (2) a compressed boll setting period. With the crop set over a long period, it would be possible to have a poor set of mid-canopy bolls, with bolls split between early-season and late-season bolls. Under this circumstance, it could be too early to defoliate even with 60 percent open bolls, since a significant part of the crop is in late-maturing bolls. In a crop with a compressed boll setting period, with bolls set early, on most successive fruiting branches, and with a relatively early vegetative cutout, it could be safe to defoliate at much less than 60 percent open boll. Under these types of situations, other evaluation techniques can prove useful. The following discussion addresses some other useful relative indicators of readiness for harvest aid applications.

Sharp Knife Technique/Seed Development Evaluations:

In this method, seed and lint development and appearance are evaluated as a tool to assess maturity. This technique is called the "sharp knife" method by many people since it requires cutting bolls expected to be "mature" in half (perpendicular to the carpel wall suture lines) with a sharp knife. The evaluation technique can involve both: (a) ability to cut through the lint and (b) seed maturity. More "mature" fibers can be more easily cut with a sharp knife. This characteristic can be used as an index of boll maturity, but this can be fairly imprecise since knives differ in "sharpness," and this is at best a "relative" term difficult to quantify. Inspection of the seeds for maturity can be done more consistently once the bolls are cut in half, and this can be done without removing the seeds from the boll. Seeds in mature bolls will have the characteristics mentioned at the beginning of this section. If the seeds remain immature, they will have the following characteristics:

- Appearance of "free" water in the boll
- "Jelly-like" appearance in material around seeds in the boll
- Seed coat still white instead of tan or brown

- Cotyledons white instead of green

If cutting bolls is used as an estimate of boll maturity, efforts must be made to cut bolls of different ages /positions on the plant to gain a field average when assessing uppermost bolls likely to mature and open.

Nodes Above Cracked Boll (NACB) Approach

This technique is based upon the idea that bolls will "crack" open (split along the boll suture lines) and be ready for harvest in roughly the same sequence that flowers were produced on the plant (ie. there will be a fairly regular progression in opening of bolls from the bottom of the plant towards the top). In general, the recommended time that harvest aid applications can be made on Acala and CA Upland varieties is 4 NACB and for Pima 3 NACB. If defoliant applications are timed to match these stages of boll opening in the crop, fiber quality and yield will not be affected. The first step is to determine the last first position boll on the main stem that you determine will be carried all the way to harvest, and begin counting down the stem to the first cracked boll (boll starting to open and dry). The number of nodes above cracked boll will be calculated as the node position difference between that uppermost last boll to carry to harvest and that of the uppermost first position cracked boll.

Fields best-suited to this approach are those in which plant populations are moderate to high, and where plant populations and growth are relatively uniform. The NACB approach is less easy to use in fields or with varieties where a high proportion of the boll set is on vegetative branches, or where there are large gaps in position of fruit on the plant. When retained bolls are not evenly distributed within the plants (due to pest impacts or weather-related problems), there can be special cases to consider when evaluating the use of NACB for determining defoliation timing. Particularly when there are late-season boll losses, the last harvestable boll on the plant may not be in the first position on the fruiting branch.

FACTORS TO CONSIDER IN SELECTING A DEFOLIATION STRATEGY

Growers need defoliants with different modes of action to insure continued best results under a variety of environmental and crop conditions. However, it also is important to consider the importance of prevailing environmental and crop conditions in determining a cost-effective approach for each field.

Weather Conditions. It might seem a straight-forward decision to determine what to use and how much to spend on harvest preparation, but factors such as crop late-season vigor, nitrogen status, and water status can exert a big influence on success in defoliation. In many years, the often dominant factor going into each harvest season is typically hard to guess, and that is, the weather. Efficacy of harvest aids with different chemistries, the importance of adjuvants, and the need for repeat applications can be strongly influenced by both the weather (primarily temperature) as well as by crop vigor and levels of water or nutrient stress. Defoliants are much more effective when temperatures are warm, with daytime high temperatures greater than 80F. In general, earlier harvests, with longer, warmer days, are much more effective and time efficient and allow much more picker "power" than during the shorter, cooler and possibly wet days of November. Earlier harvests also make it easier to help preserve fiber quality.

Crop Vigor and Boll Load Impacts. In general, most harvest aids will do best, often even with lower labeled rates, in fields with a uniform boll load, strong cutout and little late-season vegetative growth. Choices become more complicated in fields with low and/or extended boll loads, where non-uniform cutout and rank vegetative growth have to be considered. For a more thorough discussion of the relationships between crop condition (cutout, rankness of growth, relative boll load) and choice of approach for harvest aid applications, see the August, 2000 issue of the "CA Cotton Review Newsletter" available through your University of CA Cooperative Extension county office or at http://cottoninfo.ucdavis.edu.

Harvest Aid Chemical Choices. Several harvest aid chemicals are registered for use in California (Table 1 and 2). Primary defoliant materials are generally limited to the organosphosphate (OP) defoliants (DEF / Folex), or sodium chlorate, Ginstar and Dropp. Long-term UC studies, however, have identified some specific conditions which influence the performance of some materials versus others. With OP's, best results are usually obtained when they're applied in combination with ethephon. In University studies, Dropp when used alone has been more inconsistent in performance, especially with Acala Upland varieties. Sodium chlorate and Ginstar, when applied at high rates in combination with warm to hot temperatures, can cause leaves to freeze or desiccate on the plant.

Multiple applications of sodium chlorate can be used effectively for defoliation under some conditions, but it is most often used as a second application following an OP to desiccate remaining leaves before harvest. There are many defoliant enhancers, such as Accelerate, Cotton-Aid, Harvade and Starfire. Under some situations - rank growth, poor boll set, excessive moisture and/or nitrogen - these enhancers will increase efficacy when used in combination with Ginstar or OP's.

Late Season Weeds

Fields with significant population of weeds can present problems for defoliation and harvest operations. Late season weed problems can include field bindweed, johnsongrass, bermudagrass, nutsedge, annual morningglory, pigweed and nightshade. If the weeds are tall and grow into the upper canopy, such as johnsongrass, pigweed and nightshade, they can intercept some of the applied defoliant, reducing its effectiveness. Weeds that twine up through the cotton canopy such as annual morningglory and field bindweed can also intercept applied defoliants and reduce application and harvest efficience. Any type of weed at harvest will likely increase the trash content of lint resulting in "grassy bales" and reduced value of lint. If weed tissue that is green and hydrated at harvest time is not removed with defoliants or dehydrated with desicants, it may stain the cotton lint. Seed berries of nightshade can also cause lint staining all resulting in lower quality lint. Weed populations in fields grown for foundation, certified or registered seed can be very problematic. Weed control efforts need to be intensified much earlier in the growing season for seed fields.

Herbicide options for late season weeds are limited mainly to glyphosate applied alone at 8 NACB or later (4 NACB) in combination with defoliants. University studies (Table 3) have shown significantly increased control of johnsongrass, annual morningglory and black nightshade when glyphosate was applied tank mix with either Def or sodium chlorate when compared with either applied alone. Although the weeds are controlled, the desiccated weed skeletons still remain and reduce lint quality at harvest. Glyphosate cannot be used on fields grown for seed as cotton seed from fields treated at or near defoliation have shown reduced seedling vigor.

Just recently registered in 2003 for cotton defoliation, Shark (carfentrazone) will provide growers with another option for pre harvest weed problems. When used as a defoliant, Shark provides effective burn down of annual morningglory and many others weeds.

Table 1

Harvest Aid Chemicals		
Type	**Common Name**	**Trade Name**
Boll Openers/Conditioners	Ethephon	Prep
Boll Openers/Defoliants	Ethephon + Cyclanilide Ethephon + AMADS	Finish Cotton Quik
Defoliants	Tibufos Thidazuron Thidazuron + diuron Demethipin carfentrazone Sodium chorate	Def, Folex Dropp Ginstaar Harvade Shark Defol 6

Table 2

Harvest Aid Chemicals		
Type	**Common Name**	**Trade Name**
Desicants	Paraquat Sodium chlorate	Starfire Gramozone Max Defol 6
Other/Enhances	Endothall Cacodylic acid Glyphosate	Accelerate Cotton aid Roundup Ultra Max Touchdown IQ

Table 3

Percent Control Preharvest Weed Control 1986 - Steve Wright, UCCE Tulare County				
Treatments	**Rate/A**	**Johnsongrass**	**Annual Morningglory**	**Black Nightshade**
Roundup fb Sodium Chlorate	2 pt + 2 gal	97	85	67
Roundup + Def	2 pt + 2 pt	88	70	40
Sodium Chlorate	2 gal	55	25	25
DEF	2 pt	30	10	10

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Impact of Water Quality Regulations on Horticultural Production

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Water quality laws and regulations began specifically with California's Porter-Cologne Act of 1969. As with many environmental laws, this California act set the stage for federal water quality regulation. In 1972, the federal government passed the Clean Water Act, which provided the basis for regulation of point sources of pollution, or water pollution originating from an easily identified source, such as the end of a pipe. Some success was achieved, but water quality problems still persisted. In the late 1980's, the federal government amended the Clean Water Act, to include nonpoint source pollution, or water pollution that has no easily identified source.

It is the responsibility of state and local governments to uphold the federal Clean Water Act, and in doing so, they must provide regulatory actions against those contributing to water pollution. There have been several instances where a local government has been sued by an environmental group for failure to uphold the Clean Water Act. An example of this is *Baykeepers vs. the City of Encinitas* in San Diego County. The lawsuit was filed because the city had failed to enforce laws that would minimize water pollution in the streams leading to recreational areas of the beach, and there were high levels of various pollutants in the coastal waters. As occurs in many of these suits, the City of Encinitas and the Baykeepers entered into a consent decree with the courts, and as part of this agreement, the City of Encinitas had three years to rectify the water pollution problems.

Numerous greenhouse and container nurseries located near the coastal areas of Encinitas were under close scrutiny, and many of them had to change growing practices to minimize or eliminate runoff. The greenhouse and nursery industry was treated in the same manner as other businesses that were contributing to the runoff problems- supermarkets, fast food restaurants and any other business that had created impermeable surfaces that exacerbated the likelihood of polluted runoff leaving their property. After the three-year time period, several of the nurseries have shut down or relocated; however this is due to a greater extent to development pressure and value of their property, and only in part to the water quality regulations.

Another part of the federal Clean Water Act is the Total Maximum Daily Load or TMDL program. Total Maximum Daily Load refers to the amount of a specific pollutant that a water body can assimilate on a daily basis, depending on the beneficial uses of the water. The Clean Water Act establishes a "List of Impaired Water Bodies" for each state, called the 303(d) list. Water bodies can be added to, or removed from this list as their pollutant status changes. A priority list for improvement and development of a TMDL program is selected from the 303(d) list, and specific pollutants are addressed for the impaired water body. The TMDL process sets target maximum daily pollutant levels for individual pollutants, and activities that contribute to the pollutant loads are scrutinized and altered. Horticultural practices are included, and nurseries have had to modify growing practices drastically in some cases, to minimize their contribution to the pollutant levels. As was the case with ligtigation, growing practices that have been altered include fertilization application methods, irrigation scheduling, types of irrigation systems, leaching alterations, capture of runoff, and pesticide applications. Many other non-production practices, such as cleaning walkways in greenhouses, washing equipment and capture of roof runoff are being changed in various growing operations.

Stormwater regulations relate primarily to non-stormwater runoff from all types of commercial activities. The state holds a "Stormwater Permit", and again, each local government is responsible for upholding the terms and conditions of this permit. In San Diego County, each municipality, the County of San Diego, the Port District and the US Navy are co-permittees on a "Stormwater Ordinance", specifying rules and regulations for meeting the state's permit requirements. Again, horticultural and other agricultural operations have been included as high priority contributors to the local water quality problems. Alterations in practices include many of the same things that a horticultural operation must change when included in a TMDL process. The main emphasis is on source reduction of runoff, and elimination of any runoff leaving the growers' properties. In addition, records of activities related to reduction of runoff are encouraged.

The Water Quality Program of the UC Cooperative Extension in San Diego County has worked with growers for many years on water quality issues and regulatory requirements. Best Management Options have been developed for the greenhouse and container crop industries and tree crops. A record keeping system for water quality has also been developed. This and other information is available on the UC Cooperative Extension website at http://cesandiego.ucdavis.edu.

UC DAVIS ENVIRONMENTAL HORTICULTURE DEPARTMENT ESTABLISHES IR-4 CENTER

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The Department of Environmental Horticulture at the University of California Davis recently began developing a program to develop data needed for registration of crop protection materials that are of interest to growers of specialty crops in the Western United States. This activity will result in a center for ornamentals that is part of the the USDA Interregional Research Project #4 (IR-4). The latter is the only publicly funded program in the U.S. that conducts research and submits petitions to the Environmental Protection Agency (EPA) for registration of pest control agents on specialty crops. Specialty crops include, nursery and landscape plants as well as cut flowers and potted plants (in addition to most vegetable, fruit, nut, herb, and spice crops).

The crop protection industry lacks incentive to pursue registrations on specialty crops for many materials because the low acreage involved means relatively low return on investment. Recognizing this, the state land grant universities and the U.S. Department of Agriculture (USDA) organized the Interregional Research Project #4 in 1963 to address the shortage of pest control options for minor crops. A separate Ornamentals Program was created in 1977 and, since then, over 9000 registrations have been processed for ornamentals. The Biopesticide Program to support research and registration activities on biological pest control agents began in 1982, and 1998 saw the establishment of a Methyl Bromide Alternatives Program.

The IR-4 Program has evolved as a bridge to registration by generating and supplying independent, high-quality research data needed by EPA in order to register compounds for use on specialty crops. Collaborations are the strength of the IR-4 program. Input is sought continually from the commodity production side of agriculture as well as from the crop protection industry, USDA and federal and state regulators.

The Environmental Horticulture Department at UC Davis has made a commitment to develop an IR-4 Center at the Department and we have begun to set up researchable projects. In order to make the program most effective, we need industry input to identify labeling issues that will provide the greatest benefit to growers. Some examples of projects that would be considered for funding include:

- Registering a material for a particular application where there is currently no effective, registered product.
- Registering a material to provide a different class of chemical to use in a spray rotation.
- Registering a material that provides a shorter reentry interval.
- Registering a material that is currently registered, but does not contain provisions for commonly used application equipment such as ultra-low volume or electrostatic sprayers.

(Note that "material" refers to insecticides, miticides, fungicides, plant growth regulators, insect growth regulators, as well as various biological pest control agents.)

Our highest priority is to respond to the needs of the California ornamentals industry. Initially our work will focus primarily on plant growth regulators, for which we are equipped to determine both efficacy and phytotoxicity data. As our program progresses we also intend to work with other pesticides, including herbicides, but these projects will primarily focus on collecting phytotoxicity data.

Initially we identified a set of experiments to carry out during our start-up by selecting a set of projects identified as important in the National IR-4 database. We further screened these projects to assure that they would be of importance to growers in California. Once this set was identified, we worked with an IR-4 coordinator verify that the selected projects were indeed relevant to the various manufacturers or vendors of the chemicals.

The table below shows the experiments that have been carried out as of Dec 2003.

Plant	Material	Control Objective	Experimental conditions	Results
Lily (Lilium)	Bacillus Subtilis	Botrytis cinerea	Growth Chamber	No disease detected (even on controls)
Angelonia (Angelonia angustifolia)	Cycocel	Growth	Greenhouse	not yet available
Umbrella Tree (Schefflera)	Cycocel	Growth	Greenhouse	variable
Arborvitae (Thuja)	Ethephon	seed prevention	Outdoor Nursery	No effect
Coleus, Flamenettle (Coleus)	Ethephon	Growth	Outdoor Nursery	Results varied with cultivar
Japanese rose, Turkestan rose (Rosa rugosa)	Ethephon	defoliation	Outdoor Nursery	No effect
Sweet potato vine (Ipomoea batatas)	Ethephon	Growth	Greenhouse	not yet available
Egyptian-Star-Cluster (Pentas lanceolata)	Uniconazole P	Growth	Greenhouse	Results not significant
Feather reed grass (Calamagrostis acutifloria)	Uniconazole P	Growth	Greenhouse	Results significant only in first two weeks
Sage, Mexican bush (Salvia leucantha)	Uniconazole P	Height	Greenhouse	Results significant only in first two weeks
Sweet potato vine (Ipomoea batatas)	Uniconazole P	Growth	Greenhouse	Results significant

The table shows the plant that is being "protected" or "controlled" (note that none of these are herbicide studies); the material that is being evaluated, the desired control objective and the specified experimental conditions. The last column provides a brief synopsis of the outcome of the experiments.

As can be seen, some of the results are not conclusive and some are counter to what was supposed to happen. As a result of these studies we are now aware that some proposed experiments were foolishly proposed to the IR-4 program without knowledge as to what is the outcome would be. This appears due to an inadequate understanding by some users of the IR-4 program as to what the program is supposed to do. We are currently working with National IR-4 program staff to improve understanding of the program among the various segments of the ornamentals industry that use this program.

Oxalis corniculata and Oxalis pes-caprae Biology and Control in Container and Field Grown Ornamentals

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Oxalis corniculata and Oxalis pes-caprae are two weeds that while in the same genus have completely different biology and therefore different methods of control. In this presentation I will cover only those methods of control that are pertinent or registered for use in container or field grown ornamentals.

Oxalis corniculata: Known as creeping woodsorrel, creeping oxalis, yellow oxalis, yellow woodsorrel and simply as oxalis, is a perennial weed that is a problem in greenhouses, lawns, landscape and nursery ornamentals. While it appears to be associated with human activity it is not a large problem in cultivated fields. Established plants are not easily controlled with herbicides in container ornamentals. Hand pulling of established plants, followed by herbicide application has been effective. The whole plant must be pulled or any stem material left can develop into a new plant.

Leaves are composed of three heart-shaped leaves attached to the petiole and the flowers have five small yellow petals that occur in clusters of one to five at the end of flower stalks. Plants must be controlled before seeds are produced. Seedlings flower in as little as four weeks nearly year around. Seedpods are 1/3rd to 1 inch in length and contain 10 to 50 seeds. These red, rough seeds can be expelled up to eight feet from the parent plant when the okra-shaped capsule ruptures. Sunlight is required for the seeds to germinate. A single plant can produce a total of 5000 seeds!

Oxalis pes-caprae: Known as Bermuda buttercup, buttercup oxalis, soursob, sourgrass, and yellow sorrel is a perennial that grows in full sun in cool coastal areas and in shaded areas inland. It is a problem in lawns, landscape, field-grown ornamentals, and increasingly in wild land and natural preserve areas. It is generally a problem in cultivated areas, but repeated cultivation before bulbs develop may reduce infestation. There are several reports of sheep loss in Australia when soursob, as the locals there call it, is eaten.

Plants form a single, short vertical stem which is mostly underground. Small, whitish bulblets develop on the stems at the base of the rosette of leaves. New bulbs form underground. These bulbs will germinate in the fall after the first rain. Leaves are larger and more fleshy than in Oxalis corniculata. Bright yellow flower clusters form at the end of a leafless stock from November through April. Plants in California rarely, if ever produce seeds. Foliage dies and the bulbs become dormant as the temperatures rise in the late spring and summer.

There are several methods to control these two weeds, some more successful than others. Cultural practices such as cultivation, hand hoeing or pulling, sanitation, irrigation control and crop timing have been used in ornament production. In container ornamentals where Oxalis corniculata is big problem hand pulling of this weed is widely used. This method of weed control is labor intensive and therefore can be expensive and the plants can be damaged by this operation. It is important to keep the area around the containers free from weeds that can contaminate the containers with weed seeds. All soil media used should be weed-free. Irrigation should be applied so that the soil on top of the container dries out between irrigations. In field grown ornamentals where O. pes-caprae is much more prevalent cultivation can be done with tractor implements before bulbs are initiated. Hand weeding is also widely used. It is important that all implements that are moved from a field infested with O. pes-caprae be cleaned before being used in a field that does not have this weed. If O. pes-caprae is a major weed in the field then planting a crop that grows in a different cycle than this weed may reduce the competition effect.

Herbicides are used in field-grown ornamental production, but are not very effective in the control of O. pes-caprae because of the perennial biology of the weed. There are several herbicides that are effective for the control of O. corniculata in container ornamentals. Isoxaben, prodiamine, pendimenthalin, napropamide, oxadiazon, oryzalin, trifluralin, diclobenil, and oxyflurofen alone and in combinations are registered for use in ornamental production. These herbicides have an approximate residual persistence of from one month to one year. This is an important consideration in a container nursery where water is recycled onto crops that may incur phytotoxicity.

Several types of mulches are used for weed control and moisture conservation in container ornamentals. Sand, nut shells and man made material disks are just a few of the materials effective for weed control. Mulches are of limited use in annual field grown ornamentals.

When weather conditions in coastal flower growing areas are conducive to solarization this method of weed control is effective against O. pes-caprae. Because of the cool, cloudy conditions that are often prevalent during the summer in the flower growing region solarization is often ineffective. Solarization for container ornamentals is limited to pre-potting treatment of planting media.

Fumigation is used in container ornamentals for pre-potting soil media sterilization. Chemical and steam sterilization use is widespread.

The use of fumigation in field grown ornamentals is undergoing review and experimental with the impending loss of the use of Methyl Bromide in 2005. Several fumigants are being tested as replacements for Methyl Bromide. Iodomethane, chloropicrin, 1, 3- D, and metam are among the most promising compounds.

Because of the nature of both Oxalis corniculata and Oxalis pes-caprae these two weeds will continue to be a major pest of ornamental production in the future. By understanding and utilizing the biology of these pests in combination with cultural and chemical controls future control efforts can be made more effective.

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WEED CONTROL IN CONTAINER AND FIELD PRODUCTION WITH FLUMIOXAZIN

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Introduction

It has been over seven years since a new active ingredient for an herbicide has been registered for the ornamental market. There are many herbicides currently on the market, which do a fairly good job of weed control. Unfortunately, no single herbicide, tank mix, or premix will control all the weeds. Research on new candidate herbicides is an ongoing process. The objective in this research is to eventually provide the grower a new herbicide that will control a broader spectrum of weed species, including the hard-to-control weeds. Hand weeding problem species can cost the grower thousands of dollars per acre if there are no effective herbicides available.

During October/November 2003, the EPA granted Valent U.S.A. Corporation Section 3 registrations for two formulations of flumioxazin, BroadStar™ Herbicide and SureGuard™ Herbicide. The California registration for these two herbicides, unfortunately, is probably several months away.

Mode Of Action

Flumioxazin (2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynl)-2*H*-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1*H*-isoindole-1,3(2*H*)-dione) works primarily as a preemergence herbicide, but with considerable postemergence activity, depending on formulation, which is influenced by extent of coverage on the weed seedling. Flumioxazin is an N-phenylphthalimide herbicide. The mode of action in this family of chemistry is the inhibition of protoporphyrinogen oxidase (PPO), an enzyme important in the synthesis of chlorophyll. This PPO inhibition causes porphyrins to accumulate in susceptible plants, and when seedling weeds are exposed to sunlight, membrane lipids undergo peroxidation. The peroxidation of membrane lipids leads to irreversible damage of membrane function and structure in susceptible plants. Treatment of soil with flumioxazin will cause susceptible emerging weed seedlings to turn necrotic and die shortly after exposure to sunlight.

Toxicology

Flumioxazin has considerable safety and therefore has only the "Caution" signal word on the BroadStar and SureGuard labels. The hazards are minimal with an oral LD_{50} of >5000mg/kg, dermal LD_{50} of >2000mg/kg, and inhalation toxicity of only 3.93mg/L. It is non-carcinogenic and does not present a genetic hazard. The risk to mixers, loaders, and applicators is minimal, assuming protective clothing is worn, consisting of long pants, long-sleeved shirt, waterproof gloves, and shoes plus socks.

BroadStar Herbicide

BroadStar Herbicide is the 0.25% granular formulation of flumioxazin. It is labeled for preemergence weed control in container and field-grown shrubs, trees, and ground covers. The use rate for BroadStar is 150 Lb product (0.375 Lb ai)/acre, with a maximum of two applications/year. This granular formulation of BroadStar has a high quality carrier, with no dust.

BroadStar controls a wide spectrum of annual broadleaf weeds and grasses; including hairy bittercress (*Cardamine hirsute*), spotted spurge (*Euphorbia maculata*), liverwort (*Marchantia polymorpha*), common chickweed (*Stellaria media*), yellow woodsorrel (*Oxalis stricta*), common groundsel (*Senecio vulgaris*), eclipta (*Eclipta prostrata*), crabgrass (*Digitaria* spp.), and annual bluegrass (*Poa annua*). BroadStar will provide at least 8-12 weeks of residual activity following the 0.75" of initial irrigation necessary to activate the herbicide.

The primary granular herbicides on the market include OHII (2% oxyfluorfen + 1% pendimethalin), Rout (2% oxyfluorfen + 1% oryzalin), Snapshot (0.5% isoxaben + 2% trifluralin), and Regal O-O (2% oxyfluorfen + 1% oxidiazon). These four herbicides also provide broad-spectrum weed control, but require two active ingredients. The use rates for these premixes also require a much higher amount of active ingredient (2.5-5.0 Lb ai/acre) compared to only 0.375 Lb ai/acre for BroadStar.

Field research conducted by Dr. Jeff Derr (Virginia Tech) resulted in BroadStar 0.34 Lb ai/A) providing the best control of spotted spurge, common groundsel, long-stalk phyllanthus (*Phyllanthus tenellus*), and large crabgrass (*Digitaria sanguinalis*) compared to OHII (3.0 Lb ai/acre), Snapshot (3.75 Lb ai/acre), Regal O-O (3.0 Lb ai/acre), and Rout (3.0 Lb ai/acre) twelve weeks after application. Other trials by Dr. Derr showed that BroadStar was the most effective of the same five treatments in controlling long-stalk phyllanthus, eclipta, doveweed (*Murdannia nudiflora*), and mulberry weed (*Fatoua villosa*).

Early research conducted by Dr. Joe Neal (North Carolina State University) with a .17% granular formulation of BroadStar (0.25 Lb ai/acre) resulted in more effective control of spurge, bittercress, phyllanthus, doveweed, and eclipta than OHII (3.0 Lb ai/acre) ten weeks after application. However, this reduced rate of BroadStar was not as effective as OHII against crabgrass.

In 2002, Buzz Uber (Crop Inspection Services, Valley Center, CA) and Dr. Cheryl Wilen (UCCE, San Diego, CA) established trials comparing BroadStar (0.34 Lb ai/acre), OHII (3.0 Lb ai/acre), Rout (3.0 Lb ai/acre), Snapshot (5.0 Lb ai/acre), and Regal O-O (3.0 Lb ai/acre). Eight weeks after application, BroadStar was providing significantly better control of groundsel, mustard (*Brassica* spp.), and pigweed (*Amaranthus* spp.) compared to the other 4 treatments.

There is considerable crop safety with BroadStar, as long as the applicator follows the list of tolerant ornamental species found on the label. BroadStar does not inhibit root growth, which is a possibility when using herbicides containing dinitroanalines (OHII, Rout, Snapshot). However, BroadStar has considerable contact activity, similar to herbicides containing oxyfluorfen (OHII, Rout, Regal O-O), so care must be taken not to apply these granular herbicides to wet foliage. Although BroadStar will not translocate within the crop, necrotic leaf spotting can occur if the foliage is wet at application. Even if there is some leaf spotting, subsequent growth is unaffected.

