2013 Proceedings of the California Weed Science Society

Volume 65

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Preface

The proceedings contain contributed summaries of papers presented at the annual conference as well as the minutes of the annual business meeting, year-end financial statement, award winners, sponsors, exhibitors, and names, addresses and phone numbers and email addresses given by permission of those attending the meeting.

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VEGETABLE CROPS

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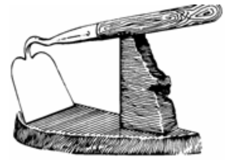
California Weed Science Society
and
The Story of the Short Handle Hoe



Norman D. Akesson
University of California, Davis

The California Weed Science Society Short Handled Integrated Tool (Short Handle Hoe) is a descendent of a long line of hand powered digging tools handed down through the millennia from generations of tillers of the soil. But unlike most of its genre, the short handle (overall about 18 inches) introduces an operational requirement, the stooped body position that could only have been developed in the chambers of the medieval torturers. However, it appears to have been a product of the culture of sugar beets in the irrigated fields of the Western United States, where it was thought that the untested laborer of the period (largely nationals from South of the border) couldn't aim the hoe and cut out the weeds accurately enough unless he stooped over and intimately selected the weed from the crop plant.

The CWSS hoe is a unique representative of this line. This particular tool was said to have been used by Dr. W.W. Robbins as a poignant reminder of the pest and an urgent reason for the further development and use of chemical weed control. He carried with it with him on his rounds of the farmer weed control meetings and punctuated his talks with references to this tool, the demon of the farm laborer and the lowest rung of the weed control ladder which was shortly to lead into the heady synthetic herbicide period of post WW II.

Today, it is difficult for us to relate to pre-chemical herbicide farming; we now accept these miracle materials (as they were dubbed in the 1940's) as a part of the arsenal (but certainly not the weapon) in the never-ending battle of crop plants versus weeds. However, to the farm laborer who had to assume the stooped, lock-kneed position and maintain this while swinging the little hoe for 8 to 10 hours per day "hell could have had no greater torture". Many California farm operators had, by the end of WW II, abandoned the short handle hoe in favor of the five-foot handle model and at some point during this period the California Assembly passed a resolution further condemning its use. This and the rapid development of the synthetic herbicides relegated this little torture tool to the museum.

The CWSS hoe probably started out as a work roughened model liberated from the tool shed at the University Farm by "Doc" Robbins and carried by him on his rounds of the farmer weed control meetings. In 1951 the hoe was spirited away, unbeknownst to Robbins by Walter Ball, a former student of Doc's when they were both at Colorado State. Walt had the hoe cleaned up (the blade and shank were cadmium plated) and polished to a mirror-like finish. At the 1951 California Weed Conference held in Fresno, CA, the hoe was presented by Walter to W.W. Robbins in honor of his many years of dedicated service to the science of weed control and to his key role in founding the California Weed Conference. Walt provided an old well-worn brown duffel bag to hold and protect the hoe. W.W. Robbins died in 1952 and his wife, Barbara, returned the hoe to Walter who then presented it to the California Weed Conference with the stipulation that it be passed on from the outgoing President to the incoming President in memory of W.W. Robbins. Thus over a period of about 10 years, a progression of Conference Presidents dutifully accepted the hoe and passed it on to their successors as a part of an installation ceremony at the annual conference.

In 1966 when I became President of the conference, several of the founding group looking to develop the image of the conference with a more polished symbol suggested we should “dress up the old hoe”, fit it with an identifying name plate and perhaps a mounting pedestal and give it rebirth as the conference symbol in honor of Doc Robbins.

On a holiday trip with my family to Fort Bragg I visited a local hobby shop and was shown some nice looking cuts from a redwood burl. I purchased a couple of these and brought them back to the wood working shop of the Agricultural Engineering Department at Davis where Paul Rutherford, our spray equipment mechanic and I fashioned the present mounting for the hoe. We polished up the hoe, handle and the burl and gave it a couple of coats of varnish. Walt Ball had a brass identification tab made which was installed on the base but we retained the “old brown duffel bag” which we felt maintained the proper aura as a fitting container for the venerable hoe. In its new reborn form it was first presented to Cecil Pratt, the incoming President of the 1967 Conference which was held in San Diego, California.