SureGuard Herbicide

SureGuard is the 51% water dispersible granule (WDG) formulation of flumioxazin. It is applied as a spray, and labeled for use in container and field-grown ornamentals, conifers, deciduous trees, and bare-ground non-crop areas. The use rates are 8-12 oz product (0.25-0.375 Lb ai)/acre, with a maximum of 24 oz (0.75 Lb ai)/acre/year. Only 0.5" of initial irrigation/rainfall is required to activate SureGuard, which will result in at least 3-6 months residual weed control. Similar to the preemergence activity of BroadStar, SureGuard controls a broad spectrum of broadleaf weeds and grasses with 92 species on the label.

SureGuard also has excellent postemergence activity on weeds up to 2" in height. For optimum activity, a non-ionic surfactant (0.25% v/v) or crop oil concentrate (1qt/acre) should be added to SureGuard.

Field studies have shown excellent residual weed control activity with SureGuard. In one trial, SureGuard (12 oz product/acre) provided 100% weed control 3½ months after application, compared to Pennant (metolachlor) at 2 pt/acre + Princep (simazine) at 1.5 Lb product/acre which was completely overrun with hoary alyssum (*Berteroa incana*), common ragweed (*Ambrosia artemisiifolia*), marestail (*Conyza canadensis*), and common lambsquarters (*Chenopodium album*). In another study, SureGuard at 12 oz product (0.375 Lb ai)/acre was providing 100% control of mustard and 95% control of marestail 9 months after application.

Research conducted by Dr. John Ahrens (University of Connecticut) showed that SureGuard (0.25 Lb ai/acre) was 93% effective against common ragweed after 3 months and still 84% effective 9 months after application. This compares to a tank mix of Princep at 2.0 Lb ai/acre + Surflan (oryzalin) at 3 Lb ai/acre which was only 79% active against ragweed after 3 months and providing only 28% control after 9 months.

Some nursery growers still utilize contact weed control programs, and must make many applications throughout the year to maintain "weed-free" areas. This compares to a residual program with a preemergence herbicide that should result in effective weed control for several months. In one trial, SureGuard (0.375 Lb ai/acre) was applied in willows. Less than 2 months after application, the grower had to apply Roundup (glyphosate) in the untreated trees, due to a high population of large crabgrass that had taken over the pots. Within 1-2 weeks following the Roundup application, spotted spurge began germinating, which in time would have completely covered the large pots if the grower did not make another application with a contact herbicide. During that same period of time, SureGuard was providing 96% crabgrass control and 99% control of spotted spurge.

SureGuard is safe to the crop, assuming the label instructions are followed. Due to the contact properties of SureGuard, caution must be taken when making applications. SureGuard should never be applied to actively growing foliage. Applications should be made only to woody perennials (at least 1 year old) prior to bud swell in the spring or after dormancy has initiated in the fall (or after foliage has hardened off in conifers). SureGuard can be safely applied directly over conifers, provided bud break has not occurred.

SureGuard can also be applied to maintain bare ground in non-crop areas. These areas include bare ground around buildings, along fence rows, road surfaces, and gravel shoulders. SureGuard can be used at 8-12 oz (0.25-0.375 Lb ai)/acre. The length of residual activity would be based on rate, as well as sufficient irrigation/rainfall soon after application. Obviously the 12 oz/acre rate followed by at least ½" of initial irrigation/rainfall will optimize the residual activity of SureGuard.

Conclusion

BroadStar and SureGuard offer the nursery growers new choices for their weed control programs. Both herbicides provide excellent broad-spectrum control of annual broadleaf weeds and grasses. They are safe on the crop, with no root pruning (such as can occur with the dinitroanalines) and there is no volatility, which can be a potential injury problem as with herbicides containing oxyfluorfen. This new active ingredient (flumioxazin) and chemical class (N-phenylphthalimide) decreases the potential for development of resistant weeds, which makes BroadStar and SureGuard good rotation partners with existing herbicides.

Selecting the Right Herbicide for Nursery and Landscape Use

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For many weed control practitioners in the nursery and landscape industries, chemical weed control means the use of a common pre-emergent such as Ronstar and a post such as Roundup. Relative safety, effectiveness and low cost when compared with hand weeding limits their consideration of other options.

Actually, a more careful look at herbicide choices can reap benefits in lowering weed control costs, possibly improving quality of control, and decreasing environmental and safety concerns. For each application situation a different herbicide or herbicide combination may perform better and the extra effort in evaluating the situation will pay for itself. The first step is to determine the weed spectrum that will need to be controlled as well as the mix of ornamental species that might be present in the treated areas. References such as The Nursery and Landscape Weed Control Manual (1) and the Turf and Ornamental Reference for Plant Protection Products (2) provide cross references that will facilitate the process of determining which herbicides will control all or the majority of the weeds while being safe to use on the desirable ornamentals.

Economics

There are a number of factors that should be considered as a part of the process of evaluating the cost of weed control:

♦Cost of product/unit area—i.e. $100/acre

♦Duration of effective weed control (how long will the product effectively control weeds and how long do you need weed control?)

♦Are there formulation options with differing costs (granular vs. WP for example)

♦Weed spectrum controlled (will the product control all the weeds or will escapes have to be controlled by hand or post-emergence)

♦Consider a tank mix to pick up uncontrolled species rather than increasing the rate of one herbicide to control difficult species (often the combination of two herbicides at low rates will provide better and more cost-effective control than using one herbicide at a higher rate)

♦Incorporation flexibility (how long can you wait after application before incorporating the herbicide)

♦Will an older, out-of-patent material work as well as a higher priced patented material?

♦Risk of hidden phytotoxicity (i.e. dwarfing, slowing of growth, poor rooting of stolons)

♦Risk of drift injury to surrounding plants (translocated vs. contact post-emergent materials)

♦Risk of injury due to adverse weather (i.e. leaching of positionally selective herbicides)

♦Risk of obvious phytotoxicity**Environmental Savings**

When contemplating the environmental concerns associated with a herbicide treatment thought should be given to factors such as:

Long term cost of the herbicide as it relates to environmental problems:
♦Leaching, runoff, non-point source pollution, recycling of water in nurseries
♦Volatilization, photo degradation
♦Pre-emergence vs. repeated post-emergence
♦Resistance and herbicide rotation

Remember that herbicides are one tool in your weed control toolbox and should be used as a part of an integrated weed control program that includes the use of mulches, competition and proper ornamental plant choice and density, preventive practices such as equipment cleaning and prevention of seed production, solarization, and steam sterilization of nursery soils among others. Ultimately, proper herbicide choice coupled with an integrated approach to weed management will result in maximum economic and environmental savings.

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Weed Control in Celery and Spinach with Dual Magnum®

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Introduction

Celery has a good set of herbicides available such as linuron (Lorox) and prometryn (Caparol) that control most weeds in celery. However, yellow nutsedge is difficult to control in celery with existing herbicides. We found that *S*-metolachlor (Dual Magnum), applied prior to transplanting, controlled yellow nutsedge and was safe on celery.

In contrast, spinach has few herbicide options for control of broadleaf weeds. Cycloate (RoNeet), is the only herbicide available for broadleaf weed control in fresh market spinach. Dual Magnum also appears to be another herbicide option for spinach.

Methods

Celery field studies were conducted near Salinas and Oxnard, CA during 2002 and 2003. Pre-plant (PRE) applications of Dual Magnum 7.6 E were made at 0.5, 0.67, and 1 pt/A. About two weeks after celery was transplanted, post-plant applications of Lorox 50 DF at 2 lb product/A and Caparol 4 F at 3 pt/A were made. The trials utilized a randomized complete block design and treatments were replicated 3 to 4 times. The plots were one 40-inch bed wide by 20 ft. long. Weed densities and crop injury estimates (0 = no injury, 10 = dead) were measured early in each growing season. At commercial maturity, celery was harvested and graded by marketable and non-marketable stalks, and fresh weights were measured.

Ten spinach field studies were conducted near Salinas, CA during 1999 and 2000. Treatments included post-plant preemergence applications of Dual Magnum 7.6 E at 0.5, 0.67, and 1 pt/A and the commercial standard RoNeet 6 E at 4 pt/A. The trial designs and assessments were similar to those used for celery above. At commercial maturity, spinach was harvested and fresh weights were measured.

Results

Visual injury symptoms and marketable yields indicated that Dual Magnum was safe on celery (Tables 1&2). Nutsedge control in Dual Magnum treatments was better than Lorox or Caparol (Table 1). Dual Magnum at 0.5 and 0.67 pt/A treatments were safe on spinach, but the 1 pint treatment injured spinach in one trial (Table 3). Dual Magnum provided better control of common chickweed than RoNeet, and Dual Magnum and RoNeet both provided good control of nettle leaf goosefoot and shepherd's-purse. Requests for special local needs registrations for Dual Magnum on celery and spinach have been submitted to the California Department of Pesticide Regulation.

Table 1. Celery visual crop injury and nutsedge control resulting from Dual Magnum in two trials at Salinas in 2002 and 2003, and visual crop injury in one trial at Oxnard in 2002.

		Crop injury			Nutsedge control	
Herbicide	Rate	Salinas 02	Salinas 03	Oxnard 02	Salinas 02	Salinas 03
		--------- 0 = no injury, 10 = dead --------			------------- % -----------	
Dual Mag.	0.5 pt	0.1	0.4	1.0	94	88
Dual Mag.	0.67 pt	0	0.3	1.7	93	91
Dual Mag.	1.0 pt	0.1	0.6	1.0	96	98
Lorox	2 lbs pr/A	0.3	0.1	0.5	46	39
Caparol	3.0 pt/A	0.1	0	1.2	0	30
Check	0	0	0.2	0	0	0
LSD 0.05		NS	NS	NS	12	24

Table 2. Marketable celery yield at Salinas in 2003 and at Oxnard in 2002 resulting from Dual Magnum treatments.

		Marketable yield	
Herbicide	Rate	Salinas 03	Oxnard 02
		------------------------- lb/A -----------------------	
Dual Mag.	0.5 pt	162,171	75,608
Dual Mag.	0.67 pt	179,449	70,720
Dual Mag.	1.0 pt	177,606	67,558
Lorox	2 lbs pr/A	168,194	71,295
Caparol	3.0 pt/A	185,587	66,983
Check	0	186,817	63,677
LSD 0.05		NS	NS

Table 3. Spinach visual crop injury and yield resulting from Dual Magnum treatments in ten trials in coarse to medium or coarse soils at Salinas in 1999 and 2000.

		Crop injury			Yield	
Herbicide	Rate	Coarse-med. [1]	Coarse 1	Coarse 2	Coarse-med. [2]	Coarse
		--------- 0 = no injury, 10 = dead --------			------------- lb/A -----------	
Dual Mag.	0.5 pt	0.3	0.6	0.4	13,082	11,662
Dual Mag.	0.67 pt	0.9	1.0	0.5	13,894	11,418
Dual Mag.	1.0 pt	1.0	1.9	1.5	13,912	8,889
RoNeet	4 pt/A	0.6	1.0	1.5	13,028	12,478
LSD 0.05		0.4	0.7	0.8	2,022	3,427

[1] Data pooled from six locations

[2] Data pooled from four locations

Table 4. Weed control in spinach provided by Dual Magnum treatments.

		Weed control		
Herbicide	Rate	Chickweed	Goosefoot	Shepherd's-purse
		-------------------------------- % ----------------------------------		
Dual Mag.	0.5 pt	81	98	96
Dual Mag.	0.67 pt	82	97	88
Dual Mag.	1.0 pt	99	99	100
RoNeet	4 pt/A	17	96	98
LSD 0.05		46	23	34

ECONOMICAL METHODS FOR CONTROLLING DODDER IN TOMATOES

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Dodder, a parasitic plant, is often considered a disease rather than a flowering plant (Dodder is included in the Encyclopedia of Plant Pathology!). Germinating dodder seeds emerge as rootless, long yellow-orange thread-like leafless stems. The thread-like seedling coils around the host stem, adheres to it by adhesive discs, penetrates its tissue and vascular system via haustoria, and exploits the host by withdrawing nutrients and water. The part of the seedling in contact with the soil dies soon after haustoria formation. Dodder infests many broadleaf crops. Dodder is estimated to be present in about 30,000 acres of tomatoes in California, in addition to parasitizing many rotational crops including alfalfa, asparagus, carrot, onion, safflower, sugarbeet and melon (Ashton and Santana 1976). Dodder also infests many broadleaf weeds. New shoots are continuously produced, forming new attachments to the same plant and allowing attack of neighboring plants. Thus, the vigor of the host plant is lowered and crop production is dramatically reduced. Dodder that is not controlled can reduce tomato yields by over 75% and produce thousands of seed that can remain viable for up to 20 years.

Dodder control can be achieved by avoidance, hand removal, resistant tomato varieties, and herbicides. None of these methods work 100% of the time, but all offer some hope for managing this native, parasitic weed. Another complicating factor is that several dodder species are involved, with field dodder (*Cuscuta pentagona*) being the most common. Field dodder populations have also been observed to vary in virulence and susceptibility to treatment. Thus, an integrated approach to managing dodder will be needed.

Fluctuations in soil moisture and temperature near the soil surface may initiate dormancy breaking of buried dodder seed (Hutchison and Ashton 1979). Temperatures during the spring and early summer months are ideal for dodder emergence. However, dodder emergence in field trials was observed to cease in early to mid May, despite temperatures in the optimum range for germination and emergence (Hutchison and Ashton 1980). We have confirmed these observations in several tomato fields. Thus, a way to avoid major dodder infestations is to plant after the mid-May. Late planting can reduce dodder infestation, but that is not always practical due to cannery delivery dates. Some growers have utilized transplants in order to plant late, but still deliver tomatoes within the delivery time frame.

Due to the absence of roots, dodder seedlings (before attachment to the crop) are easy to control by light and shallow cultivation. In addition, tillage may hasten drying the soil surface, thus preventing further dodder germination and emergence. Complete dodder removal can only be achieved with the destruction of the infested crop plants. Removal by hand crews, of the tomatoes with dodder attached, remains a viable but expensive option, when infestations are small. When infestations are extensive, hand removal would be prohibitively expensive, not to mention the loss in the tomato stand. Hand removal is often done when dodder is first detected to prevent spread and seed production. In a trial area, farm workers were observed to remove dodder approximately 90% of the time. The remaining 10% was generally missed, because it was too small to be easily detected. If a hand crew can be sent back through a field about 15 to 21 days after the first hand weeding, the remaining dodder plants can be removed prior to any dodder seed production. Plants with attached dodder do not need to be removed from the field unless they have viable seed. Dodder can reattach to a new host if left in close proximity to living tomato plants, but if the plants that are hoed are moved 6 or more inches from the remaining tomato plants, the dodder will not be able to reach a new host.

Biological control has not been effective in California. United AgriProducts has been developing a disease organism (*Alternaria destruens*), specific to dodder. This organism has been effective against certain dodder species in craneberry production systems. In field tests of this organism, it has not been effective under California conditions, due to the dry climate and possibly the different dodder species.

Dodder resistant tomato varieties continue to be a viable option for preventing dodder infestation. Thus far, four Heinz varieties have been shown to be dodder resistant – H9492, H9553, H9992, and H 9888. Heinz seed has also advertised that 2 other varieties are also resistant to dodder infestation – H1100 and H1400. Some dodder is able to attach and survive on these varieties, but generally, tomato yields are not reduced and dodder seed production is very low or non-existent. Heinz 9492 was originally developed to be resistant to bacterial canker. Thus, the mechanism of disease resistance may be what prevents dodder growth.

The preemergent herbicides used in tomatoes are not effective in preventing dodder germination or attachment to tomato plants. Metam sodium controls many weeds prior to vegetable planting, but hard seeded species, such as dodder are not affected. Trifluralin controls dodder well in alfalfa, but the incorporation of the herbicide in tomatoes, allows dodder seed near the soil surface to escape control. Layby herbicides, such as Tillam or Treflan, are applied too late to control attached dodder.

The nature of attachment and association between host and parasite requires a highly selective herbicide to destroy the attached dodder without crop damage. Matrix (rimsulfuron) has been shown in studies conducted by Bob Mullen in San Joaquin County, to suppress dodder, particularly when split applications are used (Mullen et al. 1998). Further studies have shown that treatments made soon after dodder attachment were more effective than applications made after dodder became well established. Herbimax was the most effective surfactant for control of dodder with Matrix. However, the control achieved by the best Matrix treatments was only about 50%. Even when Matrix rates were increased to 2X the current label rate, dodder still survived. By the end of the season, dodder growth in the best Matrix plots was still extensive, indicating that Matrix alone is not providing adequate control.

Sandea (halosulfuron), like Matrix, suppresses dodder for a short time, but dodder growth quickly resumes. Maverick (sulfosulfuron) is an herbicide developed by Monsanto and used in winter wheat (except California). In field and greenhouse studies, we found processing tomatoes to be fairly tolerant of sulfosulfuron and we were able to achieve fair to very good dodder control. In greenhouse studies conducted in Israel, sulfosulfuron treatments resulted in 100% post-attachment control of dodder. Tomato tolerance to herbicides may be due to reduced herbicide absorption, reduced translocation within the plant, or metabolism of the herbicide. Any of these processes would also reduce the amount of herbicide reaching the dodder. Since dodder, in a sense, is just another stem on a tomato plant, we believe that some tomato injury may be necessary to achieve dodder control with herbicides. Thus, higher rates may be needed, regardless of the herbicide used.

The primary means of dodder spread from field to field is on equipment. As more custom operations are performed, the chances for dodder spread increase. T prevent the spread of dodder (and other diseases), wash equipment after leaving an infested tomato field, before entering another. If new dodder patches are detected, eradication of these patches should be done before they have a chance to produce seeds. Patches can be removed by hand removal, spraying both host and parasite, with a contact herbicide or by searing with a flame-throwing torch or hand burner.

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Past, Current and Future IR-4 Projects in Vegetable Crops

Rebecca Sisco, UC Davis, California

The Western Region IR-4 Program is part of the National IR-4 Program supported by a USDA federal grant. The Western Region is based at UC Davis in Davis, California and is housed in the Environmental Toxicology Department. The Western Region is comprised of the following states: California, Alaska, Arizona, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming and the Pacific Islands.

Since 1963, the IR-4 Project has been a unique partnership of researchers, producers, the crop protection industry and federal agencies designed to increase pest management options for specialty crops-which includes most vegetables, fruits, nuts, herbs, nursery and flower crops.

IR-4 researchers and cooperators generate field and laboratory residue data that are submitted to the U.S. EPA for the purpose of securing regulatory clearances for these crops.

IR-4 supports Section 18 exemptions and in many cases, these exemptions have been converted to Section 3 registrations. Projects are prioritized based on requests from growers, commodity groups and USDA/Land Grant university researchers.

To ensure the pest management tools you need are there when you need them, IR-4 needs your help by: Identifying the pest problems critical to your crop. Working with farm advisors or researchers to identify possible solutions. Submitting a Project Clearance Request (PCR) to IR-4. IR-4 work cannot begin without a PCR. PCRs can be submitted by anyone except a chemical company representative. PCRs can be submitted via the IR-4 website at ir4.Rutgers.edu.

To find out more about the IR-4 Program, how you can participate and how IR-4 can assist growers, contact Rebecca Sisco, Western Region Field Coordinator, UC Davis, Davis, CA 530-752-7634 or rsisco@ucdavis.edu.

Postemergence Weed Control Studies on Broccoli in the Salinas Valley

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Background: Broccoli and other cole crops have a waxy cuticle on their leaves that can provide a margin of safety for various postemergence weed control applications. For instance, topical applications of liquid fertilizers (i.e. ammonium nitrate and ammonium thiosulfate) kill small weeds but are relatively safe on broccoli. However, the waxy cuticle must be thick enough, and in the winter when cuticle development is minimal, substantial damage can occur to broccoli from topical fertilizer applications. Fertilizers applications provide substantial weed control in broccoli, however they do not effectively control weeds such as Common Purslane (*Portulaca oleracea*). As a result, we were interested weed control that might be provided by postemergence herbicides. Over the past three years we evaluated the following materials as postemergence herbicides on broccoli: pyridate (Tough – Syngenta), glufosinate (Rely – Bayer), clove oil plus acetic acid (Matran – EcoSmart), ethanmetsulfuron methyl (Muster – Dupont), flumioxazin (Chateau – Valent), carfentrazone (Shark – FMC) and oxyfluorfen (Goal 4F and Goal 2XL – Dow AgroSciences). Many of the materials evaluated in 2001 and 2002 did not have sufficient safety for postemergence use on broccoli and were not evaluated in 2003. Carfentrazone, flumioxazin and oxyfluorfen were further evaluated in 2003.

Methods: Trials were conducted in several locations in the Salinas Valley. Trials were located in cool sites such as Castroville and in warmer locations such as Soledad with cooperating growers in order to examine the impact of cuticle development on crop safety. Plots were 20 feet long by one 40-inch bed wide replicated 4 times. Postemergence applications were applied to 30-35 day old direct seeded broccoli. Materials in all trials were applied 72 gallons of water with two passes of a single-nozzle wand with an 8008E tee jet nozzle at 30 psi pressurized by CO_2.

Results: Carfentrazone and flumioxazin were too phytotoxic on broccoli even if applied as directed sprays and were discontinued from later evaluations in 2003 (data not shown). The 4F formulation of oxyfluorfen is safer than the 2XL formulation for postemergence use on broccoli. For instance, less phytotoxicity was observed with Goal 4F at 0.0625 lb a.i./A than Goal 2XL at the same rate (table 1). Goal 4F provided improved control of Common Purslane at all rates over topical applications of AN20. Each incremental increase in the rate of Goal 4F further improved control of Common Purslane. However, Goal did not provide significantly greater control of Shepherds Purse than the untreated control or AN20 treatments. Increasing the rate of Goal 4F increased phytotoxicity ratings. Directed spray application at 0.0625 lb a.i./A had less phytotoxicity than the over-the-top application at the same rate. Most of the herbicide treatments reduced the yield of the first harvest (table 2). Goal 4F at 0.063 either applied over-the-top or as a directed spray had good total yields. A summary of four trials conducted in 2003 showed that Goal 4F as a directed spray and Goal 2XL at 0.031 had the highest yields (data not shown).

Discussion: Goal 4F, a flowable formulation of oxyfluorfen, is a promising postemergence herbicide for use on broccoli. In the trials conducted in 2002 and 2003 it showed acceptable phytotoxicity at 0.0312 to 0.0625 lb a.i./A; The 0.125 lb a.i. rate also looked promising, but was not consistently safe. Directed sprays improved the safety over over-the-top applications. Goal 4F at 0.0625 lb a.i./A had improved safety over the 2XL formulation at the same rate. However Goal 2XL at 0.0312 lb a.i./A also showed promising safety. Goal 4F provided improved weed control over AN 20 for Common Purslane but not Shepherds Purse in these studies. Postemergence applications on Goal 4F had greater safety on summer-grown broccoli away from the immediate coast. In 2002 we observed unacceptable phytotoxicity of broccoli grown in the Castroville area, presumably due to less cuticle development due to the cool weather. The same phenomena was observed with topical fertilizer applications, however no yield reduction was associated with the observed phytotoxicity for either material. Goal 2XL is registered for pretransplant use on broccoli. Postemergence use of Goal 4F on broccoli is a new use pattern. The 4F formulation of oxyfluorfen was granted an "A" priority at the IR-4 Food Use Workshop in September 2003 and a tolerance for its postemergence use will be developed.

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able 1. Phytotoxicity, weed counts and weed biomass on August 25, 2003

Treatment	Rate lb ai/A	Material per acre	Application	Phyto*	No. of Weeds/ 8 sq. feet					Total Weed Biomass (g)
					Purselane	Goosefoot	S.Purse	Other	Total	
Untreated	----	----	----	0.0	32.5	4.8	10.3	2.3	53.3	351.0
Dacthal 75W	7.5	10 lbs	Preemergence	0.0	0.0	0.0	11.3	1.3	15.5	12.8
Ammonium Nitrate	60 gallons	60 gallons	over top	4.0	31.3	1.5	2.5	0.0	38.3	72.5
Oxyfluorfen 4F	0.031	1.0 fl. oz	over top	2.0	20.3	5.3	9.8	1.5	40.8	34.8
Oxyfluorfen 4F	0.063	2.0 fl. oz	over top	3.0	10.3	6.8	10.3	1.0	32.5	31.4
Oxyfluorfen 4F	0.063	2.0 fl. oz	directed	1.0	5.0	4.8	11.5	0.0	22.3	23.2
Oxyfluorfen 4F	0.125	4.0 fl. oz	over top	3.8	0.8	1.5	7.0	0.8	11.0	11.2
Oxyfluorfen 4F	0.25	8.0 fl. oz	over top	4.5	2.8	3.3	8.8	0.0	17.0	13.4
Oxyfluorfen 4F	0.5	16.0 fl. oz	over top	5.3	1.3	2.0	11.8	0.0	16.3	8.3
Oxyfluorfen 2 XL	0.063	4.0 fl. oz	over top	4.8	3.8	2.5	10.0	0.0	19.8	13.4
Oxyfluorfen 2 XL	0.125	8.0 fl. oz	over top	6.3	1.5	3.3	12.8	0.0	18.8	11.6
LSD				1.0	9.0	3.8	9.0	1.4	15.1	60.7

Scale: 0 no crop injury to 10 crop dead

'able 2. Broccoli harvest data

Treatment	Rate lb ai/A	Material per acre	Application	Phyto	Oct. 23		Oct. 27		Oct. 30	Harvest Totals		
					No.	Wt	No.	Wt	No.	No.	Wt	Mean Wt
					5.00	3.30	8.25	4.05	4.25	17.50	7.35	0.6
Dacthal 75W	7.5	10 pounds	Preplant	0.0	3.00	1.78	8.50	4.30	7.00	18.50	6.08	0.5
Ammonium Nitrate	72 gal	72 gal	over top	4.0	2.75	2.28	7.50	4.00	7.00	17.25	6.28	0.7
Oxyfluorfen 4F	0.031	1.0 fl. oz	over top	2.0	2.75	1.83	9.00	4.65	7.75	19.50	6.48	0.4
Oxyfluorfen 4F	0.063	2.0 fl. oz	over top	3.0	3.50	2.33	10.25	4.85	10.00	23.75	7.18	0.4
Oxyfluorfen 4F	0.063	2.0 fl. oz	directed	1.0	3.50	2.53	10.75	4.75	9.00	23.25	7.28	0.6
Oxyfluorfen 4F	0.125	4.0 fl. oz	over top	3.8	2.75	1.88	10.00	4.83	6.50	19.25	6.70	0.6
Oxyfluorfen 4F	0.25	8.0 fl. oz	over top	4.5	2.50	1.68	7.75	3.53	9.25	19.50	5.20	0.4
Oxyfluorfen 4F	0.5	16.0 fl. oz	over top	5.3	0.50	0.43	7.50	3.45	6.50	14.50	3.88	0.3
Oxyfluorfen 2 XL	0.063	4.0 fl. oz	over top	4.8	4.50	2.93	7.75	3.83	6.00	18.25	6.75	0.6
Oxyfluorfen 2 XL	0.125	8.0 fl. oz	over top	6.3	1.00	0.60	8.00	4.43	7.25	16.25	5.03	0.3
LSD				1.0	2.35	1.5	2.75	1.38	5.33	5.88	1.82	0.33

Caltrans Structural Vegetation Management Solutions for Roadsides

Jennifer A. Malcolm, Caltrans Headquarters, Division of Maintenance

Caltrans VegCon Program implemented an Integrated Vegetation Management Program that consists of seven distinct methods for vegetation control. This document focuses on the "structural" method for vegetation control. Historically, structural applications have been the most expensive and least utilized method at Caltrans, but currently structural methods show promise for Caltrans' future.