Today, some 30 years and as many Presidents later, the hoe is still being passed on in its little brown bag. To those of us who have watched and participated in the events which have resulted in a virtual revolution in weed control practices, the hoe is a practical reminder of the past. Perhaps a sobering thought or two may pass through our minds as we recall a long gone time when, for a brief period, the Short Handle Hoe was the tool of choice for weed control in California.

W.W. “Doc” Robbins, Bill Harvey, Walter Ball, Alden Crafts, Murray Pryor and the many others who have been honored by the California Weed Conference might look askance at the name change that was visited on the organization in the mid 90’s when the name was changed to the California Weed Science Society. I can hear Bill Harvey murmur to no one in particular “my, my, now ain’t that something fancy” while Walt Ball would likely have simply mumbled a “mild expletive” and Doc would have pontificated something to the effect that “progress does take strange and exotic forms”. They would have all agreed that the little hoe was and is a suitable reminder of the humble origins of weed control and that it matters not what the new name of the conference may be – its spirit will continue.

Odd as it may be, Doc Robbins never accepted the Presidency of the California Weed Conference. He retired from the University in 1951 after 29 years of service and lived with his wife, Barbara, in their little brown redwood house at the top of Oak Avenue in Davis until his death in 1952.

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California Weed Science Society
Honorary Member – 2013

Scott A. Johnson
Vegetation Management Specialist
Wilbur Ellis Company

At the 2013 Annual Membership Business Meeting in Sacramento Scott Johnson was awarded the title of Honorary Member of the California Weed Science Society. The Honorary Member is the highest honor awarded by the Society and recognizes role models in the profession of Weed Science and outstanding service to the CWSS. The recipient is determined by the Nominating Committee and approved by the CWSS Board of Directors.

A fifth-generation Californian, Scott was born in Sacramento. He attended UC Davis and earned a BS degree in Agricultural Economics in 1972. His career as a PCA started in crop agriculture in 1974. When he joined the Wilbur-Ellis Company in 1981, his emphasis switched to a single crop, timber (forest vegetation management), and non-crop work.

Scott works mostly with government agencies, utilities, and habitat managers. One of his most challenging experiences was helping clients reforest about one-half million acres after the catastrophic forest fires in the late 80s-early 1990s. Going in after the salvage logging, it was Scott's job to make recommendations on site preparation regarding preplant and post plant herbicide treatments to protect new forestry seedlings.

Scott was one of the first CWSS chair/moderators of the Forest, Range, and Wildland session under the 1993 Conference Chair Jim Greil. This session split off from the Industrial Weed Control or Non-crop Session. This was also about the time that invasive weeds came into their own spotlight at the CWSS Conference.

Dr. Nelroy Jackson (CWSS President 1995) recruited Scott to serve on the Executive Board of CWSS. Scott was Vice President and Program Chair for the 50th Anniversary Conference in January 1998 in Monterey, when the membership received briefcases complete with the CWSS logo. Scott is also very proud to have recruited the first woman to the CWSS Executive Board. Pam Geisel served as CWSS President in 2004.

Scott has been a regular participant and advocate at the annual CWSS Conference. He received the CWSS Award of Excellence in 2005. Congratulations are extended to Scott Johnson on becoming an Honorary Member of the California Weed Science Society.

California Weed Science Society
Award of Excellence – 2013

Rick Miller
Sales Representative
Dow AgroSciences

The California Weed Science Society has presented the 2013 Award of Excellence to Rick Miller for his contributions and service to the society.

Rick earned his Bachelor's Degree at UC Santa Barbara in Environmental Biology and Environmental Sciences and then received a Master of Science Degree in Entomology from Oregon State University.