When choosing an appropriate vegetation management strategy, Caltrans considers safety for our highway maintenance workers, safety for the traveling public, and increased mobility. Structural methods can also decrease sight distance concerns. Generally, structural methods involve higher costs during initial installation, but they lead towards reduced maintenance needs and costs in the long run. Structural elements can also help Caltrans with its herbicide reduction goals. Hardscaping can unify and tie elements together while also being aesthetically pleasing – due to the wide variety of treatments, colors and patterns available.

Hardscape and Structural methods can be interchangeable terms. Basically, hardscape is the use of hard inert material surfaces such as asphalt, concrete and rock – in comparison to living soft material surfaces such as organic mulches and plants. Caltrans typically utilizes ten different highway hardscaping treatments. This document covers four products in detail – fiber weed control mats, polyureas, rubber weed control mats, and CRMCrete.

Fiber Weed Control Mats are synthetic polyester fibers spun together to create a mat that prevents weed growth while allowing for water and air percolation.

Fiber Weed Control Mat benefits include:
- Best for long straight runs of new guardrail or sign post installations
- Best on level compacted bases free of vegetation
- Less expensive than hard surface treatments
- Requires limited expertise to install (roll out mats, put on collars and seal)
- Simple removal replacement and repairs

Fiber Weed Control Mat limitations include:
- Not easily applied to curves (labor increases dramatically)
- Not recommended in high wind areas
- Labor intensive for existing guardrail and sign posts

Polyureas (or elastromers) are derived from the combination of isocyanate and resin-blend components. The result is a hard, but semi-flexible product that cures in less than one minute. Polyurea applications are typically applied through a spray with the two components combined at the nozzle. They are applied in relative thin coats over a geotextile fabric stapled to the ground surface. The ground surface must be well-prepared, compacted, and have a smooth surface. The amount of pockets should be limited.

Polyurea benefits include:
- Can be colored
- Semi-flexible end product
- Bonds well to wood
- Fairly long lifecycle
- UV stable
- Spray-on application allows product to be applied around existing features.

Polyurea limitations include:
- Water gets under edges.
- Wind lifts the product, especially on non-solid bases (such as sand)
- Snow removal operations destroy the product
- Does not bond well to concrete and asphalt
- Sometimes has a smooth-sheen look until weathering occurs
- Requires specialized equipment to apply the material
- High level of expertise required for proper product installation
- Required safety gear due to sensitivity issues for VOC's released prior to curing.

Rubber Weed Control Mats were originally developed for the recreation industry (specifically to address playground safety surfacing and ADA accessibility issues). It is recycled tire rubber bonded together with a resin through a cold press process into a mat that lays directly on the ground. The rubber weed control mat tiles prevent sunlight from reaching the ground surface, retarding seed germination and plant growth. Rubber Weed Control Mat installation includes uses under new and existing guardrail, around sign posts and under fences. The tile's weight keeps the mat in place, so no staking is required. Tiles are joined together with an overlap that is sealed with asphalt crack filler or resin adhesive.

Rubber Weed Control Mat benefits include:
- Manufacturing process allows for specific requirements such as size or color.
- Integral color can be added during the manufacturing process.
- Product is flexible and not adhered to the ground surface. It is easier to repair compared to other products
- One person can make repairs without specialized equipment.

Rubber Weed Control Mat limitations include:
- Multiple joints in continuous runs may become unsightly over time
- Not applicable to curves
- Labor intensive on long runs
- Slow installation in comparison to other products

Potential to ignite
Joints have potential for separation and vegetation growth if not sealed properly
Long-term degradation is unknown (for UV light and other factors)
Potential storm water concerns
High shipping costs (due to weight)

CRMCrete is short for Crum Rubber Modified Concrete. CRMCrete is a concrete-based product that includes recycled scrap tire crum rubber material and homopolymer polypropylene high performance reinforcing fibers blended into a slurry. Placement is similar to that of concrete and stamped concrete. Typical installation includes pouring CRMCrete into place, tamping and leveling as necessary, and in this application, Caltrans added a stamped texture to the top finish.

CRMCrete benefits include:
Wide variety of colors to match soil colors by utilizing concrete stains
Formwork is not always necessary
Higher daily production rates – faster than other surface treatments
Fairly easy installation
Uses standard equipment and concrete mixes

CRMCrete limitations include:
Consistency of mix may limit its use on slopes
Limited history of maintainablility and life cycle costs
Repairs are difficult to match to the original color
It is rigid and requires a 150 millimeter gap between the product and nearby guardrails/sign posts

So which is Caltrans preferred method? None. No single product is perfect!

Railroad Vegetation Management

Rodney Scrivner, Monsanto

Uncontrolled vegetation on railroad rights-of-way makes successful maintenance and operation a difficult, if not impossible, task. The major impact of uncontrolled vegetation is economic. Unmanaged vegetation accelerates the deterioration of every component of the railroad structure that is essential to the successful operation of the system

Aside from the economic reasons, a few general reasons to control weeds on railroads are:

- Remove health or safety hazards
- Improve or maintain working conditions
- Conform to local, state and federal regulations
- Improve the appearance of the railroad
- Reduce fire hazards
- Facilitate proper inspections

There are three basic methods of weed control used on railroads: controlled burning, mechanical and chemical. Controlled burning is rarely used today. The fuel and labor costs are high, the air pollution caused is no longer acceptable to the general public and control is temporary. Weeds may have to be burned several times a year.

Mechanical control includes mowing of weeds and cutting of brush on railroad property. It is more costly than chemical but may be used when the use of herbicides is restricted due to laws or proximity of crops. Most mechanical control is directed towards brush cutting. Brush cutting is costly and control is temporary but it is appropriate where removal of all standing vegetation is required. Once brush is cut, it will be more economical to control regrowth by chemical methods.

Chemical control is by far the predominate method of controlling vegetation on railroad rights-of-way. It is the most cost effective method in a railroad environment. In addition, chemicals are easy to apply, the degree of control can be regulated and productivity is much higher than with mechanical methods.

Most of the major railroads use private contractors to perform the vegetation control programs on their systems. The contracts are either <u>Guaranteed Performance</u> or <u>Specified</u>. In Guaranteed Performance programs, the pattern width and areas to be treated are specified and the contractor is free to use treatments of his choice. The railroad pays a lump sum amount on the condition that the property will be maintained to the satisfaction of the railroad. Any additional work required to achieve the expected level of control is at no additional cost to the railroad. In Specified programs, the railroad specifies the chemical treatments and acreage to be treated. The contractor provides a price per acre and the railroad must pay extra for any additional work necessary.

Railroad vegetation control programs contain the following applications: yards and off-track, bridges, line-of-road, road crossings and brush.

Yards and off-track areas must be kept weed free for the safety of workers, to permit inspections and to allow workers to perform maintenance. Railroad cars must be removed from rail yards to apply an herbicide treatment. This is costly and time-consuming, therefore one application, providing season-long bareground control is desired. These are pre-emerge treatments applied out-of-face with high rates of residual herbicides. Some common treatments (rates per acre) are:

- 8-12 pounds diuron
- 6-8 pounds Krovar
- 4 ounces Oust plus 5-6 pounds diuron
- 4 ounces Oust plus 2 pounds Spike

Bridges are treated to permit proper inspections of the structure and in the case of timber bridges to prevent fires. For that reason alone, bareground, long-term control is essential. Like, yards, these are pre-emerge treatments applied out-of-face with high rates of residual herbicides. Care must be used under bridges so that herbicides are not applied to water.

Line-of-road applications are the largest portion of a railroad program. They are needed to provide safety, promote drainage, increase visibility and permit inspections of track and trains. The treatment pattern on mainline tracks can be from 16 to 24 feet wide. These are usually post-emerge treatments providing season long control. The shoulder sections of the roadbed (outside 2-4 feet of the pattern) are treated out-of-face and the ballast area between the shoulders is usually spot sprayed where needed. The standard treatment is 2 quarts Roundup PRO plus 3-4 ounces Oust plus 1 pint 2,4-d per acre. In sensitive areas the 2,4-d can be omitted. Another option is to replace the Oust in the previous tank mix with 6-8 pounds diuron.

Public road crossings must be treated to improve visibility and conform to legal requirements. These are usually post-emerge applications designed to suppress but not eliminate vegetation. A few of the common treatments are the following tank mixes:

- 3 pints Roundup PRO plus 2-3 ounces Oust
- 3 pints Roundup PRO plus 1-2 pints 2,4-d
- 6 pounds diuron plus 2 quarts 2,4-d

Brush control is the final part of a vegetation control program. It is done to prevent fouling of communication lines and to maintain visibility at crossings, signals and around curves. The most effective brush treatments are late post-emerge. Excellent brush control can be obtained with:

- 6-8 quarts Roundup PRO
- 5-6 quarts Round PRO plus 8-16 ounces Arsenal 2WS
- 2 quarts Tordon plus 4 quarts Garlon 3A

The equipment used for railroad applications can range from a truck with a tank, pump and hose to a multi-system spray train. Most of the equipment used on the rails is custom built by the major contractors. Most of the equipment has the ability to apply multiple treatments to different parts of the railroad at the same time. This reduces the time required to complete the job. Spray trains, once the workhorse of mainline applications, have almost entirely been replaced by trucks, which don't require as much manpower.

Spray trains consist of a spray car, several large tank cars and a boxcar to carry the concentrated herbicides. They have a high capacity and are very productive on long runs. They are propelled by a railroad locomotive and the speed control is not very precise. They require a railroad operating crew and more spray technicians than a truck.

Hy-rail trucks have the capability to be driven on-rail or off and have capacities ranging from 500 to 5,000 gallons. This allows them to be more flexible logistically than trains. They are self-propelled and a railroad crew is not required. One spray technician can perform most hy-rail applications. One drawback to trucks is the reduced capacity increases downtime spent filling and mixing.

Vegetation control has become complex. Since the days when section gangs grubbed weeds, and simple one-system cars applied diesel fuel, the field has become mechanized and herbicides regulated. The term "management" has been substituted for "control". Such a change implies a concept greater than prevention or removal. It will be increasingly important for all those involved in railroad vegetation management to gain greater proficiency.

Biology and Control of Flax-Leaved Fleabane in Trees and Vines

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Flax-leaved fleabane or hairy fleabane (*Conyza bonariensis*) is a common weed found infesting thousands of acres of orchards and vineyards throughout California. Preliminary observations suggest that flax-leaved fleabane populations have increased in recent years. With poor economic returns in recent years (particularly in the south Central Valley), some growers have reduced weed control inputs to help save costs. This may, in part, explain the noticeable increase of this weed throughout the state. To prevent its spread, it is essential to understand the biology of this weed and some management strategies.

Biology

Flax-leaved fleabane is a summer annual weed that is native to South America. It belongs to the Asteraceae (sunflower) family. Its seeds germinate from late fall to spring. Under certain environmental conditions, it overwinters and behaves like a biennial. The plant usually matures from July to September in the Central Valley and is often found growing in the same areas as horseweed (*C. Canadensis*). The cotyledons or seed leaves of flax-leaved fleabane are dull green, oval, and covered with fine, short hairs. At the early stages of growth, flax-leaved fleabane looks very similar to horseweed. The true leaves are light green to dull green and may appear crinkled, compared to horseweed, which has darker green leaves.

Young plants have narrow leaves with slightly toothed-shaped margins. The leaves often have very short stalks, or more commonly, are stalkless. Mature plants are multi-branched, without a main stem and are from 1½ to 3 feet tall. The stem is smooth or covered with shaggy hairs. The plant has small, yellowish flower heads at the end of the branched stems. The mature flowering heads are rounded, about ½" in diameter and when mature, contain from 50 to 200 seeds each.

Flax-leaved fleabane grows readily in orchards, vineyards, and waste areas. It competes severely for water, and grows and spreads rapidly. The main reason for its rapid spread is its ability to be readily disseminated by wind. The seeds have attached pappus (tiny hairlike bristles) that is easily carried by wind. This dispersal mechanism helps its seeds to travel great distances (much like dandelions) and establish themselves elsewhere. Another reason for its rapid spread is that its seeds do not have to undergo dormancy to sprout. Once mature, they can begin to germinate. It can also spread rapidly from field margins. A single plant can produce 10,000 or more seeds.

Like horseweed, this weed prefers undisturbed situations, such as tree or vine rows, where the seeds that are on the soil surface can easily germinate. The seeds generally do not survive for more than 3 years under most conditions.

Problems associated with control

In recent years, poor economic returns for grapes, especially raisin grapes, have led to abandonment of numerous vineyards in the South Central Valley. Other growers have reduced weed control measures to save operation costs. This phenomenon may have led to the more recent increase in the occurrence of flax-leaved fleabane in these vineyards. As long as these weeds are allowed to go to seed, its prevalence may keep increasing in the future. It is said that 'one year's seeding is worth seven years weeding' and this certainly applies to flax-leaved fleabane.

Control strategies

The critical first step to limit the spread of flax-leaved fleabane is to prevent it from producing seeds. It is more easily controlled at an early stage (seedling and rosette stage) than at later stages when the plant becomes somewhat woody. Therefore, chemical or mechanical control measures should be used before this weed becomes too large. Table 1 shows a list of herbicides currently registered in California for flax-leaved fleabane control in orchards and vineyards. Always refer to the appropriate label for recommendations for effective weed control.

Pre-emergence herbicides with soil residual activity can help control flax-leaved fleabane before they emerge. If some plants have emerged by the time of soil treatment, the addition of a post-emergence herbicide as a tank-mix partner is recommended. Adequate rainfall is needed within a certain amount of days following treatment (refer to label).

Since flax-leaved fleabane has a large window for time of emergence, it is often difficult to predict the best time to apply post-emergence herbicides for maximum control of seedlings. Several timely sprays are usually required during the season for adequate control. For best degree of control, it is important to treat this weed when it is in the seedling stage, prior to bolting. Although glyphosate controls this weed, timing of application influences the amount of herbicide needed for it to be effective (Table 2).

Table 1. Herbicide options for flax-leaved fleabane control in orchards and vineyards

Pre-emerge	Lb ai/A	Control	Post-emerge	Lb ai/A	Control
Bromacil	3.2	P	Diquat	0.375	P
Bromacil + Diuron	3.2	C	Glufosinate	1.0	C
Diuron	2.4	P	Glyphosate	1.0	C
EPTC	2.1	P	Oxyfluorfen	0.25	P
Isoxaben	0.5	C	Paraquat	0.6	P
Norflurazon	2.0	P	Sulfosate	1.0	C
Oxyfluorfen	1.0	P	2,4-D amine	1.4	C
Simazine	2.0	C	Oxyfluorfen + 2,4-D amine	0.125 1.4	C
Thiazopyr	1.0	P			
Diuron + Simazine	1.5 1.5	C			

C = effective control and P = partial control

Table 2. Flax-leaved fleabane control at varied growth stages and herbicide rates

Flax-leaved fleabane growth stage	Lb ai/A for effective control (>95%)
3 – 6 leaf	0.5
7 – 12 leaf	1.0
13 – 19 leaf	1.5
21 – 21 leaf	2.0
>25 leaf	2.0 (poor control)

Data by Dr. Tim Prather, UC KAC, Parlier, CA, 1999

A study was conducted in a grape vineyard in Fresno County during 2003 to determine the effect of glufosinate (Rely), a relatively new contact-type, post-emergence herbicide, on flax-leaved fleabane control, when compared to current standard post-emergence herbicides. Rely was tested at 1 and 1.5 lb ai/A in a total volume of 20 and 40 gpa. Standard post-emergence herbicides (Roundup UltraMax, Touchdown IQ, and Gramoxone Extra) were included in the trial at recommended rates and at similar volume mixes. The treatments were applied to small plots, replicated four times each in a randomized complete block design. Treatments were applied in May when flax-leaved fleabane was from 5" to 14" tall. A CO_2 backpack sprayer was used to deliver the treatments using two flat fan nozzles per pass.

Rely outperformed all the other treatments tested (Table 3). It was shown that control was best achieved when Rely was applied at 1 to 1.5 lb ai/A in a spray volume of 40 gpa. While Gramoxone Extra provided statistically similar results, it was less effective, and Roundup UltraMax and Touchdown IQ did not provide effective control. Reducing the volume of water resulted in slightly lower weed control.

Table 3. Flax-leaved fleabane control

Treatment	Lb ai/A	Total gpa/A	Control 21 DAT	Control 55 DAT
Rely*	1.0	20	9.5 a	9.4 a
Rely*	1.5	20	9.8 a	9.7 a
Roundup Ultra*	1.0	20	6.3 c	6.0 c
Touchdown IQ*	1.0	20	5.3 d	6.0 c
Gramoxone Extra**	1.9	20	9.6 a	9.3 a
Rely*	1.0	40	9.9 a	9.8 a
Rely*	1.5	40	9.9 a	9.9 a
Roundup Ultra*	1.0	40	6.5 c	7.8 b
Touchdown IQ*	1.0	40	8.3 b	6.5 c
Gramoxone Extra**	1.9	40	9.6 a	9.4 a
Statistical notation @ p=0.05				
CV:			4.17%	4.74%
LSD:			0.56	0.63

*Ammonium sulfate added at 5 lb/100 gal and **Non-ionic surfactant added at 0.25% v/v
DAT = days after treatment

Tillage is also useful for controlling flax-leaved fleabane if properly timed. Using specialized mechanical equipment (weed blades, hoe plows, tillers, disks, and others) within the tree and vine rows can provide adequate control of flax-leaved fleabane as long as they are in the seedling stage, prior to bolting. Mowing is not a viable option for control, since mowing tends to stimulate lateral bud sprouting from near the base of the plant. This can harden off plants, making it nearly impossible to control with post-emergent sprays. Although there as been some success with control through flaming, it often requires follow-up applications when they are in the seedling stage of growth.

Flax-leaved fleabane appears in more orchards and vineyards than ever before. To help resolve this ongoing situation, growers need to be aware of the issues contributing to this problem. Early recognition of this weed within fields, along field edges and borders, and along property fence lines, preventing new seeds from being produced, using timely herbicide and mechanical options, and rotating control strategies are all essential steps needed for the long-term management of flax-leaved fleabane.

Alternatives to Preemergence Herbicides in North Coast Vineyards

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Introduction

The California winegrape industry has taken a keen interest in finding alternatives to preemergence herbicides. One reason for this interest is the threat that preemergence herbicides pose to water quality. Preemergence herbicides have been found to contaminate both surface and ground waters due to the amount of time that they remain active (Pimentel et al., 1992). Growing concerns over water quality and impending legislation may make some preemergence herbicides unavailable to growers; alternatives may soon be a necessity. Another reason that the industry is interested in alternative methods is a current trend toward sustainable viticultural practices. Some winegrape growers in the region have reduced their use of preemergence herbicides in the name of sustainability. However, fear of ineffective weed control is still the largest reason farmers cling to more conventional methods (Barberi, 2002). Research into alternative methods can provide the evidence that some growers may require before converting to more sustainable methods.

The objectives of our research are to test the efficacy of several alternative weed control strategies on not only weed establishment, but also on grapevine yield, growth, and nutrition. First, we address the use of alternatives to preemergence herbicides used on the berms, where weeds that can compete with vines or grow into the canopy are directly controlled. Secondly, we address cover crop management in the middles. Understanding how management of the middles affects weed population dynamics on the berms may prove to be a helpful tool to aid growers in indirectly reducing weed pressure on the berms. We initiated two field experiments in November 2002 to address our objectives.

Methods

The two field experiments (berm study and middles study) were conducted in a commercial, drip-irrigated winegrape vineyard in the town of Oakville, Napa County, California, USA. The vineyard was established in 1996 with Merlot (clone 314) on 110R rootstock to a 6 x 6 ft. spacing. An annual, no-till cover crop of Zorro fescue (*Vulpia myuros* var. *hirsuta*) is maintained in between every row.

Berm Study

Seven weed control treatments (Table 1) were arranged in a randomized complete block design with five replicate blocks. Treatments were applied to the first 50 vines, with buffer rows (where no data is collected) in between treated rows (where data is collected). Each treatment was restricted to two practices that were carried out in a single pass per practice, in an effort to use the same number of weed control attempts per treatment.

Table 1: Weed control practices associated with experimental weed control treatments and the associated dates and rates of application.

Experimental Treatment	Practice	Date Applied	Rate Applied
1. Winter Round-up/Spring Round-up	Round-up[a]	22-02-03	0.28 kg a.i. ha^{-1}
(WRU/SRU)	Round-up	22-05-03	0.56 kg a.i. ha^{-1}
2. Fall Cultivation/Spring Cultivation	Clemens	27-11-02	in-row cultivation
(FC/SC)	Clemens	16-05-03	in-row cultivation
3. Fall Cultivation/Spring Matran	Clemens	27-11-02	in-row cultivation
(FC/SM)	Matran[b]	22-05-03	3.72 l a.i. ha^{-1}
4. Fall Cultivation/Spring Round-up	Clemens	27-11-02	in-row cultivation
(FC/SRU)	Round-up	22-05-03	0.56 kg a.i. ha^{-1}
5. Winter Matran/Spring Matran	Matran	22-02-03	2.48 l a.i. ha^{-1}
(WM/SM)	Matran	22-05-03	3.72 l a.i. ha^{-1}
6. Native Vegetation	Mow	18-04-03	mow
(NV)	Mow	15-05-03	mow
7. Spring Cultivation Only	Mow	15-05-03	mow
(SC)	Clemens	16-05-03	in-row cultivation

[a]Active ingredient: Glyphosate
[b]Active ingredient: Clove Oil

Aboveground weed biomass per species was collected at peak biomass in June 2003. Four random samples were taken from each treatment berm using a 0.25 x 0.25m quadrat. Two samples were taken from around vine trunks and two from in between vine trunks. Total aboveground weed biomass, broadleaf versus grass biomass, annual versus perennial biomass, and weed diversity were compared across treatments using ANOVA (Proc Mixed, SAS Institute, 1996) with block and block interactions treated as random effects.

From the grapevines, yield data were collected in September 2003 from six adjacent vines per replicate vineyard row. Pruning weights were collected in November 2003 from the same vines from which yields were measured. Vine nutrient status was assessed in spring 2003. From each replicate vineyard row, 75-100 petioles were collected, dried, ground, and analyzed for N, P, K, Mg, Zn, and B. Yield per vine, average cluster weight, number of clusters, pruning weights, number of shoots, yield to pruning weight ratio and leaf petiole nitrogen, phosphorus, potassium, boron and zinc were compared across treatments using ANOVA (Proc Mixed) with block and block interactions treated as random effects.

Middle Study

For this experiment, three cover crop management treatments and a standard control were arranged in a randomized complete block design with four replicate blocks. Cover crop treatments included:

1) an annual, tilled cover crop of triticale (x *Tritisosecale*),
2) an annual, no-till cover crop of Zorro fescue (*Vulpia myuros* var. *histuca)*, crimson clover (*Trifolium incarnatum)*, and blando brome (*Bromus hordeaceus* ssp. *Molliformi),*
3) a native perennial, no-till cover crop of California barley (*Hordeum brachyantheum)*, California brome (*Bromus carinatus)*, molate red fescue (*Festuca rubra)*, blue wild rye (*Elymus glaucus)*, and white yarrow (*Achillea millefolium*).

The control was a standard, clean-floor treatment, which was disked twice annually. Treatments were applied to 50 consecutive vines of three consecutive rows. The inner berm and middle served as data collection areas, creating one buffer berm and one buffer middle on either side of the area were data was collected. Two Roundup applications peryear were used to control weeds under the vines in every block.

In late May, aboveground weed biomass per species was collected as described above from one berm and one middle per replicate row. Total aboveground weed biomass, broadleaf versus grass biomass, annual versus perennial biomass, and weed diversity were compared across treatments using ANOVA (Proc Mixed) with block and block interactions treated as random effects.

Results and Discussion

Berm Study

The Winter Roundup/Spring Roundup treatment was most effective at controlling weeds, as measured by aboveground biomass. Weed control was significantly better than that of the Winter Matran/Spring Matran treatment, the natural vegetation treatment, and the Spring cultivation treatment. All three treatments with a Fall cultivation resulted in intermediate weed control (Figure 1).

There was no significant difference between grass and broadleaf weeds for any of the treatments ($P = 0.5362$; data not shown). All treatments had similar proportions of grass and broadleaf weeds, except for the Winter Matran/Spring Matran treatment, which had significantly higher grass weed biomass than broadleaf weed biomass. Interestingly, the biomass of broadleaves for this treatment was almost as low as that of the Winter Roundup/Spring Roundup treatment.

Annual weed biomass was higher than perennial weed biomass in every treatment ($P = 0.0013$; data not shown). Perennial weed biomass was, in fact, only a fraction of the total biomass for all treatments, so patterns of differences in annual weed control closely mimic those of total weed control in Figure 1.

There were no significant differences in any of the grapevine yield or growth parameters. Among the petiole nutrient analyses, there was a significant difference for only one nutrient, potassium, which was significantly lower in all three treatments with a Fall cultivation ($P = 0.0093$;data not shown).

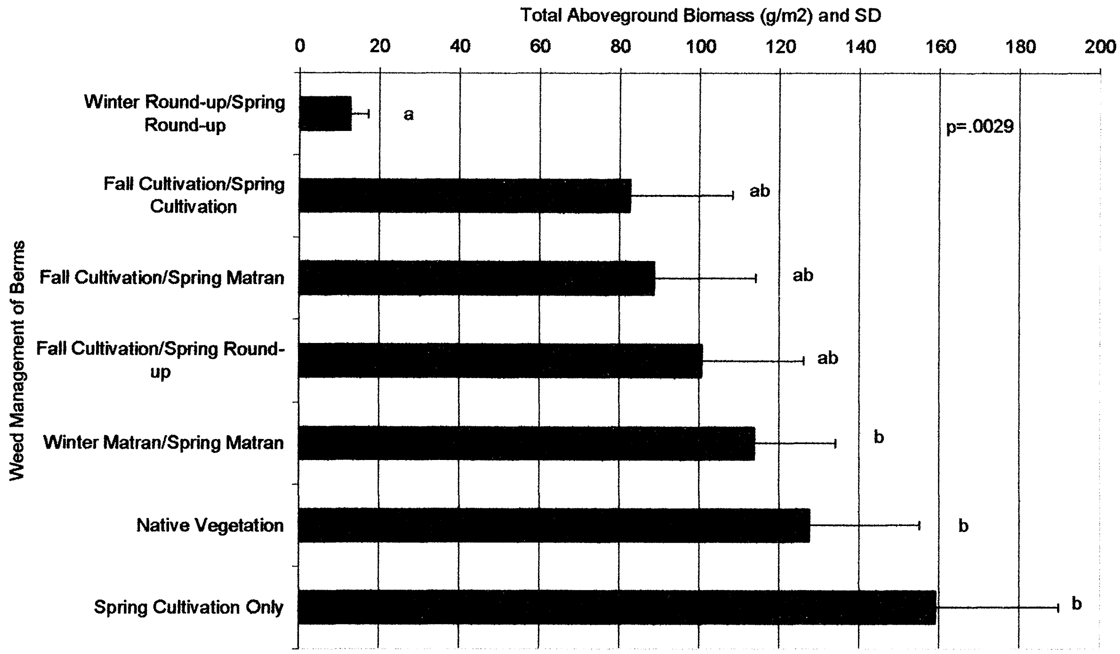

Figure 1: The effect of weed management on total aboveground biomass of weeds. Bars with no letter in common indicate a significant difference in weed control between the associated treatments.