He started out with Driscoll Strawberries before working 12 years with Biosys, a biological insecticide company (now Certis USA). He then spent 8 years representing SePRO Corporation in twelve western states covering the Turf & Ornamental and Aquatics markets. Since 2005 Rick has been responsible for managing Dow AgroSciences Specialty sales in Central California. Key customers are in T&O, Industrial Vegetation Management, and Range & Pasture markets.

Rick has been actively involved with CWSS since 2005 participating as a session chair moderator and presenter. He has served as a Board member in charge of Membership and is now serving on the Executive Board. Prior to 2005 Rick was President of the Western Plant Growth Regulator Society, an organization that had close ties to CWSS.

Rick does a quality job with every task that he performs for CWSS. As Membership Director he has been instrumental in securing sponsors and exhibitors for the conference and in managing the Poster and Exhibitor Section of the Conference. The CWSS Board wanted to recognize Rick for all of his past accomplishments, involvement, and dedication to the Society as he now takes on his next role as the CWSS Vice President and the 2014 Chair of the 66th Annual Conference.

2013 Student Awards

Presented by CWSS Director-Student Liaison Oleg Daugovish

Pictured left to right: Michelle Dennis, Sonia Rios, Gerardo Banuelos, Joy Hollingsworth, Sarah Alatorre

Research Papers

($500) Michelle Dennis – Evaluation of saflufenacil on glyphosate and paraquat-resistant hairy fleabane

($300) Joy Hollingsworth – Weed population dynamics in overhead and subsurface irrigated no-till cotton cropping systems

($200) Sonia Rios – Horseweed (conyza Canadensis) control in almond orchards with pre and postemergence herbicides in the southern San Joaquin Valley

Research Posters

($500) Rolando Mejorado – Evaluation of C14-Glufosinate translocation in young almond *(Prunus dulcis)* trees

($300) Rafael Pedroso – Predicting *Cyperus difformis* emergence for improved control timing in rice fields; Propanil resistance in *Cyperus difformis* of California rice fields: a new challenge

($200) Marcelo Moretti – Postemergence control options for glyphosate-resistant junglerice in nut tree orchards

2013 CWSS Student Scholarship & Internship Recipients

Undergraduate Scholarship Award ($1000)

Nadia Juarez, California State University, Fresno

My name is Nadia Noemi Juarez, I attend California State University, Fresno and pursuing a bachelor's degree in Plant Science. My project will be working with Oyster Mushroom (Pleurotus ostreatus) Substrate as a Pre-emergent Bio-herbicide with my advisor Dr. Anil Shrestha. My future career goal is to obtain a masters degree in weed science and pursue a career in plant research and development. nadiajuarez@mail.fresnostate.edu

Graduate Scholarship Awards ($1500)

Gerardo Banuelos, California State University, Fresno

I'm in my 2nd semester at CSU Fresno and am truly enjoying my time as a graduate student. All my professors are great and it's been a good experience learning more about agronomy. The best part is getting to know a lot of new young agronomist that will have a great future in agriculture. I would like to say thank you to the CWSS committee for the scholarship and the great opportunity to be part of the CWSS. gbanuelos@ucdavis.edu

Whitney Brim-DeForest, University of California, Davis

Whitney Brim-DeForest is a second-year PhD student in Horticulture and Agronomy at the University of California, Davis, under the direction of Dr. Albert Fischer. Her dissertation focuses on weeds in rice in California, specifically Late Watergrass (Echinochloa phyllopogon) and Smallflower (Cyperus difformis). She is validating laboratory models using field buried over-wintered seed, as well as modeling their germination and emergence under reduced-water irrigation systems. She hopes to continue in extension and teaching after completing her degree. wbrimdeforest@ucdavis.edu

Elizabeth Karn, University of California, Davis

Elizabeth Karn is currently a Ph.D. student in Plant Biology at UC-Davis. She is currently working on a dissertation research project with advisor Marie Jasieniuk. This research is focused on glyphosate resistance in Italian ryegrass in orchards and vineyards of northern California. She is using genetic data to understand the processes involved in origins of herbicide resistance and routes of spread. After graduate school, Elizabeth plans to pursue a career in weed science research either in industry or academia. evkarn@ucdavis.edu

Marcelo Moretti, University of California, Davis

I am a Ph.D. student at UC Davis working advised by Dr. Bradley Hanson. My dissertation project focuses on understanding the mechanisms of glyphosate and paraquat resistance in hairy fleabane. I am also involved in applied research in weed management of nut-tree orchards. My career plans are to continue working on the area of weed management with academia or industry. mlmoretti@ucdavis.edu

Internship Award ($3000)

(Advisors Steve Orloff and Rob Wilson, UC-ANR)

Matt Barber, California State University, Chico

I am currently a junior at California State University Chico seeking a bachelor’s degree in Plant Science, Horticulture, and Land Management. I plan to continue my education by pursuing a master’s degree in Agriculture. I am looking forward to expanding my weed management knowledge and experience this summer working with Rob Wilson on weed management projects in the Tulelake basin. mattbarber55@hotmail.com

Perennial Plants: The Tricks and Turns of Their Perennating and Overwintering Structures

Ellen A. Dean, UC Davis Center for Plant Diversity, Plant Sciences M.S. 7, One Shields Ave., Davis, CA 95616. eadean@ucdavis.edu

Perennial plants live more than two seasons. This can be contrasted with annual plants which complete their life cycle in one season, or biennials, which complete their life cycle in two seasons. Perennial plants can be woody shrubs and trees, or they can be perennial herbs. Many perennial herbs produce new fresh growth each year when the weather is optimal and then die back during their dormant season to storage stems or roots. In California, we have perennial herbs in the mountains that persist through the winter snow as storage stems or roots. In other parts of the state, the dormant season is the drought months of June through October; many of perennial herbs in the Central Valley specialize in producing above-ground growth between November and May, dying back to storage stems and roots once drought starts. Our California weed flora includes many perennial herbs with a variety of storage stems and roots, and an understanding of these structures can be key to their control.

It is useful to review the basic landmarks of stems and roots. When a seed germinates, it produces a shoot and a root. The shoot becomes the shoot system, which includes the stem and the leaves. The stem is divided into nodes, where the leaves emerge, and internodes (the areas between the nodes). At each node, just above where the leaf meets the node, there is usually a small bud called an axillary bud. Finding these landmarks on a plant part means it is a stem.

In many plants, the seedling root develops into a tap root system, best illustrated by carrot or dandelion. However, in grasses, lilies, and other monocotyledons, the initial seedling root does not continue to develop, and roots develop instead from the stem system. This type of root system is called a fibrous root system. Another term used for roots that develop from stems (or sometimes leaves) is “adventitious roots.” Adventitious roots often develop from stem nodes, and they can be present in plants that also have a tap root system. Regardless of how they develop, roots do not have nodes, internodes or axillary buds.

After the initial seedling stage, as plants age, growth patterns can be complex and it can be difficult to distinguish roots from stems. Some roots are able to produce stems (root-borne shoots), and as discussed above, some stems can produce roots (shoot-borne roots). Stems and roots differ anatomically when examined in cross-section. Roots have their vascular tissue in one large cylinder in the middle of the root, while stems have their vascular tissue distributed in a number of vascular bundle cylinders that are arranged either in a ring (non-monocotyledons) or scattered throughout the stem (monocotyledons).

In perennial herbs, there are many different types of storage stems that are used to persist during the dormant season. Short upright storage stems that form at the very base of the seedling (below the first seedling leaves), such as those found in crocuses, are called corms. Stems with very short internodes and thickened storage leaves (onion) or storage axillary buds (garlic) are called bulbs. In both corms and bulbs, offset cormlets and bulblets can be produced that allow the plant to reproduce asexually through cloning.