To summarize these results, based on total weed biomass, the most effective weed control treatment was the Winter Roundup/Spring Roundup treatment. The least effective were Winter Matran/Spring Matran, Spring cultivation, and the natural vegetation control. Intermediate were the three treatments with a Fall cultivation. Matran applications appeared to be very effective against broadleaves, but were least effective against grasses. Although the Matran applications did not control grasses, the dominant grass weed was the cover crop (Zorro fescue), a low stature grass. Given that Matran controlled the more problematic broadleaves, this treatment was still successful. Finally, although there were differences in weed control efficacy among treatments, there was no effect of weed management on grapevine yield or growth.

Middle Study

There was a significant difference in the aboveground weed biomass on the berms compared to in the middles for only one treatment, the perennial, no-till cover crop. For this treatment, weed biomass in the middles was more than three times that of the berms. When weed biomass was compared across all middles, the weed biomass was significantly higher in the perennial, no-till cover than in all other treatments. However, when weed biomass was compared across all berms, there were no significant differences among treatments, although there were more weeds in the berm adjacent to the perennial, no-till cover (Figure 2).

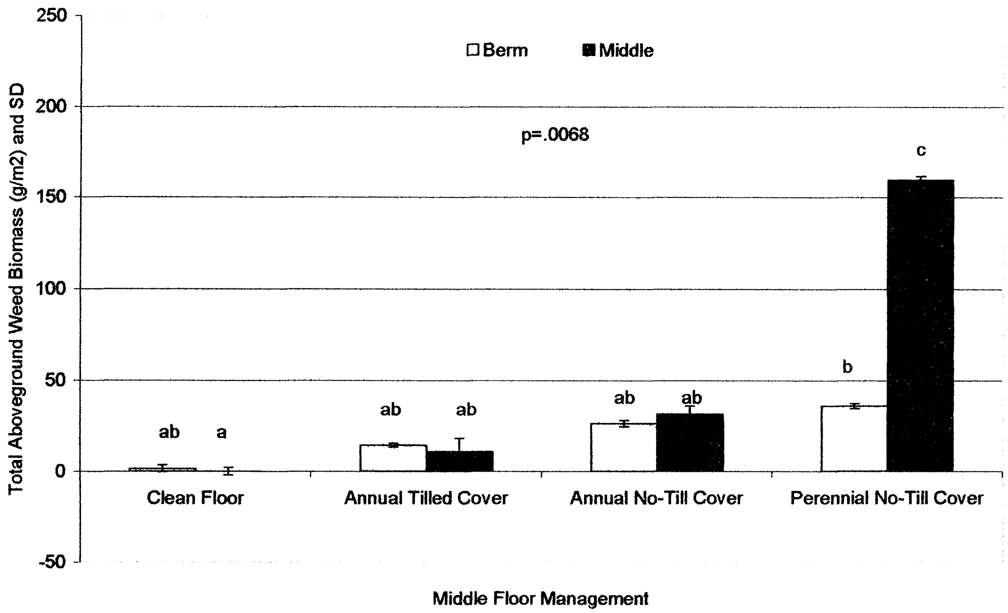

Figure 2: The effect of middle management on aboveground weed biomass on middles and adjacent berms. Again, bars with no letter in common indicate significant differences between associated treatments.

Broadleaf biomass was generally higher than grass biomass in every treatment in both locations (berm and middle), but, these differences were not significant (P = 0.1108;data not shown). While annual weed biomass was higher than perennial weed biomass in all treatments, the difference was significant only in the middles for the perennial, no-till cover crop (P = 0.0008;data not shown).

In summary, weed biomass in the middles was significantly lower in both annual cover crop treatments than in the perennial cover crop treatment. Among the three cover crop treatments, the vigorous annual cover crops had the highest cover crop biomass and the lowest weed biomass in the middles. Their ability to compete with weeds in the middles was associated with lower weed biomass in the adjacent berms. Over time, the perennial, no-till cover crop will likely develop a denser canopy enabling it to compete better with weeds in the middles.

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TELAR DF® HERBICIDE IN RANGELAND

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In early summer 2003, California granted Dupont registration of a supplemental label allowing for use of Telar® DF Herbicide (chlorsulfuron) in Pasture, Range, and Conservation Reserve Program (CRP) in the state of California. This is important news for California ranchers, wildlife biologists conducting habitat restoration, and Vegetation Managers in general. Telar DF was developed by Dupont to provide control of unwanted vegetation, thereby helping to provide protection from the introduction and/or spread of invasive species which can have a negative impact on species diversity.

Dupont Telar® DF is a member of the Dupont family of sulfonylurea (SU) herbicides which are characterized by very low use rates-typically ¼ to 2 ounces per acre. This is beneficial because, as compared to higher use rate products, the use of Telar® DF and other SUs helps decrease the load of chemicals in the environment. Additionally, SUs have been found to be very low in toxicity to mammals, birds, insects, and fish.

Treatments may be applied by any ground equipment or by fixed wing aircraft or by helicopter.

Telar® DF herbicide offers a two way approach to controlling weeds offering foliar systemic activity, and soil residual activity.

There are no grazing or hay harvest restrictions for any livestock, including lactating animals, with application rates up to 1 1/3 ounce product/acre of Telar® DF. No exclosure is required for any animals.

Application Rates and Weeds Controlled
The following application rates are recommended for broadcast applications on the respective forage grasses:

¼ to 1 ounce/acre

Bahiagrass
Bermudagrass
Blue gramma
Bluegrass
Bromegrasses
(smooth, meadow)

Orchardgrass**
Wheatgrass
(crested, intermediate, thick spike, pubescent, slender, streambank, tall, and western)

¼ to ½ ounce/acre

Bluestems (big, little, sandy)	Indiangrass
Buffalograss	Kleingrass**
Fescue* (tall, Kentucky, hard creeping)	Lovegrass
Green needlegrass**	Sideoats gramma
	Switchgrass
	Wildrye

*Some types of fescue are sensitive. Use rates at the lower end of the rate range.
**Except California

In pasture, range, and conservation reserve program (CRP), Telar® DF's maximum use rate is 1 oz/acre. Application rates higher than those recommended for specific grasses, up to 1 1/3 oz/acre, may be made as a spot treatment provided the resulting injury and possible loss of forage can be tolerated by the grower.

Weeds Controlled

Telar® DF effectively controls weeds when applied at the use rates shown. When applied at lower rates, Telar DF provides short term control of weeds listed; when applied at the higher recommended rates weed control is increased or extended. Make a single application per season to control the following weeds:

¼ to ½ ounce/acre (product)

Annual sowthistle	Mayweed**
Blue mustard	Miners lettuce**
Common chickweed	Pineapple-weed**
Common speedwell	Prostrate pigweed**
Conical catchfly**	Redroot pigweed
Fiddleneck (tarweed)**	Shepherd's-purse**
Field pennycress	Smooth pigweed**
Flixweed*	Treacle mustard**
Hempnettle**	Tumble mustard (Jim Hill)
Henbit	Wild mustard
London rocket**	

**Except California

½ to 1 ounce/acre (product)

Bouncingbet	Goldenrod
Bur beakchervil**	Groundsel**
Buttercup	Marestail
Canada thistle*	Musk thistle
Common lambsquarters	Sweet clover*
Common Sunflower	Tumble mustard

Common speedwell** | Turkey mullein*
Dandelion* | Whitetop (hoary cress)

Prebloom to bloom and fall rosette are recommended timings for Canada thistle, and Whitetop.
*Partial Control only
**Except California

1 to 1 1/3 ounces/acre (product)

Bedstraw*	Horsetail (Equisetum spp)
Black mustard	Pepperweed (perennial)
Bull thistle	Poison hemlock
Burclover	Puncturevine
Canada thistle	Red clover**
Common cinquefoil*	Russian knapweed
Common mallow	Scotch thistle
Common mullein	Scouringrush (Equisetum spp)
Common tansy	Tansymustard
Common yarrow	Whiteclover
Curly dock	Wild carrot

*Partial control only
**Except California
Prebloom to bloom and fall rosette are recommended timings for Russian knapweed.

Broadleaf forage species, such as, clover and alfalfa, are sensitive to Dupont Telar DF and will be severely stunted or injured by Telar DF.

Forage grasses should be well established before applying Telar DF as the newly emerged seedlings of some forage grasses are sensitive to Telar DF.

Varieties and species of forage grasses differ in their tolerance to Telar® DF. Ryegrass (perennial and Italian) may be severely injured. Fescues may be temporarily stunted or yellowed. When using Telar® DF on a particular grass for the first time, limit the area treated. If no injury occurs, larger areas may be treated in subsequent years.

Given Telar® DF's effectiveness on key invasive species, such as, whitetop and perennial pepperweed, and other invasive species, such as Canada thistle, Scotch thistle, and Russian knapweed, California ranchers, and vegetation managers now have another valuable tool available to them in the battle against invasive weed species in our rangeland settings. In 2004, Dupont will seek a 2EE label in California allowing Telar® DF herbicide to be tank mixed with Dow Agri Science's Transline® herbicide for control of yellow Starthistle.

This document is not a label. Please refer to the Telar® DF Herbicide Supplemental Labeling for weed control in pasture, range, and conservation reserve program (CRP), available from Dupont for complete use instructions, precautions, and guidelines for use.

TAMARISK AND ARUNDO CONTROL ON CACHE CREEK

The Cache Creek Conservancy is a 501(c)(3) non-profit corporation dedicated to the restoration of the lower 15 miles of Cache Creek. Our mission is to promote the restoration, enhancement and prudent management of the stream environment along the Creek from Capay Dam to the settling basin, east of Woodland, California. The Conservancy developed and manages a 130 acre Nature Preserve for Yolo County in addition to working on stream bank stabilization and revegetation with native species. Early in our seven-year existence it became obvious that removal and control of Tamarix and Arundo had to precede revegetation if restoration was to be successful.

In 2001 the Conservancy received grant awards from California's Wildlife Conservation Board (riparian program) and the California Bay Delta Authority (then known as CALFED) to remove and control Tamarix and Arundo donax along a 12 mile reach of the lower creek. In preparation for this project the Conservancy had formed partnerships with Yolo County's Resources Manager, Yolo County Flood Control and Water Conservation District, USDA-ARS, and 43 of 45 landowners. The project kicked off in October of 2001 for a short season to initiate mechanized mulching, train and equip spray crews, orient hand crews to remove invasives around native trees and educate cooperating landowners in the methods that would be employed over the next five years.

Our strategy was and is to employ the best tools available for each type of treatment method to achieve maximum resultant control for the least cost and effort. To develop the most efficient and effective machine to mulch Tamarix and Arundo vegetation we consulted with Holt of California, the regional Caterpillar Tractor dealer andPacific Gas and Electric Co. who has extensive experience in brush control along utility easements. This was critical to properly size and equip the power unit with the "slash buster" chopping head that was to be used. Rather than cut the plants at the base and remove the vegetative mass from the corridor, the Tamarix and Arundo were chopped from the top down and the mulch that remained was left to desiccate in the summer sun. Chemical company representatives with extensive knowledge in invasives control, including Scott Johnson-Wilbur Ellis, Mike Krebsbach-Monsanto and John Smith-BASF, were asked to advise us on the best materials to spray, the most effective application techniques, equipment, timing and necessary safety training and clothing. We met with Pest Control Advisors, the County Agricultural Commissioner and local farmers to ensure that project implementation would comply with all regulations and recommendations.

The initial proposal to Wildlife Conservation Board and CALFED required 300 acres of Tam and Arundo to be removed and controlled over the five-season life of the grant. To date we have treated over 1,000 acres with excellent (we think) results of 80%+ control in all treated areas. The equipment that we used to mulch Tamarix and Arundo turned out to be so effective and efficient that we stopped using it after the second season because all necessary chopping was done! We continue treatment with hand crews and application of herbicides by trained agricultural worker crews.

From the initial planning phases of the project, bio-control was seen as the long-term management tool. We started working with Dr. Ray Carruthers of USDA-ARS, Albany, CA in 1999 on caged studies of leaf beetles (diorhabda) from China. The Saltcedar Consortium obtained funding for studies in three watersheds in California (and in other states), Cache Creek was chosen as one of those watersheds. The expertise and experience that comes with the Consortium's involvement is invaluable and certainly helped to make our project a success.

Integrating all aspects (mechanical, manual, chemical, biological, educational and outreach) of the project was a challenge in and of itself. Both the project manager, John Watson, and Conservancy Executive Director, Jan Lowrey, are acquainted with integrated pest management through our agricultural backgrounds. By hiring a local progressive farming operation as sub-contractor to implement mechanical and chemical work, we were able to speak the same language of IPM weed control and take advantage of the economies of a local operation with all necessary infrastructure already in place.

While the outside contacts with state and federal agencies, university specialists, equipment dealerships and chemical companies was and is important, local networking with landowners, neighbors and the local community in general is crucial. Because the project manager was a local agricultural manager and the on-the-ground contractor is a well known and respected farming family, the riparian landowners were open to discussing and signing the 10-year licensing agreements that allowed treatment, monitoring and revegetation work on their property. And after all, if the landowners would not agree to the work the project would never happen.

We now find ourselves in the position of being approached by landowners outside of the original project area to do work on their property. The Rumsey Band of Wintun Indians (Rumsey Rancheria) approached us last summer to partner on a five-year project that will remove Tamarix, Arundo, yellow starthistle, perennial pepper weed and Ravenna grass from their riparian corridor and replace them with native plants that are culturally significant to the Tribe. There will also be education and outreach components to the project which is being funded equally by the Tribe and F&WS. Other property owners, especially upland folks are interested in removing Tamarix from their rangeland to improve water quantity and quality for livestock.

Partnerships with the Bureau of Land Management (Gregg Mangan at the Ukiah, CA office), American Land Conservancy, Lake County Public Works and Colusa County RCD are expanding. It is only through these collaborations that watershed-wide control of invasives is possible.

Jan Lowrey, ED
Cache Creek Conservancy

John Watson, Project Mgr.
Cache Creek Conservancy

Spotted Knapweed Management in the Cleveland Fire Rehabilitation Area

Wendy K. West and Kirk T. Taylor, El Dorado County Department of Agriculture

Project Background

Spotted knapweed has been introduced to the Sierra Nevada Mountains east of Sacramento, California, in an area known as the Cleveland Fire Area. The Cleveland Fire burned 22,485 acres in 1992 after a small 5-foot fire exploded in a matter of hours. One-half of the burned area is public land within the Eldorado National Forest. The remainder is privately owned property, the majority owned and managed by Sierra Pacific Industries (SPI) as commercial timberland. The fire adversely affected many important resources including the watershed stability, wildlife habitat, fisheries, water quality and timber. Over 70 miles of streams and fisheries habitat have been impacted by the damage caused by the fire. This area remains highly susceptible to noxious weed spread and the resultant degradation to the South Fork of Silver Creek and Twenty-five Mile Canyon watersheds.

Spotted knapweed, a highly invasive California Department of Food and Agriculture A-rated noxious weed, was most likely brought in on equipment used during fire suppression, erosion control and timber salvage efforts. The weed was detected on Sierra Pacific Industries commercial timberlands near Peavine Ridge in 1999. Beginning in 1999, hand-pulling and herbicide treatments reduced the size of the infestation at the initial site. Three factors delayed additional survey and eradication efforts: 1) dense fire and slash debris hid many of the plants from view, 2) very steep canyon terrain made detection difficult and labor intensive, 3) funding for the eradication efforts was limited and insufficient.

During fall 2001, the project was raised to emergency status by the El Dorado County Noxious Weed Management Area (WMA). A project partnership and WMA committee were formed which included the Eldorado National Forest, Sierra Pacific Industries, El Dorado County Department of Agriculture, California Department of Food and Agriculture and volunteers from the El Dorado Chapter of the California Native Plant Society. Funding for additional eradication efforts was secured from California Department of Food and Agriculture via an USFS/State and Private Forestry grant, the WMA Senate Bill 1740 grant plus in-kind equipment, materials and labor commitments from the project partners.

During spring 2002, the WMA project committee outlined four objectives to eradicate spotted knapweed on the 20-acre project site:

- Remove debris and lower tree limbs to improve weed detection and treatment effectiveness

- Establish treatment zones within the project area that would provide flexibility in the use of integrated pest management techniques including mechanical and herbicide treatments
- Delimitation and mapping beyond the current 20-acre infestation site, including along the South Fork of Silver Creek, on both private and public (national forest) lands
- Outreach and educational efforts to alert the public to the importance of stopping the spread of invasive weeds. In addition, evidence of unauthorized All Terrain Vehicles (ATV) entering SPI lands prompted the plan to install informational signage and additional fencing at key sites on the property.

Survey and Eradication Activities - 2002

As planned, the fire debris on the steep slopes was hand cleared and piled by California Department of Forestry - Growlersburg Crew and a private contractor during early summer 2002. Plantation trees were also limbed up (to three whorls) and branches piled and burned. The clearing phase was completed in July 2002.

Transline® herbicide was applied utilizing a contracted crew with backpack sprayers at the maximum application rate. The area was resurveyed in August and seven (7) infestations were detected, mapped and mechanically removed in the main project area. A major infestation was also found on the South Fork of Silver Creek. This infestation was mechanically treated by clipping seed heads and hand pulling immature plants. The increased accessibility after the completion of the clearing phase of the project led to the detection of these weed populations.

Delimitation surveys began August 1, 2002 and were initially designed to survey a radius of 1 mile beyond the project area. Teams of 4 to 6 volunteers worked at 20-foot intervals traversing blocks of the steep terrain outlined on topographical maps. The initial delimitation survey included both sides of the South Fork of Silver Creek just below the boundary of the project area. Six infestations were found along the creek ranging from 1 to over 500 plants each. Four other infestations (all <10 plants) were also found on the hillsides. The infestations were mapped utilizing Global Positioning Satellite (GPS) technology and the plants were pulled and/or seed heads clipped and bagged.

The second and third survey days were re-focused to monitor all of the South Fork of Silver Creek to Junction Reservoir, particularly since the creek appeared to be a major corridor for seed movement. In all, forty-six (46) sites were mapped along the creek to the reservoir, a distance of approximately 5 miles. This creek segment runs through both Eldorado National Forest and Sierra Pacific Industries lands. It should be noted that no spotted knapweed was found for approximately ½ mile up the creek from the reservoir where the terrain was not damaged in the Cleveland Fire. This area had good shade and vegetative competition that inhibited the establishment of spotted knapweed.

The delimitation surveys continued through September 2002 with a total of 141 sites mapped and either mechanically or chemically treated. Crews treated infestations utilizing a variety of methods including: 1) Transline® herbicide was utilized on private lands, when deemed appropriate in regards to proximity to the creek, plant maturity 2) by hand pulling plants that had not yet developed seeds and 3) if mature plants were found, seed heads were clipped and bagged to stop the dispersal of seeds that might be associated with hand-pulling the mature plant. The bags of plant and seeds were sealed and transported to the CDFA Pest Exclusion Inspection Station at Truckee for incineration. In-kind contributions of volunteers and staff were provided by U.S. Forest Service, El Dorado County Resource Conservation District, Sierra Pacific Industries, El Dorado County Department of Agriculture and California Department of Food and Agriculture.

In October 2002, the project area was expanded by the WMA committee to include a total of 50 acres of SPI timberlands plus the South Fork of Silver Creek to Junction Reservoir. Subsequently, the additional 30 acres of SPI property was cleared of debris, trees limbed and treated with herbicide. Fencing was installed along Peavine Ridge to discourage All Terrain Vehicles (ATV) from going around the SPI gates into the project area, contributing to the spread of spotted knapweed seed. The Eldorado National Forest began the Environmental Assessment process to treat the infestations found on public lands during the 2002 delimitation survey.

Survey and Eradication Activities - 2003

The detection and eradication efforts continued during 2003, including extensive work by all project partners:

- The Eldorado National Forest completed an Environmental Assessment, which allowed treatment of twelve (12) spotted knapweed infestations detected during the 2002 delimitation survey. Eradication treatments included spot applications of glyphosate, mechanical removal of plants and/or clipping and bagging viable seed. Forest service staff also completed a survey of the surrounding area (approximately 50 acres) insure that all infestations had been documented and treated.
- Sierra Pacific Industries completed the limbing and clearing of the plantation within and bordering the project area and treated the area with herbicide.
- The El Dorado County Weed Management Area received continued funding from the CDFA grant during 2003, which allowed for the hiring of seasonal personnel by the El Dorado County Department of Agriculture to continue the eradication efforts. The crew concentrated efforts in three phases between July and November including, 1) survey and eradication of spotted knapweed along the creek (three times over the season), utilizing herbicide and mechanical methods, as appropriate 2) resurveying and eradicating (as needed) within the project area on SPI property, 3) surveying and eradicating within 100 yards of the canyon on both sides of the creek.

- Volunteers and staff from the El Dorado Chapter of the California Native Plant Society, USFS, SPI and El Dorado County Department of Agriculture completed two delimitation surveys.

A total of 92 infestations were mapped and treated in 2003 within the project area plus 12 sites on USFS property. All sites will be re-evaluated in 2004 by the project partners.

Education and Outreach Components
As with any pest eradication plan in a public area, an effective education and outreach component is vital to the success of the project. The education and outreach activities utilized for the Cleveland Fire Area Spotted Knapweed Eradication Project included:

- Media outreach to publicize the threat posed by the spread of spotted knapweed in El Dorado County and the Sierra Nevada Mountains;
  - ✓ Articles were generated in two newspapers
  - ✓ A television news segment was produced by Sacramento Channel 3, which was broadcast throughout the region
- Worked to educate the public regarding the importance of preventing the spread of this invasive weed, especially by ATVs entering around SPI gates;
  - ✓ A sign was posted at the gate to discourage entrance into the area
- Produced a handout/flier for distribution to the general public with information about spotted knapweed and the threats (water quality degradation, loss of wildlife habitat, etc.) posed by the spread
- Posted informational posters at campgrounds and public areas in the Crystal Basin area describing how to identify spotted knapweed and whom to contact if the plant was found

Results
Adequate funding and planning for survey and eradication work has been instrumental toward meeting the goal of eradication of spotted knapweed in the Silver Creek Watershed. The clearing and delimitation surveys over the past two seasons have defined the extent of the problem. Continued funding and support will be needed to meet the eradication goal by 2010.

This project has also highlighted the importance of collaborative efforts in invasive weed eradication work that has been supported by the California Weed Management Area infrastructure. Without all parties cooperating and communicating, logistic, environmental and regulatory challenges could not have been dealt with in a timely manner. This is a classic illustration that planning and funding are imperative--- *invasive weeds won't wait*!

Control of Cut Juniper Stumps and Small Trees in Northeastern California

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Western juniper (*Juniperus occidentalis*) has invaded over three million acres of sagebrush rangeland in northeastern California. In the absence of fire, juniper will spread into a variety of sagebrush habitats. Prior to settlement fire frequencies are thought to have limited juniper to fire safe sites, such as rim-rocks, and shallow soils that lacked sufficient understory fuel. With the advent of fire control efforts and reduction in fine fuels by livestock, fire has been largely suppressed which has contributed to a tremendous increase and spread of western juniper over the past century (Miller and Rose 1999) (Soule et al. 2002). The proliferation of juniper is easily borne out in many areas by comparing photos from the early 1900's with the same landscape today. Likewise, efforts to age juniper, indicate the vast majority of trees are from 80 to 120 years old.

The potential negative impacts from juniper invasion are well documented (Miller et al. 2000) (Bedell et al. 1993). On most range sites, once juniper reaches approximately 10% canopy cover it begins to have a serious impact on the understory, shrubs grasses and forbs. At 30 to 50% canopy cover, almost all the understory vegetation is lost from the site, and highly accelerated rates of erosion may result. Juniper dominated sites have far lower value habitat for most native wildlife, reduced forage for livestock, and at times impaired watershed function. Despite these widespread impacts, the proliferation of juniper continues to far out pace any efforts to control or remove it on a meaningful scale.

Mechanical shearing and chipping operations that harvest juniper to produce biomass fuel is one approach that does have the potential to clear significant acreages of juniper dominated rangeland. Using feller-buncher logging equipment independent operators have begun supplying biomass power plants with juniper chips. Several ranches have participated in these operations. The typical arrangement is that the chipping operators do not pay or receive payment for taking juniper off the ranch. Their income is based only on selling the chips. The benefit to the ranch is that removal of juniper usually results in increased understory production, biomass and plant diversity which equates to more livestock forage and better wildlife habitat (Bates et al. 2000). Concurrently the Bureau of Land Management in northeastern California is developing an EIS to allow substantial juniper chipping on the lands they manage.

Objective

From a rangeland forage and wildlife habitat standpoint, there are two key shortcomings of shearing operations. First is that there are often live stumps with low growing limbs below the cutting level that are left to re-grow, and many smaller trees (2 to 6 feet in height) that are impractical for the shearing/chipping equipment are left in place, poised to reclaim the site. Furthermore there are vast areas that make up the “advancing front” of juniper encroachment that are made up entirely of small trees that are not practical for chipping operations. The objectives of this study were to test chemical, mechanical and fire treatments on the control of living juniper stumps and small juniper trees that are left behind following the shearing operation.

Methods: Juniper shearing was conducted at two locations in Lassen County in 2000 and 2001. Sites were within the Willow Creek drainage south of Adin, CA and the other was just below sagehen summit south of Likely, CA. The Sagehen site is at approximately 5100 ft elevation, with a northeasterly aspect. The soils are mapped into the Searles-Orhood-Davada association characterized as a well-drained, very stony loam with 20 to 40” rooting depth. Plant community is dominated by big sagebrush, juniper, and perennial bunch grasses. The Willow Creek site is at approximately 4900 feet elevation with a southwesterly aspect. Soils are mapped into the Pass Canyon-Los Gatos family complex characterized as a well-drained very cobbly to gravelly loam with a rooting depth from 10 to 40 inches. Plant community is dominated by juniper, big sage brush, bitterbrush, low sagebrush and perennial bunch grasses.

This study can be separated into two parts; first, treatment of cut stumps of larger trees (6 to 14” dbh) and second, treatment of small trees (1 to 6 ft in height). Living cut stumps were treated with different formulations of imazapyr (Arsenal and Chopper). Herbicide applications were applied by thoroughly wetting the stump surface with a backpack sprayer. Small trees were treated with hexazinone (Velpar L and Pronone Power Pellet), imazapyr (Arsenal AC and Chopper), hand-held brush saws, and a weed propane burner. Spray treatments consisting of basal, thin-line, and overtop techniques were applied and compared for effectiveness on the small trees. Treatments were applied both in the fall of 2001 and spring of 2002 at both locations. Twelve individual trees were treated and tagged per each herbicide treatment at each location. Treatment effectiveness was assessed in the fall of 2002 about 10 and 6 months after the respective treatments. A control rating was recorded for each individual tree.

Results

Cut Stumps

Stump treatments with imazapyr were effective (Figure 1). Spring applied treatments were significantly more effective than treatments applied in fall ($p<.01$). This is likely a result of more active growth that occurs during the spring. Arsenal was marginally more effective than Chopper formulations.

Small Trees

Herbicidal treatments were also very effective on small juniper trees (Figure 2). While Velpar L was slightly more effective in the fall than spring, this is likely due to the extremely dry weather conditions that occurred during the spring of application. Fall applied Velpar L however, had the benefit of winter precipitation.

The extremely dry spring may well have reduced the effectiveness of the Pronone Power Pellet as well. Earlier application to take advantage of winter moisture or more typical spring rains would have probably moved the herbicide further into the root zone therefore improving effectiveness. It appears as if less precipitation is needed to move the liquid concentrate form of hexazinone than the pelleted form in to the root zone.

Similar to the cut stumps, the small tree spray applications with imazapyr were significantly ($p<.01$) more effective in the spring.

Comparison of spray techniques are shown in Figure 3. Although the overtop method takes a bit more time and herbicide it is significantly more effective than thin-line or basal applications.

Results were similar at both locations. We had better control with the spring Velpar treatments at the Sagehen site than at Willow Creek. We suggest that because of the very dry spring, better herbicide activity was attained at Sagehen which is a little wetter site with deeper soils and probably experienced better herbicide movement and longer growing conditions than at Willow Creek.

Mechanical sawing and the propane burner also effectively killed the small trees, each providing better than 90% control. However, both these techniques were approximately three times slower to apply than the herbicide treatments. A two-man crew is required to use the propane burner, one to manage the tank and hose while the other handles the torch. The propane burner is very cumbersome on rangeland sites and was not at all practical on slopes over 20 percent. The brush cutter saw is easier to use but its effectiveness is limited to trees under 2 inches in diameter and only on sites that have very few rocks.

Conclusions

This research shows that herbicidal applications can enhance the benefit of juniper shearing operations by efficiently and selectively killing the living stumps and small trees that are left behind. Herbicide treatments were much more easily applied and more feasible on rangeland conditions than the hand held saw or the propane burner. For limited applications where herbicides are not desired, those methods may be effective as well.

An important attribute to these control treatments, is that the remaining plant community can be kept intact. Small juniper trees or stumps can be selectively removed, leaving the existing vegetation in place to provide wildlife habitat, livestock forage, or other land use objectives. Although fire is the natural process to control the spread of juniper, realistically we need to recognize the many obstacles to the widespread use of fire both from a biological and social/cultural standpoint. Alternatively, combinations of mechanical and chemical juniper control have the potential to provide short and long-term benefits to rangeland health and productivity over a vast landscape.

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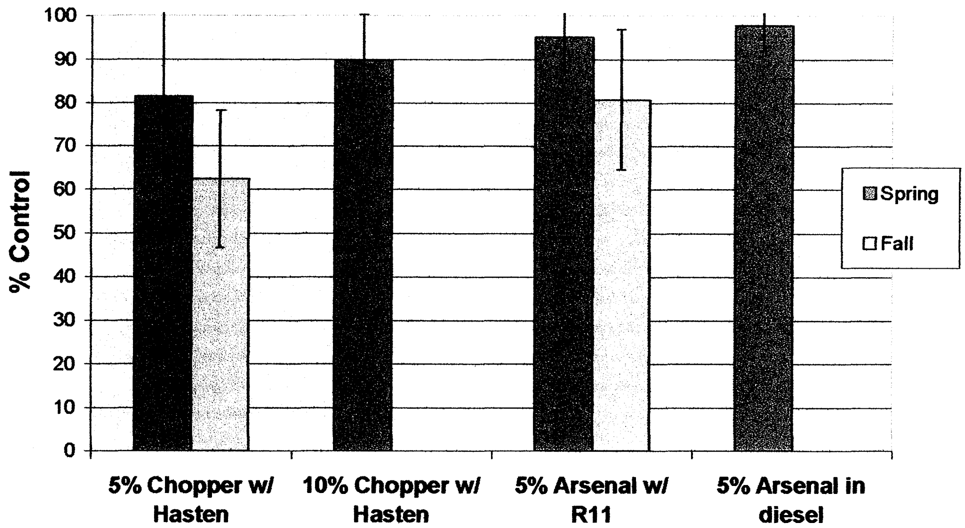

Figure 1. Herbicide effectiveness on live cut juniper stumps.

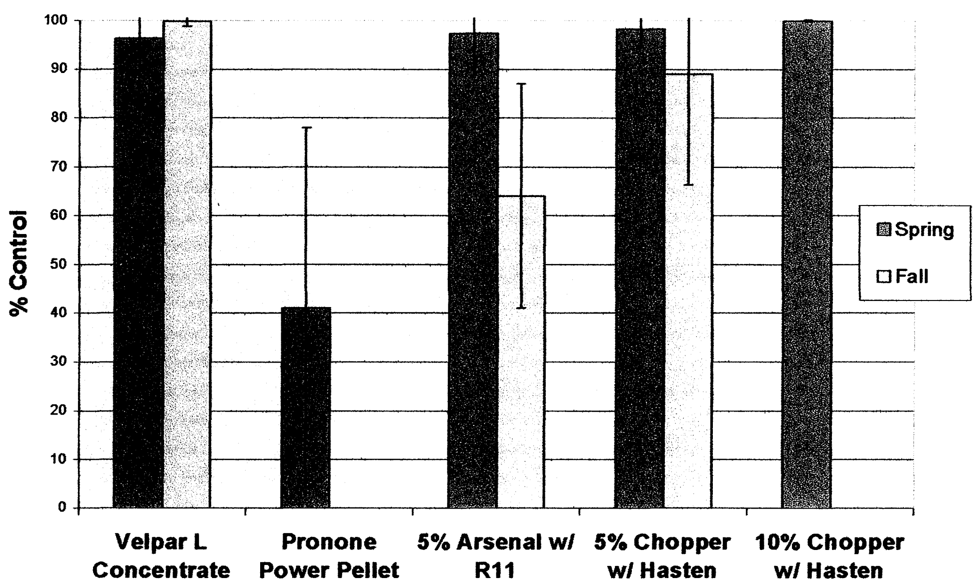

Figure 2. Herbicide effectiveness on small juniper trees < 6' ht..

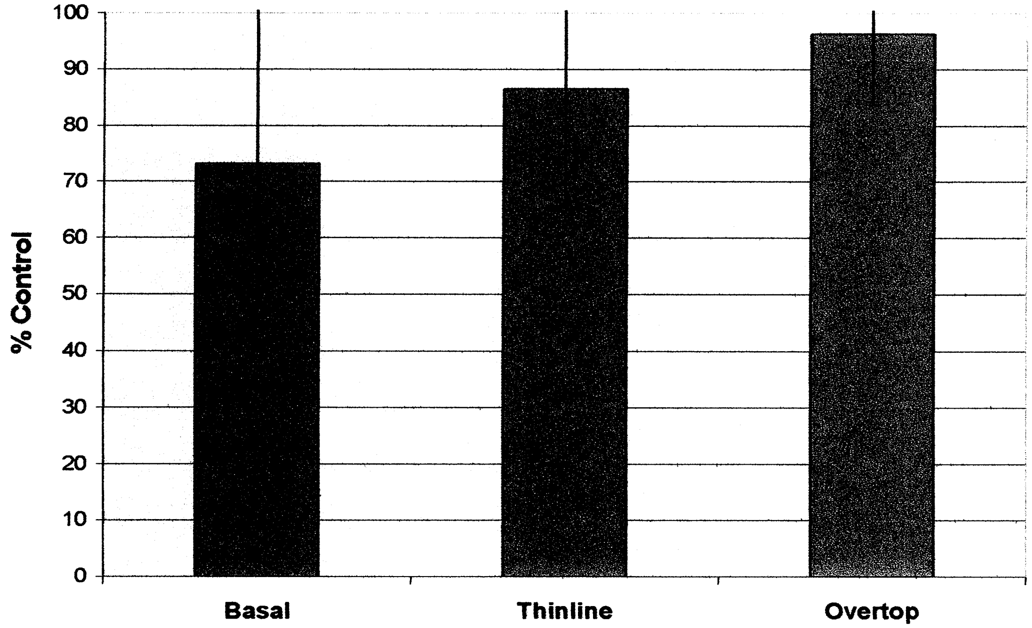

Figure 3. A comparison of spray technique on the effectiveness of imazapyr for controlling small juniper trees < 6' ht.

Hallucinogens, Medicines, and Foods, the Double Lives of Poisonous Plants

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Many of our worst weeds are plants that have been used by people for centuries. This is true of poisonous plants as well. An excellent example to start with is St. John's Wort or Klamath Weed (*Hypericum perforatum*). This weed, introduced from Europe, once infested millions of acres of rangeland in northern California; the infestation was brought under control by the release of several beetle species, mostly in the genus *Chrysolina* (the Klamath Weed Beetle); this was one of the most successful bio-control campaigns in history (Harris, 1988).

The infestation of St. John's Wort was considered especially problematic, because after ingestion of this plant, range animals (goats, sheep, horses, and cattle) develop photo-sensitization, lose areas of skin, refuse to eat, develop blindness, and may die due to starvation. The poisonous principle that causes photosensitization is hypericin (Fuller and McClintock, 1986). Yet those interested in medicinal plants know that this species has been used as a medicinal plant for centuries and is now a lucrative off-the-counter drug sold in all drugstores for the treatment of mild depression. The chemical agent thought to be involved in this is hyperforin (Barnes, et al. 2001), rather than hypericin as previously thought.

This particular example brings up several important concepts that should be considered when discussing useful poisonous plants:

- **Species Specificity**: Some poisonous plants are only poisonous to particular animal species. One of the most famous in California is yellow star thistle (*Centaurea solstitialis*) which is particularly toxic to horses (Fuller and McClintock, 1986). In the case of St. John's Wort, most reports of poisonings are in range animals, however significant photosensitive reactions do occur in humans (Brockmoller et al., 1997). Therefore, it is important to find out what species are affected by a plant that is labeled as poisonous.
- **Dosage:** Often the difference between a medicine and a poison is dosage level. In the case of St. John's Wort, probably the reason it so poisonous to livestock is because those animals ingest the plants in such large amounts. There are many examples of poisonous plants that are used medicinally in the correct dosage.
- **Preparation:** In addition, many plants that are thought to be toxic can be rendered harmless or medicinal by correct preparation of the plant for ingestion – which is again a matter of dosage. This is not true of commercial preparations of St. John's Wort, otherwise warnings about photo-sensitization wouldn't be posted on the bottles.

A good example of a very poisonous plant that when used in the correct dosage has been used as an effective medicine in both Europe and North America is Larkspur (*Delphinium* spp.).

Fuller and McClintock (1986) state that this poisonous genus probably causes more loss of cattle than any other, and the genus is also considered poisonous to humans (Hill and Fouand, 1986). The toxic compounds consist of several diterpene alkaloids including delphinine, delphineidine, and ajacine, which are found most concentrated in the seeds but are also found in other plant parts (Hill and Fouand, 1986). In high dosage, these compounds cause digestive and muscular system disruption which can lead to death (Fuller and McClintock, 1986). Used in low dosage, however, these same compounds have been used internally to cure stomach ache and intestinal parasites, as well as externally to treat lice. It must be noted, however, that taken internally, the medicine causes vomiting and diarrhea – ie. it is a bit like taking ipecac (Moerman, 1998).

Another good example of a toxic genus that has been used widely for medicine is Milkweed. The genus *Asclepias* has been known to be toxic to grazing animals, chickens, and humans, with symptoms ranging from weakness, staggering, seizures, breathing difficulty, coma, and death. The toxins, which occur throughout the plant, are not well characterized, but include toxic resinoids, cardioactive glycosides, and alkaloids (Fuller and McClintock, 1986; Hill and Fouand, 1986). However, plants in this genus have been taken internally by Native Americans for a variety of medicinal purposes including backache, stomachache, headache, rheumatism, and cough (Moerman, 1998). Many Websites dealing with medicinal herbs discuss the genus, although they warn of the toxic properties and the need for careful preparation.

Just as there is a fine line between medicine and poison, some plants find themselves walking the fine line between hallucinogen and poison. Top among these are Jimson Weed (*Datura* spp.) and the Peyote cactus (*Lophophora williamsii*). In the case of Peyote, the user becomes quite ill prior to reaching a stage where hallucination is possible. In both cases, the toxic but hallucinogenic compounds are alkaloids: scopolamine in Jimson Weed and mescaline in Peyote. Various species of Jimson Weed has been used for centuries in spiritual ceremonies by shamans on both sides of the Pacific; Peyote is a New World hallucinogen (Lewis and Elvin-Lewis, 1977; Heiser, 1969; Schultes and Hofmann, 1992).

Somewhat different in concept are poisonous plants that are used as a food source, although in many cultures, the boundary between medicine and food is very ambiguous. Here, the importance of good preparation is obviously paramount. There are many examples of food plants that fall into this category – some which are important world food crops. A good example is tapioca or cassava (*Manihot esculenta*) which produces a storage root high in starch, but also high in cyanide (O'Hair, 1995). Another well-known food plant that can be toxic is Rhubarb (*Rheum* spp.), which contains high concentrations of oxalic acid, especially in the leaf blades (Fuller and McClintock, 1986). Interesting California native plants that fall into this category include California Buckeye (*Aesculus californica*) and Elderberry (*Sambucus* spp.).

Buckeye is a multi-purpose plant that was used as both a fish-poison and a food by California Indians. All parts of the plant contain the toxic compound Aesculin, a coumarin glycoside; even the nectar is poisonous to honey bees. Symptoms of poisoning (in humans and cattle) include digestive upset, stupor, dilated pupils, abortion, paralysis, and, rarely, death (Fuller and McClintock, 1986). The poisonous nature of the plant was well-known by California

Indians. The large seeds were ground up and the flour carefully leached so that it could be used as a food source; the unleached seed flour was used as a fish poison (Moerman, 1997).

Elderberry is another multi-purpose plant: an important medicine, a source of fruit, and a source of wood for musical instruments. In Fuller and McClintock (1986) the fruits are not listed as toxic, although they warn that eating too many uncooked berries can cause nausea. All other parts of the plant are poisonous, especially the roots; toxins include alkaloids and cyanogenic glycosides. As well as being used for juice and jams, the cooked berry juice is a popular winter cold remedy in Europe (for boosting immune system function) and plant preparations are now sold in this country in both capsule and liquid form (Dean, personal experience). California Indians used an infusion made from the blossoms as a cold remedy, among other medicinal uses (Moerman, 1997).

Finally, I close by relating the the many uses of the multi-purpose weed Black Nightshade (*Solanum nigrum*), a lowly, underappreciated European weed. Most people consider this plant highly toxic and are warned from an early age not to ingest it. I, of course, have a steadily increasing population growing in my front lawn under a shade tree, and I am watching its growth and reproduction with interest. As reported in Fuller and McClintock (1986), all plants in the genus *Solanum*, including potatoes and eggplants, contain the alkaloids solanine and solanidine. These compounds can cause gastric irritation, vomiting, dizziness, coma and death, which is why people are wary of all nightshades, including green potatoes (Lewis and Elvin-Lewis, 1977).

I first became aware of the many uses of black nightshade and its close relative American nightshade, while taking an edible plants course in the Bay Area. The instructor had us eat the fully ripe berries, and it was at that point that I realized that the black berries are not toxic, perhaps just the unripe green berries (Schilling, 1992); in fact the ripe berries of these species are sought out by children in Asian cultures (Schilling, 1992), and they have been traditionally used to make pies and jams (Hedrick, 1972). However, since then, it has come to my attention that many African and Asian cultures also use this plant as a cooked pot-herb or edible green (Corlette et al., 2003; Hedrick, 1972; Schilling, 1992). In addition, Black and American Nightshades are used medicinally in many cultures – taken internally for cancer, urinary tract infections, and hypertension (Schilling, 1992; Dean, unpublished) and used externally for skin complaints (Esquival & Zolla, 1986; Badruzzaman et al., 1989).

As you can see from the above examples, the same plant can be considered a poison and a medicine, a poison and a hallucinogen, or a poison and a food. In cultures other than our own, the boundaries between these categories are often hazy and dosage may determine the toxicity of a plant.

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Weeds that Cause Dermatitis

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Most of the compounds responsible for dermatitis are not directly involved with plant metabolism. These natural products are frequently referred to as secondary compounds that function as defense chemicals. Not only can secondary compounds protect the plant by inducing dermatitis or systemic poisoning in animals, but many others act as natural insecticides, nematocides, fungicides, or even herbicides through a phenomenon known as allelopathy.

Certain dermatitis-causing plants may invoke an allergic response by simple contact, while others must be crushed to release the irritant compounds. Another significant factor is the distribution of the dermatitis-producing substances in the plant. For example, primin, the antigenic substance of the primrose, is stored in fragile glandular hairs and is released by casual contact. In contrast, the irritants found in daisies are stored in pollen or in resin canals and released only when the plant is bruised or crushed. In some plants, the sensitizing compounds may be in the leaves and stems, though in others they may be in the flowers, pollen, and roots.

Dermatitis inducing compounds are categorized into four basic groups (Benezra et al. 1985).

1. Mechanical irritants which elicit their irritating response by means of small, easily detectable rough hairs or bristles, tiny fragments of the plant, or by means of acicular calcium oxalate crystal.
2. Primary irritants which cause dermatitis within a short period of time after contact. These irritants involve chemical secretions, are non-selective and will affect all persons on the first exposure if the concentration is sufficient.
3. Contact allergens are characterized by an initial sensitizing contact with the plant chemical. These are selective responses. A rash may appear after a couple of days to a week or more, or may not appear at all. However, a subsequent contact with the plant may induce a rash within only a day or so, and usually with greater severity.
4. Phytophotodermatitis requires contact with the irritant compound followed by exposure to ultraviolet radiation from sunlight. In livestock, photosensitization can occur following ingestion of a plant. The irritant compounds are transported in the blood to the peripheral capillaries where they are activated by sunlight, resulting in dermatitis.

MECHANICAL IRRITANTS

Mechanical irritants are associated with a number of families. Some of the more notorious species occur in the tropical regions of the world, though a large number also occur in California.

Many species of the Boraginaceae (borage family) in both the United States and Europe are covered with coarse, stiff hairs, which penetrate the skin and induce dermatitis (Benezra et al. 1985). This would include genera such as *Amsinckia* (fiddleneck), *Borago* (borage), *Echium* (viper's bugloss), and *Symphytum* (comfrey).

A few grass species may cause mechanical irritation. The sharp hairs and awns of barley and other cereals cause 'cereal dust dermatitis' (utricularia papules) while the spicules on millet or foxtail (*Panicum* spp.), rice (*Orvza* spp.) and bamboo elicit dermatitis in workers handling crops or litter straw (Benezra et al. 1985).

Occupational dermatitis caused by fruit of prickly pear cactus (*Opuntia ficus-indica* and *0. cochinillifera*) is common in pickers, distributors, and sellers of the fruit (Shanon and Sagher 1956). The glochidia are small barbed bristles which readily penetrate the skin, break off, and cause 'sabra dermatitis'. It is seasonal, however, occurring between July and October.

Certainly the most noted group of mechanical irritants involves plants with stinging hairs. The trichomes of these plants are tapered, elongated cells, constricted just below the tip with a bulbous base embedded in a sheathing pedestal. When the tip of the hair is broken off on contact with the skin, it acts as a hypodermic needle injecting toxin into the wound (Thurston 1974). Mild skin irritation generally occurs with various species of stinging or burning nettles (*Urtica* spp.), however, very painful, severe dermatitis and even death can result from other tropical species in the nettle family (e.g. *Laportea* spp., stinging tree; *Urera* spp., stinging nettle) (MacFarlane 1963).

Little is known of the composition of the nettle toxins, though acetylcholine, histamine, and 5-hydroxytyptamine have been reported to be present.

PRIMARY IRRITANTS

Primary irritants produce direct inflammatory irritation to the skin in response to tissue damage. The chemical compounds responsible may be present in the leaves, bark, sap, roots, stem, flowers, fruit, pollen, hairs, or other appendages. Some substances are contacted on the plant surfaces, others are released only when the plant is bruised or crushed. The toxic potential of these primary irritants may vary with the season, stage of maturation, weather, locality grown, etc.

Several members of the Ranunculaceae (buttercup family) cause dermatitis when crushed on the skin. Such familiar genera include *Delphinium* (larkspur), and *Ranunculus* (buttercup). The irritant properties have been linked mainly to the unsaturated lactone protoanemonin (Benezra et al. 1985). When the plants are bruised, the non-irritant glycoside ranunculin is broken down to protoanemonin by means of a simple enzyme induced cleavage. Protoanemonin will bind tightly to sulfhydryl groups causing acute dermatitis at the sites of contact. Symptoms occur within an hour of application and are characterized by a burning sensation followed by inflammation. Crushed leaves release a vapor irritant to the conjunctiva. Children chewing the leaves or stems of the plants may acquire blisters on the face and around the lips.

Capsaicin and the related oleoresin capsaicinoids, are responsible for the pungent taste of chili peppers (*Capsicum minumum* and *C. fructescens*), which are members of the Solanaceae (nightshade family). In addition, these same compounds are known as powerful skin irritants, inducing erythema without blisters.

Ambrosic acid, a sesquiterpene isolated from the pollen of *Ambrosia artemisiifolia* (common ragweed) in the Asteraceae (sunflower family) has also been reported as an irritant compound. It is also known as a contact allergen.

Plants of the Brassicaceae (mustard family) contain the glucoside sinigrin, which is harmless in the dry state, but is converted into the irritant volatile mustard oils in the presence of water.

The mustard oils constitute a group of substances known chemically as the isothiocyanates (Fuller and McClintock 1986, Kingsbury 1964). These compounds are a well defined and unique class of natural irritants, having both allergenic and irritant properties. Many varieties of *Brassica oleracea* (e.g. cauliflower, broccoli, cabbage, brussel sprouts, etc.) cause hand dermatitis in plant growers. Radishes (*Raphanus sativa*) is also known to cause irritant dermatitis. Although weedy members of these two genera can also cause dermatitis, cases are very rare since they are not handled to the extent of their crops counterparts.

Many species of the Euphorbiaceae (spurge family) contain a highly irritant sap or latex (Fuller and McClintock 1986). The irritant principles of these plants have been shown to be esters of closely related diterpene polyols based on the tigliane, ingenane, and daphnane hydrocarbon skeletons. The mode of action of these potent irritants remains unknown at the present time, but it is probable that they induce inflammation by a specific effect at a membrane bound receptor site, as well as by tissue damage.

Tigliane polyol is known as phorbol (Benezra et al. 1985). It was originally isolated in *Croton tiplium* (croton), but has since been found in *Euphorbia* spp. (spurges) and from *Sapium japonicum* (Japanese tallow tree). In addition to severe dermatitis, phorbol also produces keratoconjunctivitis. Ingenane polyol esters known as ingenol have been isolated from the genus *Euphorbia*. It similarly causes severe dermatitis and inflammation of the skin.

CONTACT ALLERGENS

Contact allergens are the most frequent type of inflammatory skin condition induced by plants and plant products. The antigen may be sequestered in resin canals and released only if the plant is bruised (e.g. *Toxicodendron* spp.). It may be readily released by fragile glandular hairs (e.g. *Primula obconica*), excreted onto the leaf or coat of the pollen (e.g. some *Ambrosia* spp.), or be disseminated widely by wind on trichomes and tiny fragments of powdered dried plants (e.g. *Parthenium hysterophorus*). The amount of allergen synthesized varies not only among different populations of the same species but also in the same specimen, being influenced by the stage of growth, state of health, and geographic location of the plant.

Susceptibility to sensitization by contact allergens is genetically determined, and is related to race, sex, and possibly age. Sensitization is also dependent on the sensitizing potential of the allergen, the quantity, and the method of exposure. Consequently, there are considerable differences among sensitizing plants in their ability to induce allergic dermatitis. Once sensitization has occurred, however, subsequent exposure will induce dermatitis.

Urushiols

The urushiols are, unquestionably, the most common dermatitis inducing agents known. They are extremely common in the Anacardiaceae (cashew family), but have also been isolated from the fruit pulp of *Ginkgo biloba* (ginkgo) and from species of the Proteaceae (protea family). These substances are oleoresins related to pentadecylcatechols (PDC) (Benezra et al. 1985).

In the United States, members of the genus *Toxicodendron* (Anacardiaceae) are responsible for more cases of allergic contact dermatitis than all other allergens combined. This is often called rhus dermatitis since the genus *Toxicodendron* was once placed within the genus *Rhus*. In the eastern United States, rhus dermatitis from poison ivy (*Toxicodendron radicans*) usually occurs in the spring and summer. However, in the western portion of the country, where winters are more conducive to outdoor activities, Pacific poison oak (*Toxicodendron diversilobum*) dermatitis occurs year round. Poison sumac (*Toxicodendron vernix*) is found only in woody, swampy areas and is, therefore, not as big a problem as the previously mentioned species.

Characteristic symptoms of rhus dermatitis include the linear pattern of vesicles or papules on the skin. This pattern, however, may differ if contact with the urushiols is not by direct means. Contact with objects contaminated with sap, such as clothing, dogs, equipment, or particularly from smoke containing particulates of the oleoresin can also produce minor to severe cases of dermatitis (DiTomaso and Lanini 1996).

Antigens of *Toxicodendron* spp. enter the skin so rapidly that the oil must be totally removed with ten minutes of exposure. Washing with soap or detergents after several minutes of contact will not remove the toxin though a similar treatment renders contaminated clothing and objects harmless.

One of the most common misconceptions concerning rhus dermatitis is that the vesicle fluid is also antigenic and is responsible for the spread of the dermatitis. This is not true. The toxins may be spread if they accumulate under the fingernails or they may appear to spread as a result of differential appearance of symptoms from one region of the body to another.

Susceptibility may vary with race. Dark-skinned individuals seem less susceptible than others to the urushiol toxins. As a group, it is estimated that approximately 70 to 75% of the population of the United States would acquire rhus dermatitis if exposed casually to the plants.

The sap and oil from the shell of the cashew nut (*Anacardium occidentale*; Anacardiaceae) contains a potent sensitizer, which is destroyed by heat. Occasionally reports of dermatitis from eating raw cashews occur (Benezra and Ducombs 1987). The tree sap of the mango (*Mangifera indica*; Anacardiaceae) contains a catechol similar to *Toxicodendron* (Mitchell and Rook 1979). Persons sensitive to PDC occasionally develop a rhus-like rash around the mouth when the stem sap has contaminated the fruit.

Sesquiterpenes

The sesquiterpene lactones are another large group of compounds which frequently cause allergenic contact dermatitis (Hausen 1979). In recent years about 50 sesquiterpene lactones have been shown to elicit dermatitis in sensitized individuals.

The Asteraceae probably has the greatest number of species which cause allergenic dermatitis, particularly in California. The sesquiterpene lactones involved can be concentrated in either the fragile glandular trichomes or on the pollen grains. In the trichomes, parthenin is probably the principle allergen with its highest concentration in the hairs on both leaf surfaces, phyllaries, and achenes.

Pollen may contain two distinct antigens: 1) a protein fraction causing asthma or inflammation of the mucus membranes of the nose and 2) an oleoresin producing contact dermatitis. This type of allergy, caused by wind-borne pollen, is quite distinct from hay fever. Symptoms generally occur on the exposed surfaces around the neck, face, chest, arms, and legs. Whenever this pattern is observed it is suggestive of air-borne dermatitis.

Ragweed (*Ambrosia* spp.) dermatitis is the most prevalent form of wind-borne dermatitis in the United States. It is in no way related to an individual's sensitivity to the hay fever or asthma producing antigen present in some members of the genus. Curiously, men are much more commonly affected than women in a ratio of about 20:1 (Benezra et al. 1985).

Some members of the Asteraceae do not have air-borne pollen, yet are still common contact allergens. Daisies (*Chrysanthemum* spp.) are the most common offenders. Though the pollen is not wind dispersed, it occasionally causes dermatitis when exposed to various areas of the body, particularly the facial regions.

Several other members of the composites produce pollen induced dermatitis. These include a few species of *Helenium* (sneezeweed), *Xanthium strumarium* (common cocklebur), *Iva* spp. (poverty weed), and a few *Artemisia* (sagebrush) species.

Miscellaneous Allergens

Algerian ivy (*Hedera canariensis*) and English ivy (*Hedera helix*) of the Araliaceae (ginseng family) must be bruised to release their allergenic sap. Occupational dermatitis is rare because there are few supplying nurseries where the plant is cut and propagated, but in them dermatitis is common among the staff. The overall incidence is unknown, but it may not be rare as once thought. This may be due to its close symptomatic resemblance to rhus dermatitis (Benezra et al. 1985).

Poison oak-like rashes are also observed with *Phacelia pedicellata* (scorpion weed, phacelia) and *P. crenulata* (heliotrope phacelia) contact. However, only the viscid glandular species seem to be allergic. In the western United States this genus may be responsible for many supposed cases of poison oak dermatitis (Reynolds et al. 1980).

PHYTOPHOTODERMATITIS

Humans

Many compounds can become photo-activated on exposure to a certain waveband of light, typically in the ultraviolet or near visible range. These compounds may become either primary irritants or allergens. In the plant kingdom, the only compounds that have been reported to evoke photodermatitis are furocoumarins. These phototoxic furocoumarins act only as primary irritants such that all individuals may be expected to react on the first exposure if the concentration of the phototoxic principle and light intensity is sufficient. Under these conditions the characteristic skin conditions resemble that of sunburn about 48 hours after exposure. In addition, the residual effects of phytophotodermatitis may include hyperpigmentation which can persist for months.

Furocoumarins have only a limited distribution in the plant kingdom, having been found in the Moraceae (mulberry family), Apiaceae (carrot family), Rutaceae (citrus family), Rosaceae (rose family), and Fabaceae (pea family). Among the naturally occurring furocoumarins, psoralen is the most active phototoxic agent (Benezra et al. 1985).

Within the Apiaceae, *Pastinaca sativa* (parsnip), *Heracleum lanatum* (cow parsnip), and *Apium graveolens* (celery) are the most well known. However, other species of *Pastinaca* and *Heracleum*, as well as *Angelica archangelica* (angelica, archangel) and *Ammi majus* (greater ammi, bishop's weed) are also considered to have photosensitizing capacities. In the Rutaceae, the leaves of *Ruta graveolens* (common rue) are a well known cause of phytophotodermatitis as are several other species, including *Citrus aurantifolia* (lime), *C. aurantium* (sour orange), *C. bergamia* (bergamot orange), and *C. limon* (lemon). Only *Ficus carica* (edible fig) contains a photosensitive furocoumarin, bergapten, in the Moraceae. In the Fabaceae, *Psoralea* spp. (scurfy pea) contains the photosensitive furocoumarin psoralen, and are the only species in the family known to cause phytophotodermatitis.

<u>Animals</u>

Phytophotodermatitis in animals nearly always involves the ingestion of various toxic plants. In photosensitizations caused by plants, the photodynamic substance may come directly and unchanged from the plant, or it may be a normal breakdown product in digestion, usually eliminated by the liver. The former is often called primary photosensitivity, and the latter may be termed hepatogenic photosensitivity (Kingsbury 1964).

Photosensitivity occurs over a wide range of wavelengths at the blue end of the visible spectrum and in the longer ultraviolet. A hypersensitive animal reacts to light with the development of erythema and pruritus followed by edematous suffusions and eventual necrosis of the skin in the affected parts. The reaction will occur only in areas of unpigmented or lightly pigmented skin which are not covered by a dense light-screening coat of hair. Hence, black-skinned animals tend to be fairly resistant to photosensitization.

The photodynamic action, by itself, is rarely lethal, but deaths are frequent from starvation, other secondary effects, or from liver damage. In some animals, such as sheep, affected skin will not grow further wool.

Only two plants occurring in North America have been shown to produce primary photosensitivity; *Hypericum perforatum* (St. Johnswort, Klamath weed) in the Hypericaceae and *Fagopyrum sagittatum* (buckwheat) in the Polygonaceae (knotweed family). The vegetation from either plant contains a pigment which is absorbed through the intestinal wall, enters the circulation, is not eliminated by the liver or kidney and, therefore, reaches the peripheral circulation. All the symptoms produced by either of these plants are solely those of photosensitization.

St. Johnswort poisoning has been reported in sheep, cattle, horses, and occasionally goats. The weed is dangerous at all stages of growth. Young tender shoots may attract animals in the spring. Normally, cattle and sheep will not eat mature St. Johnswort if they have other forage. Hay containing the weed can also cause poisoning in the winter.

A particularly intense reaction may occur in sheep when sheared, since removal of the wool leaves the skin unprotected against sunlight. In severe attacks, death after convulsions occasionally occurs. More frequently, however, the animals survive the acute stages of the syndrome but suffer more or less permanently from the aftereffects.

In cattle, cases of *Hypericum* poisonings have been described in which the entire herd was found "with the white skin hanging in rags and the dark skin soft and supple as a glove." Generally, animals develop intense itching and may rub affected areas raw.

The photodynamic pigment in *Hypericum* was isolated and identified as a napthodianthrone derivative, and named hypericin. It is stable to drying and resistant to destruction by heat.

In sheep, about 5% of an animal's weight fed in one day would result in symptoms a day or two later. Cattle are more susceptible, with 1% of the body weight toxic. On the range, symptoms of photosensitization usually appear two days to three weeks after animals have access to the plant.

Puncturevine (*Tribulus terrestris*) is one of the major causes of bighead in sheep in South Africa and Australia, where it results in a great deal of economic loss. Cases of *Tribulus* photosensitization in the United States, however, appear to be rare. Typical lesions of severe photosensitization or bighead include blindness, necrosis of the skin, loss of lips and ears, and high mortality among young animals.

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Poisonous Plants in the Landscape

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Of the 20,000 species of plants native or naturalized in the United States, about 700 species have toxic characteristics[1]. Sometimes the poison is only in one part of the plant e.g. the leaf blade of rhubarb is toxic, whereas the petiole is edible. In other plants the poison is throughout the entire plant, e.g. common oleander (*Nerium oleander*).

Many homeowners and gardeners are not aware that some common ornamental plants in and around homes are highly poisonous. Some are toxic if eaten; others may cause irritation or dermatitis if they come in contact with the skin. While it is true that the effects of some plants are relatively mild and easily treated, some of the most toxic poisons known to man occur naturally in plants and can be fatal if as little as a seed or leaf is consumed.

The California Poison Action Line receives approximately 330,000 phone calls a year (820 calls per day). The majority of calls concern medicines and illegal drugs, but approximately 6% (13,800) of these calls are related to poisonous plants, fungi, and weeds. One in ten phone calls concerns an unidentified plant. In these situations the CA Poison Action Line recommends going to the nursery to get an accurate identification of the plant before going to the hospital, clinic, or doctor's office. There is usually enough time.

Most poisonous ornamental plants have such an unpleasant taste or consistency it is unlikely that anyone would chew them very long or swallow them. While this may be true for adults, small children often chew on anything that comes to hand. Children of all ages have been poisoned by sucking the nectar from flowers, using twigs for flutes, pea shooters, and campfire skewers, or sucking on beads made from poisonous seeds. Teenagers and young adults have died or been seriously sickened when experimenting with plants containing hallucinogenic compounds. Workers are hurt when they contact hazardous plants, adults have died from misidentification of herbal tea plants, and poisonous plants are occasionally to blame for suicide deaths.

Poisonous plant resources and websites commonly list 12-24 species as highly toxic to humans:

Abrus precatorius - rosary pea	*Datura stramonium* - jimson weed	*Phytolacca americana* – pokeweed
Aconitum spp. - monkshoods	*Digtalis purpurea* – foxglove	*Ricinus communis* – castor bean
Brugmansia spp. – angels trumpets	*Gloriosa superba* - glory lily	*Taxus baccata* – English yew
Cestrum spp – cestrums and night blooming Jessamine	*Lantana camara* - Lantana	*Thevetia peruviana* – yellow oleander
Cicuta douglasii - western water hemlock	*Nerium oleander* - common oleander	*Zigadenus venosus*- meadow death camas
Conium maculatum -poison hemlock	*Nicotiana glauca* – tree tobacco	

Angiosperms

SOLANACEAE - NIGHTSHADE Family: Members of this family bear flowers that are usually star or saucer shaped and five petaled; fruits are berries or capsules. They also usually contain alkaloids, some of which are extremely toxic to humans and domestic animals, such as hyoscyamine, scopolamine, and nicotine. These alkaloids remain toxic in the dried plants.

Deadly nightshade (*Atropa belladonna*) and black henbane (*Hyoscyamus niger*) contain the hyoscyamine alkaloid. Angel's trumpets (*Brugmansia spp.),* jimsonweeds (*Datura spp.),* and mandrakes (*Mandrago officinarum*) contain the scopolamine alkaloid. Tree tobacco (*Nicotiana glauca*) contains the nicotine alkaloid. There is some confusion as to whether the California cultivated *Brunfelsia pauciflora* (Yesterday-Today-Tomorrow) contains hallucinogenic compounds like the Brazilian native plants do.

Of the five species of Brugmansia three angel's trumpets are widely grown in southern California landscapes: *B. candida, B. sanguinea, and B. suaveolens.* These South American natives are related to the annual or perennial jimsonweeds (*Datura spp*.) and are often called tree datura. All are large shrubs that can be trained as small multi-trunked trees and reach a height of 15 feet. Leaves are alternate and 6-12 inches long; flowers are funnel or trumpet-shaped, nodding or pendulous, and come in colors of white, yellow, red, salmon, and pinkish. The fruit is a berry. With their oversize leaves and big tubular flowers that bloom in summer and fall they are quite showy. Blossoms are sweetly fragrant in morning and evening. The entire plant is extremely toxic, especially the seeds. Poisonings have occurred in children, who have sucked nectar from the base of the tube of the flowers and in teenagers, who deliberately ate the flowers seeking hallucinogenic effects.

Tree tobacco (*Nicotiana glauca*) and the herbaceous jasmine/flowering tobaccos (*N. alata*), *N. x sanderae,* and *N. sylvestris* are cultivated in California as ornamentals. Tree tobacco contains the alkaloid anabasine, an isomer of nicotine, and has caused poisonings and several deaths of humans in California. Seedlings of this species appear very succulent and apparently edible to some people. One case of human poisoning occurred in San Joaquin County, where the seedlings were mistaken for edible greens. The patient recovered but experienced typical symptoms of nicotine poisoning including respiratory paralysis that required use of an iron lung.

The Cestrum (Jessamine) genus contains several species grown in landscapes: *C. aurantiacum* (orange-flowered cestrum), *C. diurnum* (day cestrum), *C. elegans, C. purpureum, C. fasciculatum* (red cestrum), *C. nocturnum* (night blooming Jessamine [jasmine]), and *C. parqui* (willow-leaved Jessamine). All are native to the American tropics. They have showy clusters of slender tubular flowers attractive to hummingbirds. The entire plant is toxic, but especially the fruits, which are particularly noticed by children. The toxins are saponins, traces of nicotine and other alkaloids.

Other landscape ornamentals in the nightshade family with toxic properties include:

Yesterday-Today-and Tomorrow (*Brunfelsia pauciflora*) is an evergreen shrub reaching 10 feet. Leaves are alternate, 3-4 inches long, oval and entire. Flowers are showy, but short lived; start out purple, fade to lavender and then white.

Chinese Lantern Plant (*Physalis alkekengi*) is grown for its decorative, papery 2-inch calyxes, which look like lanterns and mature to a striking orange-red in late summer and fall.

Cup-of-gold vine (*Solandra maxima*) is a fast growing, sprawling vine. Inflated looking buds open to big (6-8-inch), leathery, bowl-shaped, five lobed blossoms that are fragrant at night. Flowers are golden yellow, with a red-brown stripe running down each lobe to flower center.

Potato vine (*Solanum jasminoides*) is an evergreen vine that twines rapidly to 30 feet. White, 1-inch flowers are carried on threadlike stalks in clusters of up to 12; bloom is almost continuous all year, heaviest in spring.

FABACEAE - PEA Family: Previously called Leguminosae, the pea family is an enormous group containing annuals, perennials, shrubs, trees, and vines. Some have flowers shaped like butterflies (sweet peas), others have a more regular flower shape (like *Cassia* and *Caesalpinia*), and still others have tightly clustered flowers that appear to be puffs of stamens, as in acacia and silk tree (*Albizia*). All bear seeds in pods (legumes). Many have on their roots colonies of bacteria that can extract nitrogen from air spaces in the soil and convert it to a form usable by plant roots; clover (*Trifolium* is a familiar example).

The pea family has almost 100 genera containing toxins. Lectin proteins found in the seeds can either agglutinate red blood cells (as in Black locust - *Robinia pseudoacacia*) or affect mitosis in white blood cells (as in rosary pea - *Abrus precatorius* and *Wisteria spp.*). The coral tree (*Erythrina sp.*) and the goldenchain tree (*Laburnum anagyroides*) contain toxic alkaloids. For some species the toxin is unknown as in the bird-of-paradise bush (*Caesalpinia gilliesii*) and dwarf poinciana (*C. pulcherrima*).

One of the deadliest plants to humans is the rosary pea (*Abrus precatorius*). The bright red shiny seeds are characterized by a black spot on one end and contain the highly toxic compound abrin. As few as one or two seeds can be fatal to a child. Although not typically cultivated in landscapes, the seeds are drilled, made into beaded necklaces, which are particularly attractive to children, and sold in California.

The black locust tree (*Robinia pseudoacacia)* is a large deciduous tree with deep furrowed brown bark, thorny branches, divided leaves with 7-19 leaflets, each 1-2 inches long. The flowers are pea-shaped, white and clustered to form large showy pendents. The flowers are not poisonous, but the seeds, bark, and leaves are.

The seeds and bark of the coral tree (*Erythrina sp.*) contain alkaloids with a curare like action (poisoning that causes death from paralysis of the respiratory system) in humans. The genus contains many species which are mainly grown in southern California. Valued for brilliant flowers, one species (*E. coralloides*) has fiery red pinecone-shaped blossoms that bloom at tips of naked, twisted, black-thorned branches in spring.

Wisterias are twining, woody vines of great size, long life, and exceptional beauty in flower. All have large, fresh green leaves divided into many leaflets, spectacular clusters of blue, white, or pinkish springtime blossoms, and velvety pods about 6 inches long. The entire plant contains a glycoside called wistarin and a poisonous resin, but the seeds are especially toxic. Two seeds are sufficient to cause serious illness in a child; however there have been no reported fatalities and usually the patient recovers within 1 or 2 days.

EUPHORBIACEAE - SPURGE Family: The Euphorbia genus of this family has more than 1000 species and most of them contain a milky sap that is caustic to the skin. The liquid contains a diterpene alcohol called phorbol, which is a parent compound that forms other toxins that are carcinogens, some of which can cause tumors in the skin even a year after application.

Several euphorbs are spiny but are distinguished from cacti by their milky sap. In general the flowers are small, one sex, grouped together into cyathia (cup-like structures) with marginal glands and sometimes petal-like fringes on the glands. The fruit is a capsule with 3 seeds.

Another one of the most deadly plants to humans is the castor bean (*Ricinus communis*). It contains a plant lectin called ricin which is one of the most toxic compounds known. It inhibits protein synthesis in the intestinal wall and agglutinates red blood cells. The most toxic parts of the plant are the seeds and to a lesser extent, the leaves. As few as 2-3 seeds have been fatal to children and 2-4-8 seeds have caused severe illness and death in adults. Animals also die after ingesting the seeds. Castor oil which is obtained from the seeds does not contain the toxic ricin. The castor bean plant was commercially grown in CA in the mid 1950s. It is a tree like shrub that reaches 15 feet in height and is purplish brown in color. The stems are soft but become woody with age. The leaves are peltate, glossy reddish brown to green, palmate, 5-11 lobed and 6 to 12 inches across. The flowers are very small and occur in dense panicles. The fruit is smooth or soft-spined and contains 3 seeds which are about 1 inch, oval in shape, and mottled.

In contrast the poinsettia *(Euphorbia pulcherrima)* is often assumed to be poisonous, but is not. Although the poinsettia contains milky sap, it is less irritating than most other species in this genus. It is thought that many people believe poinsettias are poisonous because of a misdiagnosed fatality of a young girl at Christmas time in Hawaii in 1919. Since then, documented studies at universities have investigated poinsettias, and reported that a child would need to consume 500-600 leaves to get a tummy ache.

RANUNCULACEAE – BUTTERCUP Family: Some very popular ornamental bulbs/flowers belong in the buttercup family and many of them contain toxic alkaloids or cardiac glycosides. Some species include the monkshood (*Aconitum sp.*), delphiniums, and hellebores. Several weeds also contain these toxins including bur buttercup (*Ranunculus testiculatus*), Creeping butterdup (*R. repens*), and celery crowfoot (*R. sceleratus*). In most of these examples bees make toxic honey when they forage on these species. Another toxin found in some species is the ranunculin glycoside which forms irritating oil. This can be found in red baneberry (*Actaea rubara*), anemone (*Anemone blanda*), Clematis (all species) and Ranunculus (all species). The irritating oil causes blistering of skin and it is said that beggars would use it to blister their feet to arouse sympathy.

APOCYNACEAE – DOGBANE Family: Oleander (*Nerium oleander*) seems to be the one plant that everyone knows is toxic to humans, animals, and pets. It contains the toxin oleandrin which is a glycoside with digitalis like action on the heart. The entire plant contains the toxin. This evergreen shrub is widely planted along California highways. There have been very few reported fatalities from ingesting oleander in California. In 1982 there was a suicide death of an elderly woman. There are reported illnesses from inhaling smoke of burning leaves, using the twigs as skewers, and sucking nectar from the flowers.

VERBENACEAE – VERVAIN Family: Lantana (*Lantana camara*) is another highly toxic common landscape plant. The entire plant, especially the immature fruits contain two triterpene toxins. This is a deciduous shrub that reaches 6 feet in height. Leaves are ovate 1-6 inches long, dark green thick, and rough to the touch. The flowers are yellow to red in a dense flat-topped head to 2 inches wide. The fruit is a round fleshy blue-black drupe that is only ¼ inch in size.

SCROPHULARACEAE - FIGWORT Family: The foxglove (*Digitalis purpurea*) is another highly poisonous plant that is commonly used in perennial landscape beds. Inflated, tubular-bell-shaped, 2-lipped flowers, often spotted on the inside, are arranged on tall racemes. The toxins are a steroid glycoside and saponins. The entire plant contains these compounds and the dried leaves contain the drug digitalis. This compound has been an important medicine since the early 1700s for the stimulation of the heart. However, higher doses of the drug are toxic and fatal. This plant has caused a few deaths that are attributed to misidentification in the field. On separate occasions two couples mistook the plant for comfrey (*Symphitum officinale*) and brewed it for tea, which ended up proving fatal for one couple and caused serious illness in the other.

Gymnosperms

TAXACEAE – YEW Family: Not very many gymnosperms are listed as being toxic, however the English yew (*Taxus baccata)* is. The entire plant contains the highly toxic taxine compounds, especially the seeds. Taxus is a small genus of about 8 species. Not all are toxic, but *T. baccata* can be fatal and it is widely planted in California. It is an evergreen shrub or tree to 60 feet tall; leaves are alternate, stiff, linear to 1½ inches long, and the fruit is a single seed embedded in a fleshy red aril. The aril is not poisonous, but is attractive to children who might then consume the seed. Western yew (*Taxus brevifolia*) is native to northern California and the Pacific Northwest and since it lacks the toxic alkaloids, it is not poisonous.

CYCADACEAE - CYCAD Family: All parts of the sago palm (*Cycas revoluta*) contain toxic glycosides and a toxic amino acid, especially the seeds.

What about pets?

The general rule is that plants listed as toxic to humans should be considered toxic to animals. There are a few cases of non-toxic plants causing problems to animals.

Cats like to rub up against houseplants, such as the philodendrons, pothos, anthuriums, dieffenbachia, dracaenas, and Calla lilies (*Zantedeschia aethiopica*). These are all in the Araceae – Arum Family and these plants have the same toxic potential. The toxic part of the plant is the juice of leaves and stems and the toxin is calcium oxalate crystals some of which contain toxic proteins. The reaction in the animal is a painful irritation and contact dermatitis. The calcium oxalate crystals are insoluble in water and are grouped together in bundles called raphides. When a part of the plant is bitten or chewed, the minute sharp crystals quickly penetrate the lining of the mouth. Because of the intense pain the plant material is rarely swallowed, but if it is it will cause inflammation and irritation of the gastrointestinal tract.

Dogs can have negative reactions to onion and garlic (gastroenteritis, anemia, jaundice), heavenly bamboo (*Nandina domestica*), and the houseplants *Schefflera sp.* and *Dracaena sp.* contain the irritating calcium oxalate crystals.

Birds can be poisoned by avocados. The flesh of the avocado is fine, but the seed is poisonous as are the leaves and branches. Not all species of avocados are poisonous, but many of the varieties grown in California are. Avoid using avocado branches and twigs in bird cages and aviaries.

Hundreds of ornamental plants are listed as mildly toxic, irritating, or causing dermatitis in humans. When in doubt consult the following resources to be on the side of safety.

Poison Plant References and Websites

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Poisonous Plants in the Apiaceae

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The Apiaceae, perhaps better known as the Umbelliferae, is a large family, with about 300 Genera and 3000 species worldwide. In the Jepson manual, there are 43 Genera (both native and non-native) listed as occurring in natural areas of California. Bailey's Manual of Cultivated Plants includes 24 Genera that are cultivated for food, as herbs, and for ornamental purposes throughout the US. Most of these are probably grown or have been grown in California. Nine of the species in Bailey's are also listed in Jepson as escaped from cultivation, but only two of these (Common fennel, *Foeniculum vulgare* and poison hemlock, *Conium maculatum*) are problem weeds. See the Table for a summary of the reportedly poisonous members of this family.

This is also one of the most robust families with regard to producing all sorts of chemicals not directly used for typical metabolic processes such as photosynthesis, growth, or reproduction. Some of these chemicals are toxic, including alkaloids and glycosides. These poisons are believed to aid umbels in warding off predation or disease. On the other hand, several members of the Apiaceae have been cultivated for centuries as foods or seasoning, such as celery, parsley, coriander/cilantro, fennel, and dill and for medicinal purposes. All of these species have very distinctive tastes and smells, but it is difficult to know how the chemicals involved aid the plant.

The family has very characteristic morphological features, typically with green, ribbed hollow stems; long, sheathing petioles; divided leaves; small flowers in umbel shaped inflorescences; and two sided seed. This similarity in appearance has led to some disastrous mis-identification in the field. Poison hemlock, for example, leaves have been confused with parsley, the roots with parsnips, and the seed with anise. James A. Duke, writing in the Handbook of Edible Weeds, states," I feel strongly that amateur foragers should stay away from mushrooms and the Apiaceae .... There have been too many fatalities due to mistaken identities, not always by amateurs; sometimes the experts make fatal mistakes."

Apiaceae with systemic toxins

The most famous toxic plant in this family is poison hemlock, which produces an alkaloid known as coniine. The execution of Socrates in 399 BC for criticizing the leadership of Athens was reputedly carried out by making him drink a concoction of poison hemlock. This was actually a 'humane' way to kill someone; coniine poisoning symptoms are a general, gradual weakening followed by respiratory failure. According to one source, Opium was often added to the brew to induce sleep and ease the passing of the victim. All parts of this plant are toxic, but particularly the roots and seed. Treatment is to induce vomiting as soon as possible or to have the patient ingest charcoal to bind-up the coniine. Poison hemlock, like several toxic plants, also has a medical history. In a USDA publication from 1918, it was noted as being used for rheumatism, neuralgia, asthma, and "in cases where the nervous system is in an excited condition". As noted above, it is weedy throughout California and grows readily along streams, roads, and in wet areas. A readily visible identifying characteristic is purple blotches on the stems.

Water hemlock (*Cicuta spp*) is represented by two native species in California and another 10 or so nationally. They are plants of wet areas, along streams and in marshes. The toxin in this case is cicutoxin, an unsaturated long-chain aliphatic alcohol. All parts of the plant are toxic, but especially the roots, which smell similar to parsnip. A piece of root the size of a walnut will reportedly kill a cow. The roots are hollow and often exude a yellow sap, but are still mistaken for parsnips. Poison symptoms are similar to poison hemlock, with the unpleasant addition of violent convulsions. Livestock poisonings have occurred in California during droughty periods when animals are foraging on anything green. Death takes place very quickly; livestock are generally not treated and the prospects for any person that ingests water hemlock are not good. Two related Genera from Europe, *Oenanthe* and *Aethus*a, with toxins similar *Cicuta* can be found in the US, but are not common in the west.

Apiaceae causing photosensitization

A more common form of poisoning by members of this family is photosensitization from exposure to furocoumarins (also known as psoralens). This is caused when skin comes in contact with wet foliage of plants containing the toxin. Later, when that skin is exposed to sunlight, the skin absorbs wavelengths of light not normally taken in, which can lead to second-degree sunburns. After the sunburn subsides, the skin often stays hyper-pigmented with a purple color for months, which in some cases becomes permanent. The list of known and suspected photosensitizing species in the Apiaceae is large, including some common cultivated plants like carrot, parsnip, and celery. Three other genera, *Berula* and *Heracleum*, which are native and *Ammi*, which is not, are also suspected of this type of toxicity. The case of celery is unusual, because the toxin is produced only when the pink root fungus, *Sclerotinia sclerotiorum,* is infecting the celery. Neither celery nor pink root will produce furocoumarins alone. Light skinned animals and people are more at risk for this problem than those with dark pigmentation. In the case of animals, ingestion can lead to symptoms and only unpigmented areas of skin will be affected.

In Egypt, *Ammi majus* is a documented herbal medicine for the treatment of leucoderma, a disease of that causes a patchy loss of skin pigmentation. Taken internally or as an ointment, followed by exposure to sunlight, pigmentation can be restored to affected individuals. One man's poison is truly another man's medicine in this case.

Reported/suspected poisonous species in the Apiaceae in California.

Common Name *Scientific name*	Native	Weedy	Crop	Poisonous properties
Bisnaga *Ammi visnaga*		Yes		Photosensitizing to light skinned people and livestock from contact with wet foliage and exposure to sunlight. Also used medicinally as a muscle relaxant.
Celery *Apium graveolens*		Yes	Yes	Photosensitizing when infested with Sclerotinium, tops have caused nitrate poisoning in cattle.
Water parsnip *Berula erecta*	Yes			Systemic toxin suspected of cattle death from consumption, not well documented.
Water hemlock *Cicuta spp.*	Yes 2 sp. in CA			Systemic poison (cicutoxin) considered the most toxic in North America. Symptoms similar to Poison hemlock, but also causes violent convulsions.
Poison Hemlock *Conium maculatum*		Yes		Systemic poison (coniine) causes gradual weakening leading to respiratory failure.
Wild carrot, Queen Anne's Lace *Daucus carota*		Yes	Yes	Reported to be photosensitizing.
Water parsnip *Heracleum lanatum*	Yes			Reported to be photosensitizing.
Parsnip, Wild parsnip *Pastinaca sativa*		Yes	Yes	Reported to be photosensitizing.
Water parsnip *Sium suave*	Yes			Suspected of systemic poisoning of livestock.

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Poisonous Weeds in Alfalfa

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Plants containing poisonous toxins are common throughout California and are a serious concern. Livestock and pleasure animal numbers are increasing as urban residents move to the country for a new lifestyle on small farms and "ranchettes". Poisonous weeds have long been a significant concern to alfalfa and livestock producers. Illness or even death can occur when livestock consume poisonous plants in sufficient quantities. In a pasture, animals may refuse to eat poisonous weeds—many poisonous plants are not palatable and livestock elect not to consume them. However, when consuming alfalfa hay or silage, livestock may not have a choice whether to consume it or not. This is especially the case when hay containing toxic weeds is processed into cubes or pellets. While a low-level infestation is acceptable for many weeds, nearly complete control or eradication of poisonous weeds is important.

Most livestock poisonings have no treatment so the preferred approach is to prevent livestock from coming into contact with poisonous weeds. This is accomplished by: 1) understanding which poisonous weeds are commonly found in alfalfa; 2) determining which weeds are present in a field and properly identifying the poisonous ones; and 3) developing an appropriate weed control program. This paper will discuss poisonous weeds found in alfalfa (the most common ones as well as some rare ones that are still known to occur), the type of poisoning caused, and management practices to rid a field of these poisonous weeds. Fortunately there are effective control measures to eliminate poisonous weeds in alfalfa. The important point is to know the field history—whether poisonous weeds have existed or not—and to be able to recognized poisonous plants early so that management actions can still be undertaken while they are still effective.

Common Poisonous Weeds

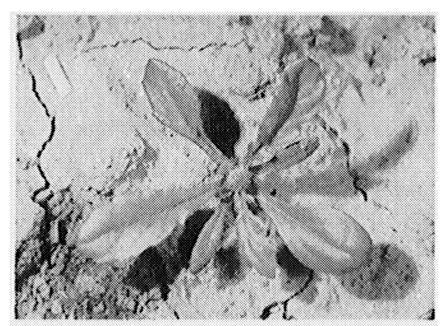
There are numerous poisonous weeds that could potentially cause problems in alfalfa (see Table). However, alfalfa competes well with most weeds and, of all the toxic weeds that could conceivably be present; very few actually cause animal heath problems on a regular basis. Two weeds account for most cases of livestock poisoning due to poisonous weeds in alfalfa: common groundsel (*Senecio vulgaris*) and fiddleneck (*Amsinckia* spp.). Since these weeds are far more prevalent in alfalfa than other poisonous weeds, these weeds will be discussed in more detail. Both of these weeds are winter annuals and are typically only present in the first cutting of alfalfa in the spring. Common groundsel and fiddleneck are especially common in fall- or winter-seeded seedling alfalfa.

Common groundsel and fiddleneck contain pyrrolizidine alkaloids (PAs). These alkaloids themselves are not toxic but they are converted to toxic pyrroles in the liver. They cause irreversible cumulative liver damage. There is currently no known remedy to counteract the toxic effects. It can take from a few weeks to 5 months before signs of poisoning occur. Groundsel and fiddleneck are toxic to horses, cattle and swine. Sheep are less susceptible to groundsel and are resistant to fiddleneck. Young animals are more sensitive than older ones. The "no effect" level for PA-containing weeds in forage is not published, however, the "no effect" level is probably less than 5% of the total ration. There was 90% mortality in horses fed alfalfa cubes with 10% groundsel for 150 days. The PA concentration in plant parts from highest to lowest is: flowers and seeds > leaves > stems > roots. PAs are resistant to heat and maintain their toxicity in dried plant material so both silage and hay can be toxic. There is some degradation of PAs in silage but the PA content remains constant over several months.

Poisonous weeds found in California alfalfa fields.

Common Name	Scientific name	Type of Poisoning
Common groundsel	*Senecio vulgaris*	Pyrrolizidine alkaloids
Curly dock	*Rumex crispus*	Oxalates
Fiddleneck	*Amsinckia* spp.	Pyrrolizidine alkaloids Nitrate accumulator
Lambsquarters	*Chenopodium album*	Nitrate accumulator
Mexican whorled milkweed	*Asclepias fascicularis*	Glucosidic substances called cardenolides
Nightshades	*Solanum* spp.	Glycoalkaloids Nitrate accumulator
Pigweed	*Amaranthus* spp.	Nitrate accumulator
Poison hemlock	*Conium maculatum*	volatile alkaloids coniine and gamma-coniceine
Yellow starthistle	*Centaurea solstitialis*	Produces nervous disorder by destroying portions of brain tissue Nitrate accumulator
Summer pheasant's eye	*Adonis* spp.	Cardenolides
Tansy ragwort	*Senicio jacovea*	Pyrrolizidine alkaloids

Identification of these weeds is key. It is important to be able to identify groundsel and fiddleneck in the seedling stage, as this is when management decisions must be made. Identification of the mature plants can also be important—it may be necessary to recognize these weeds in baled alfalfa.



Common groundsel cotyledons are narrow and linear, with smooth margins, while first true leaves are lobed (see photo A). The rosettes have deeply notched or lobbed leaves 1 to 4 inches long and about 1/4 as wide. Leaves are alternate. The stem and underside of the lower leaves are purplish in color. The mature plant has numerous small yellow flowers in clusters at the end of stems. The flowers mature into small white puffballs similar to a small dandelion seedhead. One of the most distinguishing characteristic of common groundsel is the green bracts surrounding the flower cluster have conspicuous black tips. This feature is especially useful to recognize common groundsel in baled hay and distinguish it from other weeds in the thistle family.

Fiddleneck is named for its curving flowerstalk that arches back on itself resembling the head of a fiddle. The small flowers are bright yellow-orange—giving rise to the name "fireweed" (another common name for the weed). The stem and leaves are covered with stiff hairs. This is an important characteristic for identifying fiddleneck in baled hay. An additional characteristic for identifying fiddleneck the cinnamon brown color it turns once it dries. The cotyledons are slit at the tip giving them a "Y" shape, and the cotyledons also have tiny blisters and a few fine hairs. The first true leaves have coarse, sharp hairs and are long and narrow.

Control Practices

Provided the alfalfa stand is adequate, fiddleneck is only a problem in newly-planted alfalfa. In contrast, common groundsel competes more effectively with alfalfa and is a problem in both newly-planted and established alfalfa. Many herbicides used in seedling alfalfa do not control both common groundsel and fiddleneck. For example, benefin (Balan) controls fiddleneck but does not control groundsel. 2,4-DB and imazethapyr (Pursuit) only provide partial control of both species. Imazamox (Raptor) is somewhat more effective on fiddleneck especially when applied to small fiddleneck. However, it is rarely perfect control. Bromoxynil (Buctril) is the most effective seedling alfalfa herbicide for the control of both fiddleneck and groundsel but it does not control grasses and many other broadleaf weeds that commonly occur in seedling alfalfa. Therefore, Buctril is often tank-mixed with other herbicides for complete weed control.

Common groundsel was a major weed problem in established alfalfa in the late 1970's when diuron (Karmex) was one of the primary herbicides used for weed control in established alfalfa. It controlled most of the annual weeds found in alfalfa but common groundsel escaped treatment and proliferated. Hexazinone (Velpar) was registered in alfalfa in around 1981 and was rapidly adopted by growers in most areas of California (except the Low Desert where because of the mild winter temperatures and the nondormant alfalfa varieties Velpar is too injurious to the alfalfa). While Velpar was effective for the control of a broad spectrum of weeds, one of its most valuable characteristics was that it provided outstanding control of common groundsel. It has become the standard for winter-dormant weed control in alfalfa in most areas, especially where common groundsel occurs. Over the last two years, however, the control of common groundsel with Velpar has diminished markedly in some areas—the northern San Joaquin and Sacramento Valleys. Both field and greenhouse trials showed that Velpar only provided 30 days of residual control at lower rates and that larger groundsel plants (3-4 leaves or more) were not adequately controlled post emergence. The exact cause for the reduction in control is not yet known but possible explanations include increased tolerance to Velpar and/or leaching of Velpar below the groundsel root zone from heavy winter rains. Paraquat (Gramoxone) also controls groundsel and is often tank-mixed with soil residual herbicides. This practice may be increasingly important if herbicide resistance is the cause for the reduction in groundsel control with Velpar.

Other Common Toxic Weeds

In addition to common groundsel and fiddleneck, there is another group of potentially toxic weeds that are common in alfalfa. This group of weeds, including nightshade, pigweed, and lambsquarters, are classified as nitrate accumulators. These three summer annual weeds are prevalent in most cropping systems. They would ordinarily only be toxic to livestock in an alfalfa production system when they comprise a considerable portion of the total forage and are growing in a high soil nitrate environment.

None of these weeds are usually a problem in an established crop, as they cannot compete with a dense vigorous stand of alfalfa. When they do appear in an established field, even an older depleted stand, the density of these weeds is usually low enough that they do not present a toxicity problem. From a nitrate poisoning and animal health perspective, these weeds are typically only a problem the first year (usually only the first cutting) of a spring-seeded alfalfa field.

Nitrate is a problem in cattle but not horses or sheep. Microbes in the rumen convert nitrate to nitrite. The nitrite ion produces methemoglobin which is incapable of transporting oxygen to various body tissues so the animal may die from asphyxiation. Death may occur within 6 to 24 hours after consuming high nitrate forage. Forage nitrate levels over 0.3% (3000 ppm) are potentially dangerous depending on the animal, whereas acute poisoning is likely with nitrate levels above 1% (10,000 ppm). Environmental conditions influence the nitrate concentration in these weeds as well as forage plants (such as Sudangrass and oats). Stress conditions like drought stress, inadequate sulfur or phosphorus, or freezing temperatures can increase the nitrate concentration. Levels typically decrease within a few days after the stress is removed. High nitrogen fertilization and injury (not complete control) from phenoxy herbicides such as 2,4-D are also known to increase nitrate concentration in plants.

There are several herbicides that can effectively control nightshade, pigweed, and lambsquarters in seedling alfalfa. 2,4-DB, Buctril, Pursuit, and Raptor all control most these weeds especially when the weeds are small at the time of application. Buctril only partially controls pigweed and Pursuit only partially controls lambsquarters but these potential weed escapes can be managed through tank mixes.

If high levels of nitrate accumulating weeds are present, have the forage analyzed for nitrates prior to feeding. The best way to avoid high nitrates in alfalfa hay is to control nitrate accumulating weeds and through proper management of manure affluent containing high levels of nitrate nitrogen. However, if this is not done and high nitrates are confirmed though laboratory analysis the best option may be to dilute the high nitrate feed with low nitrate feeds. Even this is risky if the feeds are not well mixed and if the nitrate levels are too high.

The weed nightshade (*Solanum* spp.) poses another risk in addition to nitrate toxicity. Nightshade contains glycoalkaloids, which are toxic to humans and livestock. Berries are more toxic than leaves which are more toxic than the stems or roots. Ripe berries are less toxic than unripe berries. Nightshade plants can cause problems with the gastrointestinal tract and can also affect the central nervous system.

Less Common Toxic Weed Problems

There are numerous other weeds that may be highly toxic but for various reasons are not common animal health problems. In most cases theses weeds are rarely found in a high enough density in alfalfa hay to cause a significant toxic reaction. However, there are cases where these weeds cause livestock poisoning so pest control advisors, producers, and others in the industry need to be aware of the potential risk.

<u>Curly dock</u> is not a common cause of livestock poisoning but may be toxic if eaten in excess. Curly dock infestations in alfalfa can be dense in some areas, particularly in soils with a high water holding capacity or poor drainage. Curly dock is a deep rooted perennial and can be difficult to control in alfalfa. Research has shown that the soil residual herbicides applied to dormant alfalfa are only marginally effective. The best treatment was an application of 2,4-DB in the fall before a frost while plants are still able to translocate the herbicide. Avoid feeding or sell alfalfa hay from portions of the field with high densities of curly dock.

<u>Mexican whorled milkweed</u> is a perennial that has been found in alfalfa fields, usually in fields that were previously pasture or range. Poisoning may occur if animals are fed hay containing large amounts of milkweed. The best control option is to treat milkweed prior to planting alfalfa and spot treat if it is found within an alfalfa field.

<u>Poison hemlock</u> is a biennial herb in the parsley family. It has shiny green, triangular, and highly dissected leaves. The stems have purple spots that make it easy to identify. All plant parts are toxic. Poison hemlock is generally considered a weed of poorly drained areas and is typically only found along ditch banks and field edges—not usually within an alfalfa field. In the peat soils of the SJ Delta, heavy populations grow along drainage ditches were seeds can be carried into fields by irrigation water. However, most hemlock problems occur in seedling stands and are primarily a problem in the fist cutting. Since hemlock is usually found on field edges, it is best to harvest contaminated areas separately and not feed the hay. A lethal dose for a horse is 4 to 5 pounds of leaves. Cattle may be poisoned with 1 to 2 pounds, and sheep with a half pound or

less. Once dried, the toxicity is considered to be reduced but not eliminated. Contact herbicides Bromoxynil and Paraquat are more effective than the phenoxy or IMI herbicides in seedling stands. Photosynthetic inhibitors such as Velpar and metribuzin (Senor) give excellent preemergence control. Spot treatment with glyphosate (Roundup) is effective.

Yellow starthistle is one of the most widespread weed problems in California and is familiar to nearly everyone. Fortunately, it is primarily a noncrop and range weed problem and rarely a problem in alfalfa—it does not compete well in a dense well-irrigated stand of alfalfa. In some locations it can infest spring planted seedling alfalfa because it emerges at the same time as the crop. Yellow starthistle causes a nervous disorder called "chewing disease" that affects horses but not other livestock. Young horses are primarily affected and there is no treatment for starthistle poisoning. Large quantities of starthistle must be consumed for there to be a problem so it is unlikely that yellow starthistle-infested alfalfa hay would cause a problem. Even contaminated fields do not have that level of infestation.

Summer pheasant's eye (*Adonis aestivalis*) is a toxic annual weed that is generally considered unpalatable but poisonings have occurred when it is fed as hay. Several horses died in northern California not long ago when Adonis-contaminated grass hay was consumed. The plant has erect stems with solitary orange flowers. This weed is rare and little information is available on this plant. It is unlikely to cause a problem in alfalfa fields but because several horses died in California from injecting this plant it is important to be able to recognize it.

Oleander is not a weed in alfalfa. However, the leaves contain cardenolides and are extremely toxic. A few leaves blown into fields before harvest can cause a problem—10 to 20 leaves can kill a horse while as few as 8 leaves can be lethal to a cow.

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Pesticide Use and Surface Water Quality Issues

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Water quality regulations in California stem from the Federal Clean Water Act (CWA) of 1972, which prohibits the discharge of pollutants in water ways at levels that affect the beneficial use of the waters, including drinking, recreation, aesthetics, fishing, and irrigation. The law focuses on both point and non-point source pollution. Point source refers to the discharge of pollutants from factories or sewage treatment plants directly into waterways. Non-point source refers to the discharge of pollutants from indirect sources such as agriculture, timber, mining, dust, and stormwater runoff into water bodies. For 25 years the CWA focused on point source pollution and cleaning up waste from discharge pipes. This has improved water quality, but not enough. As a result, the focus of water quality protection is now on cleaning up problems associated with non-point source pollution.

The amount of pollutants allowed in water bodies is set by TMDL's (Total Maximum Daily Loads) which defines the amount of a contaminant that a water body can tolerate with out adversely affecting the beneficial use of the water. For example, the insecticide chlorpyrifos is found in several of our rivers and the Sacramento Delta at concentrations that cause mortality to the aquatic test organism *Ceriodaphnia dubia* (a water flea and EPA indicator of water quality). As a result many waterways have been listed as impaired, which means that the concentration of chlorpyrifos must be reduced to levels that are not toxic to *C. dubia* (likely 80 ppt). The RWQCB is responsible for enforcing the CWA and state water quality laws. They are the lead agency that develops TMDL plans for water bodies that are adversely affected by one or more pollutants. This involves identifying pollutants, allocating loads, implementing plans, setting numeric targets, and developing and implementing plans to meet water quality standards.

There are 694 high priority TMDL's in California including pesticides, sediments, nutrients, pathogens, metals, and ammonia. Of the 125 high priority pesticide pollutants, 61% are still DDT and *chlordane,* which are no longer registered in the US. In the Central Valley, 80% or 30/37 of the listed TMDL's come from crop production, grazing, and dairies. Irrigated agriculture has had a waiver to discharge irrigation and storm water from agricultural lands but this expired in 2000. Current law states that farmers must comply with one of the following to discharge irrigation or storm water from their farms 1) apply for a waste discharge permit, 2) apply for an individual waiver, or 3) join a watershed group. Applications for waste discharge permits are not economically feasible for growers because of the high cost of permits and complying with California's Environment Quality Act. Applications for individual waivers may also be too costly because of the requirement for extensive water quality monitoring and reporting for individual farms (including metals, pesticides, pathogens, sediments, and temperature). The best choice for most growers that discharge irrigation or storm water from irrigated lands may be to join a watershed group. This group will be lead by an agency such as the Farm Bureau or Natural Resources Conservation and will work together with farmers to pool resources for monitoring and reporting water quality in select drainages. Applications for individual and group waivers are reviewed yearly by the SWRCB and attempts to improve water quality from farms must be documented.

The likelihood that a pesticide will move offsite depends on its 1) persistence, 2) soil adsorption value, and 3) aqueous solubility. Persistence or half-life refers to how long the pesticide remains active (depends on light, temperature, microbial activity and pH). The soil adsorption coefficient (Koc) refers to how tightly a pesticide binds to the soil, and aqueous solubility refers to the concentration at which a particular pesticide will dissolve in water. In general, pesticides with a long persistence, high solubility, and low binding coefficient are the worst for ground and surface water. The toxicity of a particular pesticide to aquatic life is also important to understand for water quality protection. Some pesticide (such as chlorpyrifos) are highly toxic to aquatic life, others such as bacterial insecticides are seemingly innocuous. A list of insecticides and their likelihood of moving offsite and toxicity to aquatic life can be found at http://ceyolo.ucdavis.edu pest management. Some pesticides (such as pyrethroids) that bind to sediments can move off site attached to soil particles where they may cause problems to benthic organisms. For these classes of insecticides, it is important to look for ways to reduce silt coming off the application site, including the use of sediment traps, ponds, or grass filter strips.

As an example of ways to mitigate off site movement of pesticides from farm fields, Long et al., (2000) conducted a 3-year study in alfalfa to look at pyrethroids versus organophosphates (OP's) for insect control and secondary impacts to water quality. Results showed that where OP's were applied, there was 100% mortality to *C. dubia* in irrigation tail water, compared with insignificant mortality in water from pyrethroid treated fields. Chemical analyses of tail water samples confirmed the absence of pyrethroids at 50 ppt. Although pyrethroids may move off site attached to soil particles, this does not appear to be a problem for alfalfa because the fiberous root system traps sediments. Based on the chemical properties of OP's and pyrethoids the results that Long obtained are not surprising. OP's, in general, are fairly water soluble and do not bind to sediments so will move in water. In contrast, pyrethroids are water insoluble and bind to sediments, so will not move in water, except bound to sediments.

This paper addressed concerns with pesticide contamination of surface water. To prevent offsite movement of pesticides from the site of application it is important to understand how different classes of insecticides behave in the environment and to know where irrigation and storm water flows. If water from a farm or other site drains into a natural waterway, it is important to choose a pesticide that sticks to the soil, has a low half life, is water insoluble, and has a low toxicity to aquatic life. For pesticides that move offsite attached to soil particles, growers should install sediment traps, vegetation filter strips, tail water ponds, or return systems on their farms to prevent sediments from moving offsite.

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Herbicide Management Practices to Prevent Ground Water Contamination

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Introduction

The Department of Pesticide Regulation (DPR) is proposing to regulate pesticide use in vulnerable areas of land based on specific soil properties and depth-to-ground water characteristics. Vulnerable areas will be called ground water protection areas (GWPAs), which will be 1-square mile sections of land as based on the USGS Public Land Survey System (Davis and Foote, 1966). An important aspect of the regulations is that each GWPA will be designated as either 'leaching' or 'runoff', which describes the predominant pathway for movement of pesticide residues from the site of application to the ground water resource (Troiano, 2000). The designation is important because management practices have been developed for each pathway; leaching management practices will apply to leaching GWPAs and runoff management practices will apply to runoff GWPAs. Information on the regulatory changes, proposed management practices, and supporting documents is available on DPR's Internet website at: http://www.cdpr.ca.gov/docs/empm/gwp_prog/gwp_prog.htm.

Pesticides regulated to protect ground water

Pesticides that are listed in section 6800(a) of Title 3 of the California Code of Regulations have been detected in California's ground water as a result of legal agricultural use (Troiano et. al., 2001). The active ingredients listed in 6800(a), product names, and their pesticidal action are given in Table 1.

Table 1. Pesticides regulated on the 6800(a) list as ground water contaminants.

Active Ingredient	Product Name	Pesticidal Action
Atrazine	Aatrex, Strike	Pre-emergence
Simazine	Simazine, Princep	Pre-emergence
Bromacil	Hyvar, Krovar	Pre-emergence
Diuron	Diuron,Karmex, Direx, Krovar	Pre-emergence
Norflurazon	Solicam, Predict, Zorial	Pre-emergence
Prometon	Pramitol	Pre-emergence
Bentazon	Basagran	Contact

This table is especially germane to weed control practices because those regulated in Table 1 are herbicides. Why do herbicides, and in particular pre-emergence herbicides, have a potential to move to ground water? Pesticides with the potential to move to ground water have low attraction to soil and they have relatively long soil half-lives. Many pre-emergence herbicides have similar properties because:

- They are applied before weed seeds germinate, so residues must be long-lived in order to be available when seeds germinate and weeds begin to grow.
- The residues are taken-up by emerging plant roots and shoots so the residues must be available in soil solution rather than bound to soil.

Pesticide substitution is a tricky solution to ground water contamination

Table 2 shows the physical-chemical properties of herbicides detected in California's ground water, as denoted with the superscript 'a', and of some potential substitutes. Potential substitutes with the superscript 'b' are also listed as potential ground water contaminants because their physical-chemical properties are similar to known ground water contaminants (Clayton, 2002). The active ingredients without a superscript in the table have high soil attraction compared to the known or potential ground water contaminants. High soil attraction is a property that makes a pesticide much less susceptible to offsite movement. The value for Koc is a measure of the strength of adsorption between a pesticide and the organic carbon content of a soil. A higher value indicates greater attraction to organic carbon, which in turn decreases its dissolution in soil water and subsequent potential for offsite movement. Water solubility and aerobic half-life are properties that could modify the potential for offsite movement, but for the examples in Table 2, they generally fall within the range of the known ground water contaminants. Since herbicides with contact activity, such as glyphosate, have high soil adsorption, they would be good substitutes for known ground water contaminants because they would be tightly sorbed to plant material or soil, making them unavailable for movement in percolating or runoff water. Although herbicides with high soil absorption are potential substitutes, applications could be limited to situations where it would be possible to control weeds using contact herbicides alone, or to using pre-emergence herbicides, such as oxyfluorfen or trifluralin, which may have limitations with respect to their registered uses or to the spectrum of weeds controlled.

Management practices in leaching and runoff GWPAs

We have developed the ground water protection program with the goal of understanding how pesticides move to ground water so that management practices can be crafted that allow continued pesticide use but with minimal potential for contamination. Leaching GWPAs are characterized by coarse-textured soils where percolating water produced from irrigation moves pesticide residues below the crop root zone and, eventually, to ground water (Troiano et. al., 1993). If one of the following management practices can be used, then use of a 6800(a) listed pesticide is allowed in leaching GWPAs (these conditions apply for 6 months after pesticide application):

1. Uncontrolled irrigation cannot be applied; **or**
2. The pesticide can only be applied to planting bed or berm above the level of furrow or basin irrigation water; **or**
3. Irrigation water applied to the treated area must not exceed 1.33 of the net irrigation requirement.

In some cases, existing management practices already comply with the new regulations and would not require any change. Some examples are:

- Pre-emergence herbicide applications made for winter weed control applied 6 months prior to crop irrigation.
- Applications of pre-emergence herbicides to raised beds so that the residue is located above the water level of a furrow irrigation system.
- Sites where irrigations are based on a measure of potential evapotranspiration (ETo), such as those available from the California Irrigation Management Information System (CIMIS), and do not exceed 1.33 of net irrigation requirement.

Compliance may be problematic in some cases. For instance, restricting the amount of applied water to 133% of net irrigation requirement is difficult to achieve in furrow irrigation systems used on coarse, sandy soils.

Table 2. Physical-chemical properties of selected herbicides.

			Physical Chemical Properties		
			Mobility		Longevity
Active Ingredient	Product Name	Action	Koc	Water Solubility	Aerobic 1/2-life
			----cm^3/gm----	-----mg/L----	-----days-----
Atrazine[a]	Aatrex	PRE[c]	93	32	146
Simazine[a]	Princep	PRE	340	6	110
Bromacil[a]	Hyvar	PRE	17	929	346
Diuron[a]	Karmex	PRE	499	36	372
Norflurazon[a]	Solicam	PRE	600	28	172
Hexazinone[b]	Velpar	PRE	640	29,800	222
Napropamide[b]	Devrinol	PRE	726	74	455
Oryzalin[b]	Surflan	PRE	848	3	63
Trifluralin	Treflan	PRE	9,900	1.8	180
Glyphosate	Roundup	Contact	24,000	900,000	47
Oxyfluorfen	Goal	Contact, PRE	100,000	0.1	180

[a] Herbicides that are ground water contaminants in California.

[b] Herbicides listed as potential ground water contaminants in section 6800(b) of Title 3 of the California code of regulations.

[c] PRE = Pre-emergence herbicide.

Management practices differ in runoff GWPAs because residues move offsite in runoff water to sensitive areas (Braun and Hawkins, 1991). The goal in runoff GWPAs is either to move residues below the soil surface so they are less available for dissolution in runoff water, or to prevent runoff water from contacting sensitive areas that facilitate movement to ground water. Practices that allow 6800(a) pesticide use in runoff GWPAs are:

1. Use a mechanical method to disturb soil before pesticide application; **or**
2. Incorporate the pesticide into soil within 48 hours after application either by mechanical or pressurized irrigation methods; **or**
3. Apply the pesticide in a band treatment to the crop row; **or**
4. Apply the pesticide between April 1 and July 31; **or**
5. Manage runoff water such that no runoff leaves the site; **or**
6. Store runoff water in a low permeable basin located offsite; **or**
7. Direct runoff to a fallow field.

As in leaching GWPAs, some existing management practices in runoff GWPAs may already comply with the new regulations. No change is necessary where pre-emergence herbicides are applied in band treatments to tree rows, a common practice used in almonds and other perennial tree and vine crops. But change will be required for growers who maintain clean row middles and rely on rainfall to incorporate residues into soil. Using one of the more effective incorporation methods, such as mechanical incorporation, would be a potential alternative management practice.

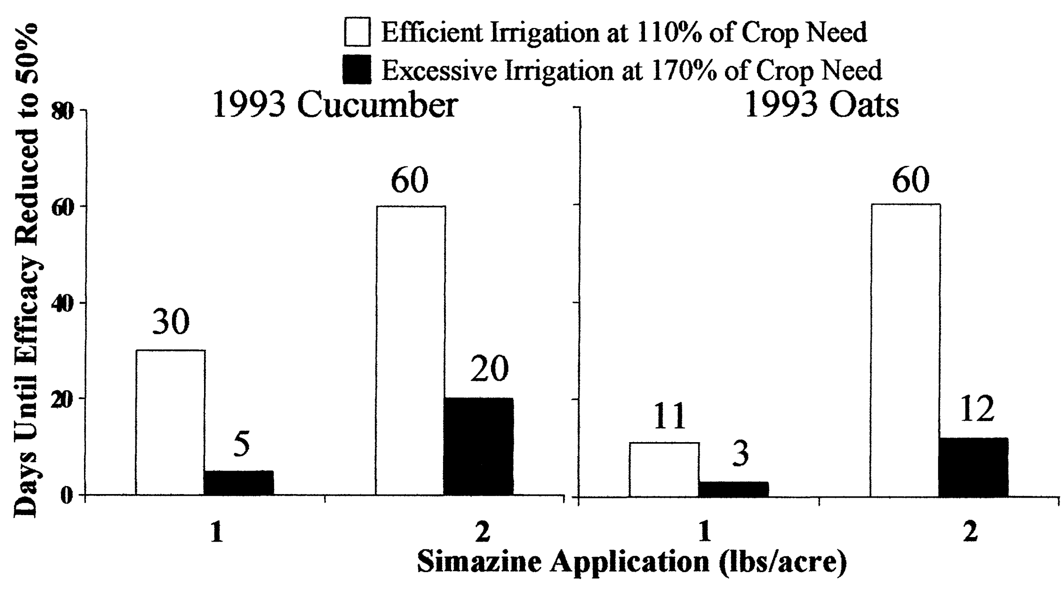
Although we have attempted to compile a comprehensive list of practices for use in leaching and runoff GWPAs, we realize that they may not be appropriate for all crop uses. In this situation, the Director may approve an alternative management practice, if supported by data. In the absence of data the Director may also allow for a 3-year period of interim use when investigations would be conducted to develop an alternative management practice. The interim use option is conditional upon submission of a written request to the Director of DPR, a protocol that would be approved by DPR staff, and progress reports submitted every six months.

If none of the management practices or alternative options can be met, then use of a 6800(a) listed herbicide would not be allowed in a GWPA. What alternative herbicides should be used? DPR advises users not to substitute herbicides that have a similar potential to move to ground

Effect of regulations on effectiveness of pesticides

Since the objective of each proposed management practice is to maintain residues at their intended site of application, a greater portion of applied residues should be available to provide pesticidal action and subsequently, should enhance performance. The potential for increased effectiveness was investigated in a study of simazine's efficacy under two different irrigation efficiencies (DaSilva et al., 2003). Simazine was applied at 0, 1, or 2 lb/acre to 3-year old nectarines. The nectarines were irrigated with micro-sprinklers. Irrigation water was applied at two levels of water management, one where water was applied efficiently at 110% of crop requirements and the other with excessive water applied at 170% of crop requirements. Simazine's effectiveness was measured as the survival rate of oats and cucumber planted at 0, 2, 4, and 8 weeks after simazine application. Based on these sequential survival data, the length of time was calculated for simazine's effectiveness to be reduced from 100% to 50% where longer time intervals indicated greater effectiveness. As anticipated, the 2-lb/acre rate of application was effective for a longer time interval than the 1-lb/acre rate when compared within each irrigation treatment, e.g. in cucumber at reduction to 50% efficacy was measured at 20 vs 5 days, respectively, in the excessive irrigation treatment (Figure 1). Within each rate of simazine application, time to loss of 50% efficacy was much greater in the efficient irrigation treatments. In fact, efficacy at the 1-lb/acre treatment in efficient irrigation was equivalent to that measured for the 2-lb/acre rate in the excessive water irrigation treatment. Historically, irrigation management and pesticide application decisions have been made independently. This study showed that linking these two decision-making areas together should result either in cost savings with respect to herbicide expenditures or in increased effectiveness of herbicide applications. For example, if a grower were to reduce percolating water through improved irrigation management, one might experience better product effectiveness when using standard rates. Alternatively, rates of application could be potentially lowered without reduction in efficacy.

Figure 1. Effectiveness of simazine measured at two levels of water management in micro-sprinkler irrigation. Effectiveness was measured as the length of time in days for survival rate of emerged seedlings to be reduced from 100% to 50%.



Although this example relates to coarse-textured soils in leaching GWPAs, similar effects could be experienced with adoption of management practices for runoff GWPAs. Reduction in losses of residues in runoff water through improved soil incorporation should provide for more residues at the site of action and consequently, increased effectiveness of pesticide applications.

The current list of management practices is not intended to be static. The regulations and management options can always be amended to reflect improvements in application technology, new methods to control offsite movement of residues, or even changes in philosophy of how pests should be managed. For example, chemigation of pesticides provides a number of benefits with respect to placement, timing, and management of pesticide residues. Since many of the pre-emergent herbicides listed in section 6800(a) are not labeled for application through low-volume irrigation systems, chemigation is currently not a management option. The DPR has contracted with the Center for Irrigation Technology (CIT), California State University, Fresno to conduct cooperative studies on the application of simazine and diuron through low-volume irrigation. Registrants are also participating in the project where the goal is to provide information that will enable chemigation to be added as a method of application to these products. Cooperating growers provide an opportunity to demonstrate the effectiveness and use of chemigation in their pest management system.

Summary

The goal of the new ground water regulations is to decrease offsite movement of residues in deep percolating water and in runoff water. Areas that are vulnerable to ground water contamination are determined by soil characteristics and depth-to-ground water data and denoted as ground water protection areas (GWPAs). Based on the pathway of offsite movement of pesticide residues, GWPAs are further designated as leaching or runoff areas. Management practices have been developed for each pathway so the effect of the new ground water regulations on pest management practices will depend on how much growers must change their current practices to meet the proposed management practices for each pathway.

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"Regulatory Tools: Section 18 and Section 24(c) Registrations"

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Pest Control Advisers (PCAs) have various tools at their disposal such as soil probes, computers, all terrain vehicles, and University Extension Specialists to utilize in providing crop protection.

One tool often overlooked is the utilization of FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act). Section 18 and Section 24(c) of FIFRA are regulations allowing States to be exempt from FIFRA or allow States to register additional uses of federally registered pesticides. PCAs should become familiar with these regulations which may provide additional help if needed.

Section 18 of FIFRA allows States to be exempt from the provision of the FIFRA if the State determines an emergency condition exists, which requires an exemption.

For an emergency condition to exist, the pest situation must be urgent and non-routine and the following conditions must be met; 1) documentation demonstrating there is no effective registered pesticides available/effective in controlling the pest; 2) documentation demonstrating there are no feasible alternative control practices which will mitigate the pest and; 3) the situation involves introduction of a new pest or will present significant risks to human health, environment or will cause significant economic loss. An urgent and non-routine situation is one that requires immediate attention and must be other than an ordinary one.

There are four types of emergency exemptions that may be requested from U.S. EPA. One type is a "Specific". This exemption is most commonly requested and issued. Specific exemptions are used to mitigate a significant economic loss to a crop from an unexpected pest. The second type is a "Crisis" exemption. Although very rarely used and approved by U.S. EPA, a "crisis" exemption allows States to issued the immediate use of a pesticide. U.S. EPA allows "crisis" exemptions in situations in which there is insufficient time for U.S. EPA to review and approve a "Specific" exemption. A third is a "Quarantine" exemption. A "Quarantine" exemption is used to mitigate the introduction or spread of any pest new to or not theretofore know to be widely prevalent or distributed within and throughout the United States and its territories. Lastly, the fourth is a "Public Health" exemption. A "Public Health" exemption is used to mitigate a pest that will cause a significant risk to human health.

Emergency exemptions are not intended or will be approved by U.S. EPA if the exemption is to mitigate a chronic or continually occurring pest problem, maximize the grower's profitability, or expand acreage.

Section 24(c) of FIFRA allows States to register a new end use product for any use and/or additional use of a federally registered pesticide product, if the following conditions exists: 1) there is a special local need within State; 2) if use is on food/feed, use is covered by necessary tolerances or exemptions; and 3) use has not been previously denied, disapproved, suspended or cancelled by U.S. EPA.

Below is a quick comparison of the two sections.

Section 18	**Section 24(c)**
♦ Applicant. Must be third party such as county, university, grower, grower association, etc. **Cannot be manufacturer**.	♦ Applicant. Any person, group, or manufacturer.
♦ Four Types – Specific, Crisis, Quarantine, Public Health	♦ Two Types – First Party (manufacturer) or Third Party (other than manufacturer).
♦ No Tolerance Established.	♦ Tolerance or Exemption Established.
♦ Emergency situation must be documented – historical pest problem (economics and lack of alternatives must be verified), urgent non-routine situation.	♦ Justification and lack of alternatives must be documented.
♦ Data – Residue, Efficacy, Phytotoxicity, and Economic.	♦ Data – Residue, Efficacy, Phytotoxicity.
♦ Scientific Evaluation.	♦ Scientific Evaluation.
♦ Letter of Authorization	♦ Letter of Authorization
♦ Post for public comment. Not required. Submit Section 18 to U.S. EPA for final approval.	♦ Post for public comment. Required.
♦ Issue. Always includes an expiration date. Use period cannot exceed a 12 month period.	♦ Issue. Usually without an expiration date.
♦ No U.S. EPA or DPR fees.	♦ Must pay U.S. EPA maintenance fee. No DPR fee.

If a PCA decides to pursue the use of Section 18 or 24(c) of FIFRA to help mitigate a pest problem, he should be aware of the processing time required by the Department and U.S.EPA. The information below should be helpful in determining when the Section 18 and/or Section 24(c) would be available for field use.

Section 18

- State – 30 days
- Federal – 50 days
- RF – 10 days
- Total – 90 days

Section 24(c)

- State – 60 days.
- Posting – 30 days
- Total – 90 days
- Federal has 90 days to disapprove.

If a PCA plans on pursuing the use a Section 18 or Section 24(c), the required application forms can be obtain on the Department's website at www.cdpr.ca.gov/docs/registration/regmenu.htm.

The application forms are self-explanatory and need to be filled out in detail. One of the most important items is the inclusion of good documentation/data supporting any claims.

Dennis Kelly
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CA Weed Science Society, 1/14/04
"A Registrants View on Herbicide Registration"

Key Points:

- The basic manufacturers of herbicides are merging/consolidating. 16 basic manufacturers in 1992, 6 in 2004.
- Some of these 6 manufacturers have integrated "seeds and biotechnology" into their pesticide platforms.
- The 6 basic registrants are all spending between 10 and 13 % of their sales receipts on Research, Technology and Development.
- Herbicides occupy a significant portion of Syngenta's sales receipts.
- The "traditional" herbicide development process is being challenged and changed by several factors, i.e. new technologies, demand for healthy food, biotechnology, market maturation, Wall Street and investors looking at R+D spend
- R+D efforts are now being targeted to business outputs.
    - New chemical products
    - Product life cycle management
    - Crop enhancement
    - New Ventures
    - Out licensing

- The rapid growth of biotech crops is affecting the herbicide market and R+D efforts are being directed to capturing opportunities. Input and output traits of biotech crops are being targeted.
- Many traditional R+D dollars are being spent on new/novel plant protectants, life cycle management, improving quality, and reducing production costs.
- High speed screening of new products is essential to meet R+D budgets and to accelerate market access. New products are selected by:
    - Target activity
    - Selectivity
    - Field activity-climates, crops
    - Toxicology
    - Ecotoxicology
    - Environmental safety
    - Production-feasibility and cost
    - Patents

- Product life cycle management is key, due to the high cost and time required (6-9 years and up to $200M) to bring a product to market. Life cycle management could include:
    - Formulation changes
    - Adjuvant research to increase activity
    - IPM and resistance management requirements

- Alliances with user groups for key product registrations. Such as, SLNs, novel registration concepts, indemnification.
- Out licensing.

- Product development process has been altered to increase the toxicology screens earlier in the development process.

Future Trends in Weed Management: Regulatory Challenges

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

This paper will discuss some of the challenges pesticide regulators face as scientific advancements and technology push changes in pesticides and applications, and other laws affect use of pesticides in diverse ways. Some changes may offer environmental benefits but do not necessarily fit into existing frameworks, and may create policy challenges.

Technology Applications: New Chemistry, Precision and Biotechnology

New Chemistry

Reducing pounds of herbicide applied is one of the benefits of some new herbicides. However, from a regulator's standpoint, reducing the total pounds of herbicide applied is not the only aspect of interest. Lower rate, more active herbicides may pose analytical technology challenges, particularly when state regulators don't have the technology needed to carry out enforcement analysis. More active but longer lived molecules may pose challenges for crop rotation. Potential phytotoxicity to nontarget crops pose challenges for managing applications appropriately to avoid offsite movement.

Precision Application

The use of global positioning systems, pattern recognition, remote sensing technology and related technologies has the potential of altering the manner in which herbicides are used. There is potential environmental benefit in targeting herbicide use where it is needed, reducing the overall amount of herbicide used. Because regulators use pesticide labels as the guide on enforcement, how these technologies influence label use directions will become important. California's use reporting system will also need to accommodate this more precise application of pesticides to more accurately reflect use.

Biotechnology

Herbicide tolerant plants derived from recombinant DNA technology are another focus of this discussion. Currently, use of genetically modified herbicide tolerant crops is not wide spread in California compared to other parts of the country, and does not pose a challenge to regulators. The use of herbicide tolerant crops may provide potential environmental benefits of reduced air pollution and groundwater and surface water contamination. Uncertainties about GM crops are driving research to answer various questions, and continue to fuel policy debates.

Other Statutes Affect Pesticides

Pesticide use, including herbicides, continues to be affected by other statutes. While most of the subject statutes are federal, delegated authority to state regulators brings the impacts back to the state level. Coordination amongst different regulators is essential to bring about needed change. Litigation under the Endangered Species Act is driving change at U.S.EPA. Lawsuit settlements will have an influence on use of some products, and future rulemaking will better define U.S.EPA's consultation with the Fish and Wildlife Service and the National Marine Fisheries Service. Changes will affect all aspects of registering products.

The Clean Water Act and the Clean Air Act are impinging on pesticides at various levels. Under the Clean Water Act, development of Total Maximum Daily Loads for impaired water bodies is proceeding, and coupled with the debate over the state agricultural drain exemption, management of pesticide applications and irrigation water containing pesticides will change in some parts of the state. California continues to require National Pollution Discharge Elimination System (NPDES) permits for many aquatic pesticide applications because of federal appeals court ruling. Clean Air Act requirements for regions that exceed air quality standards such as ozone levels will impact pesticides and agriculture increasingly. The Department of Pesticide Regulation has participated in the State Implementation Plan for areas of nonattainment since the mid 1990's, and is developing measures to implement by 2005.

Prospective New Agents for Biological Control of Yellow Starthistle.

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Six species of insects that attack yellow starthistle flowerheads have become established in California (Rees et al., 1996; Balciunas, 1998); however, they do not appear to be sufficient to control the plant in most parts of the state (Pitcairn et al., 1998; 2000). A rust pathogen (*Puccinia jaceae* var. *solstitialis*) was approved in 2003 for experimental release in California, and the first release was made last July by CDFA and ARS scientists. A weevil (*Ceratapion basicorne*) that develops inside the root crown of rosettes is being evaluated in quarantine. So far, it appears to be safe with respect to commercial crops such as artichoke and safflower and to native species of thistles and knapweeds. We expect to complete evaluation of plants on our test list (Table 1) and submit a petition this year requesting permission for release. Adults feed on the rosette leaves in late winter, larvae develop inside the root crown, and complete development by the time the plant bolts. This weevil is abundant in Turkey, attacking up to 100% of plants at a site, and many larvae can be found developing within one plant. A flea beetle (*Psylliodes* sp. nr. *chalcomera*) from southern Russia that develops in young stems has passed preliminary host specificity tests and will be studied further to see if it will be safe enough to release. Several other prospective agents are in early stages of evaluation, including: a blister mite (*Aceria solstitialis*), a lace bug (*Tingis grisea*), a rosette fly (*Botanophila turcica*), a seedhead weevil (*Larinus filiformis*), and fungal pathogens (*Synchytrium solstitiale* and *Phoma exigua*). Rapid progress to develop new agents is being accomplished through the efforts and cooperation of many scientists and a variety of institutions from many regions including California, Maryland, Montana, France, Italy, Greece, Turkey and Russia. The diversity of prospective agents greatly increases our chances of finding some that will greatly impact yellow starthistle populations in the U.S.

Table 1. List of plants to test for safety of prospective biological control agents of yellow starthistle

Family: Asteraceae
Subfamily: Cichorioideae
Tribe: Cardueae
Subtribe: Centaureinae
Acroptilon repens
Carthamus tinctorius (safflower varieties: CW-88 OL, S-518 OL, S-730 L and others)
Crupina vulgaris
Centaurea americana (native), *Ce. calcitrapa*, *Ce. cineraria*, *Ce. cyanus*, *Ce. dealbata*, *Ce. diffusa*, *Ce. maculosa*, *Ce. melitensis*, *Ce. montana*, *Ce. rothrockii* (native), *Ce. solstitialis*, *Ce. sulphurea*, *Ce. virgata var. squarrosa*, *Ce.* x *pratensis*

Table 1. (continued)

Subtribe: Carduinae
Carduus pycnocephalus
Cirsium brevistylum, *Ci. ciliolatum* (endangered CA), *Ci. cymosum*, *Ci. fontinale*, *Ci. hydrophilum*, *Ci. loncholepis*, *Ci. occidentale*, *Ci. pitcheri*, *Ci. rhothophilum*, *Ci. vinaceum*
Saussurea americana
Cynara scolymus (globe artichoke)
Onopordum acanthium

Subtribe: Carlininae
Xeranthemum cylindraceum

Subtribe: Echinopsidinae
Echinops exaltatus

Tribe: Mutiseae
Leibnitzia lyrata, or *Adenocaulon bicolor*, or *Trixis californica*

Tribe: Lactuceae
Agoseris grandiflora
Stephanomeria sp.
Latuca sativa (lettuce)

Tribe: Vernonieae
Stokesia laevis, or *Veronia fasiculata*

Subfamily: Asteroidae
Tribe: Gnaphalieae
Antennaria parvifolia, or *Gnaphalium californicum*

Tribe: Anthemideae
Artemisia californica, or *A. ludoviciana*

Tribe: Senecioneae
Packera macounii, or *Senecio vulgaris*
Senecio multilobatus (if available)

Tribe: Eupatorieae
Liatris punctata, or *Brickellia californica*

Table 1. (continued)

Tribe: Helenieae (test 3 genera)
Hemizonia, or
Madira, or
Eriophyllum, or
Layia, or
Tribe: Heliantheae
Echinacea purpurea
Helianthus annuus (sunflower)
Tagetes patula (French marigold)
Tribe: Astereae
Aster biglovii, or *A. chilensis*
Erigeron compositus, or *E. linearis*

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Weed control using a Precision Application System with Image-vision

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ABSTRACT

Researchers at UC Davis are developing an image processing based system for early weed control. The precision application system consists in a camera that captures images of the crop row, a computer that analyzes and distinguishes targets and a micro-sprayer that precisely applies the herbicide to the weeds.

The objectives of this research were: 1) Measure the ability of the precision application system to treat the target plants under field conditions. 2) Assess the weed control from treatments applied with the application system compared to a broadcast herbicide application.

In two field experiments conducted at UC Davis, weed seed was spread in the beds before cotton planting. Common purslane (*Portulaca oleracea* L.) was used in the first experiment and barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), in the second. In the first experiment the precision application system was set up to spray weed and crop plants, while in the second experiment only the weeds were targeted. Treatments and application methods are shown in Table 1. A randomized complete block design was used with four replications. Poly-ethylene oxide (PEO) was included to evaluate its ability to reduce micro-splash. The sprayer accuracy was assessed by counting the number of missed plants after each plot was applied. Weed control was assessed visually at 3, 7, 14 and 21 days after treatment (DAT). At the same time, cotton and weed mortality was determined by counting live plants in each plot.

The weed control and crop injury for both experiments is shown in Table 2. Mortality values for weeds are only for those that were treated, considering the inaccuracy of the application system. In the first experiment, the overall accuracy of the precision application system was 86.6%, varying from 78.9% to 92.8% among the treatments. Plant size and leaf position are among the factors that affect the applicator accuracy. In the second experiment, the system averaged 70.8% of proper plant recognition. Dense weed patches can be misclassified as "crop" by the system and remain untreated. Cotton mortality was very low with the micro-applied treatments, indicating that the precision application system performed well in discriminating the crop. Glyphosate was more effective than the essential oil treatments for controlling purslane and barnyardgrass. Weed recognition remains the most difficulty task in the refinement of the precision application system.

Table 1. Herbicide treatments and application methods used in the experiments.

N	Herbicide treatment	Application method
1	0.25% Glyphosate + 0.03% PEO[a]	Precision application system
2	0.50% Glyphosate	Precision application system
3	0.50% Glyphosate + 0.03% PEO	Precision application system
4	3.0% Cinammon oil	Precision application system
5	3.0% Clove oil	Precision application system
6	3.0% Eugenol oil	Precision application system
7a	Pyrithiobac 36 g ha-1	Precision application system
7b	Sethoxydim 360 g ha-1	Backpack sprayer (First experiment)
8	Control (Untreated)	Backpack sprayer (Second experiment)

[a] Polyethylene-oxide, anti-splash polymer.

Table 2. Weed control and crop injury at 21 days after treatment.

Herbicide treatments	1[st] Experiment Control %	1[st] Experiment Mortality %		2[nd] Experiment Control %	2[nd] Experiment Mortality %	
	POROL	POROL[a]	Cotton[b]	ECHCG	ECHCG[a]	Cotton[b]
0.25% Gly[c] + PEO	50.0 a	95.8 a	90.2 a	12.5 b	81.8 a	7.8 a
0.5% Gly	55.0 a	97.7 a	100.0 a	12.5 b	93.0 a	0.0 b
0.5% Gly + PEO	35.0 ab	94.5 a	76.4 a	27.5 b	70.8 a	0.0 b
3% Cinnamon oil	2.5 c	19.8 bc	6.3 c	7.5 b	27.5 bc	3.6 ab
3% Clove oil	10.0 c	23.7 b	17.4 bc	5.0 b	19.2 bc	0.0 b
3% Eugenol oil	7.5 c	24.1 b	39.9 ab	5.0 b	36.6 b	10.7 b
Pyrithiobac 36 g ha^{-1}	20.0 bc	4.0 cd	0.0 c	—	—	—
Sethoxydim 360 g ha^{-1}	—	—	—	99.5 a	98.8 a	0.0 b
Control (Untreated)	0.0 c	1.7 d	4.2 c	0.0 b	5.3 c	0.0 b

[a]Consider only treated plants. [b]Consider total number of plants (treated and untreated). [c]Glyphosate.

Broadleaf Weed Control in Turf with Fluroxypyr Based Herbicide Formulations

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ABSTRACT:

Fluroxpyr (4-amino-3,5-dichloro-6-fluoro-2-pyridyloxyacetic acid) was evaluated in combination with triclopyr, mecoprop-P, 2,4-D and dicamba for broadleaf weed control in turf. Numerous field trials were conducted across the country in 2002-2003 utilizing common protocols. Treatment combinations were applied as both a liquid spray and on a fertilizer granule carrier. Fluroxypyr was applied at 0.28kg ae/ha in each combination while mecoprop-P (MCPP), 2,4-D and dicamba were included at 1.67, 1.11 and 0.14 kg ae/ha, respectively. Triclopyr was applied at either 0.42 or 0.83 kg ae/ha depending on which combination it was included. Performance comparisons were made with both liquid and fertilizer granule combinations of triclopyr/clopyralid and mecoprop-P/2,4-D/dicamba. Broadleaf weed control evaluations were made approximately 2, 4 and 8 weeks after treatment. Results from 2002 demonstrated those liquid spray combinations of fluroxypyr with triclopyr at 0.83 kg ae/ha or MCPP resulted in greater than 90% control of *Plantago lanceolata* (PLALA), *Trifolium repens* (TRFRE), *Glechoma hederacea* (GLEHE) *and Medicago lupulina* (MEDLU). The same combinations provided approximately 80% control of *Taraxacum officinale* (TAROF). Granule fertilizer combination of fluroxypyr and triclopyr at 0.83 kg ae/ha resulted in approximately 80% control of TRFRE. These results are similar to those expressed by the comparison standards. Additional results from 2003 field studies will also be presented.

Weed Population Dynamics in Processing Tomato under different Tillage Practices as influenced by Irrigation Method.

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Project Summary: Subsurface drip irrigation conserves water and decreases weed populations compared to furrow or sprinkler irrigation. Conservation tillage systems reduce equipment and fuel costs, in addition to conserving soil and reducing dust. Conservation tillage relies heavily, however, on herbicides for weed control. In dry summer regions, lack of moisture near the soil surface prevents annual weed germination. If subsurface drip can be managed to prevent annual weed germination, the need for herbicides would be reduced or eliminated, and would allow the implementation of conservation tillage without an increased reliance on herbicides.

Design: A two-year field experiment will be conducted at the University of California, Davis. The treatments will compare subsurface drip and furrow irrigation under conventional and conservation tillage. Prior to planting, subsurface drip tape will be installed. Tomatoes will be transplanted using a no-till transplanter; fertilization and other practices will be similar to that of growers. After transplanting, furrow and subsurface irrigation treatments will be imposed. A split-split-block design with four replications will be used, with main plot being tillage type, sub-plots irrigation type and sub-sub plots being either standard herbicide treatments or no herbicides. Each irrigation/tillage combination will be a minimum of four beds wide and the length of the field. Hence, the treatments will be:

1. Conventional tillage, subsurface drip irrigation with standard herbicide application.
2. Conventional tillage, subsurface drip irrigation with no herbicide.
3. Conventional tillage, furrow irrigation with standard herbicide application.
4. Conventional tillage, furrow irrigation with no herbicide.
5. Conservation tillage, subsurface drip irrigation with standard herbicide application.
6. Conservation tillage, subsurface drip irrigation with no herbicide.
7. Conservation tillage, furrow irrigation with standard herbicide application.
8. Conservation tillage, furrow irrigation with no herbicide.

Standard herbicide treatments in tomatoes will consist of a post-transplant, banded application of rimsulfuron, made at approximately 14 days after transplanting. Comparisons of tillage type will include two intercrop tillage intensities, conventional (minimum, bed disking) tillage and conservation tillage (no-till). A Wilcox Performer implement will be used in the minimum tillage system. No intercrop tillage will be used in the no-till system. Hand weeding will be used in all plots to remove any emerged weeds at approximately 30 to 40 days after transplanting. Single-wheel (one wheel wide rather than two) harvest trailers will be used so as to maintain harvest traffic to the furrows so as to permit dedicated tractor traffic areas, or “zone production” (Carter, 1987).

Improving weed management, while reducing herbicide use is the primary objective of this study. Thus, weed density, cover, species composition, and distribution across the bed will be measured in each plot at 7, 14, 28, and 42 days after transplanting, and prior to any cultivation or hand weeding. By measuring weed distribution across the bed (assuming weed emergence in the subsurface drip irrigated plots), it may be possible to use very narrow herbicide bands. Hand weeding time will be recorded for each plot in order to assess economic returns.

Furrow irrigation will be applied as needed in amounts that replenish estimated evapotranspiration (ET) losses. Drip irrigations will be applied daily or every other day based on management guidelines recently developed by May and Hanson (Hanson, pers. comm.). End-of-season irrigation cutoff for both systems will be done in accordance with previously developed best irrigation management practices for processing tomatoes (Personal communication, D. May). Applied irrigation water volumes will be monitored using in-line flow meters. Soil water content will be measured in the surface 10 cm at four locations across the bed using a portable time domain reflectometry (TDR) instrument weekly during the first two months following transplanting to assess surface wetting. If surface moisture is excessive, weed germination would be expected to increase.

Plots will be machine harvested for determination of yields and subsamples taken for quality (soluble solid content, color, and disease). Treatment costs and net returns will also be calculated.

In 2005, the study will also be conducted at the West Side REC or with a cooperating grower in that area. Based on the first years results, additional treatments may be added to further refine weed management recommendations.

Initial Results: In the first season of the experiment the drip system showed significantly less weed growth and populations than the furrow system. Both systems had similar tomato plant biomass, and yield. The furrow yield had higher percentages of red fruit while the drip system was greener. We hypothesize that this was due to the late planting date and a learning curve in using the drip system to properly irrigate the plants. We expect that next year the differences in red fruit as a percentage of total will be minimal.

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