Other perennial herbs produce below-ground horizontal storage stems called rhizomes which when examined have clear nodes and internodes. In some cases, rhizomes only produce above-ground leaves at their nodes, often at their slowly-growing tip. This is the case in irises. In other types of rhizomes, above-ground stems grow from axillary buds produced at the rhizome nodes. This is the case in many grasses and sedges, which produce a line of erect stems (with leaves) from a below-ground rhizome. Sometimes, rhizomes produce engorged storage areas that are called tubers, best illustrated by the potato (which can produce stems from the axillary buds in its eyes, which are nodes). Related to rhizomes, are above-ground horizontal stems called stolons, best seen in strawberries or Bermuda grass. Stolons typically have long internodes called runners and then produce an upright stem with adventitious roots at each node. It is sometimes difficult to know if one is dealing with a rhizome or stolon, since the distinction has to do with whether or not the stem is above or below ground. Just as with corms and bulbs, rhizomes, tubers, and stolons can fragment, allowing the plant to reproduce asexually through cloning.

In some perennial herbs, it is storage roots that are used to get through a dormant season. As mentioned above, some roots can produce a shoot system, and storage roots are a good example of this. Some storage roots, such as carrot, are storage tap roots, which develop from a tap root system. Other storage roots develop from adventitious roots and are sometimes called tuberous roots.

Plants can be complex and have a number of different strategies for persisting through drought or cold as well as for cloning. They may combine the structures discussed in this paper, producing an initial shoot above ground and an initial tap root system, then producing a rhizome with adventitious roots and small tubers, which then can produce more upright stems. In some plants, bulbs or tubers may be produced in unexpected places, such as the inflorescence bulbs of bulbous blue grass or the aerial stem tubers of air potato. In other plants, such as Bermuda buttercup, copious storage roots, rhizomes, and bulbs may be produced underground, making the plant very difficult to eradicate. An understanding of the basic morphology of perennial herb dormancy structures, as well as the timing of when these structures are produced, can be key to the control of perennial herbs.

Evaluation of Saflufenacil on Glyphosate and Paraquat-resistant Hairy Fleabane (*Conyza bonariensis*)

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Hairy fleabane is a problematic weed in California. This problem has been further aggravated by the discovery of glyphosate-resistant (GR), paraquat-resistant, and glyphosate + paraquat resistant (GPR) hairy fleabane biotypes in the Central Valley. New herbicides are being sought to control these resistant biotypes. The objective of this experiment was to evaluate the effect of temperature on the efficacy of a fairly new herbicide, saflufenacil (Treevix ®), on glyphosate-susceptible (GS), GR, and GPR biotypes of hairy fleabane at different temperature regimes. Potted hairy fleabane plants were treated at the 5-8 leaf stage with either saflufenacil (1 oz/ac), glyphosate (28 fl. oz/ac), or a mixture of saflufenacil (1 oz/ac) + glyphosate (28 fl. oz/ac). The experimental design was a split-split-plot. Prior to treatment, the plants were kept for 3 days in growth chambers programmed at 15/10° C (sub-optimum), 25/20° C (optimum), and 35/30°C (supra-optimum) day/night temperatures. Immediately after treatment, plants were returned to the respective growth chambers and kept there for 7 additional days before being returned to the greenhouse set at 25°C with ambient lighting for additional 23 days (30 DAT). Results showed that saflufenacil alone and saflufenacil + glyphosate were equally effective at controlling all three biotypes at 15/10˚C and 25/20˚C. However, at 35/30˚C, the saflufenacil + glyphosate treatment controlled 100% of the plants, but saflufenacil alone provided only 20%-25% control of GS and GPR biotypes and 0% control of the GR biotype. Glyphosate-alone provided 100%, 60%, and up to 50% control of the GS, GPR and GR biotypes respectively at 15/10˚C and 25/20°C. At 35/30°C, glyphosate-alone provided no control of the GPR and GR biotypes and only 60% control of the GS biotype. In conclusion, during warmer periods, using a tank mix of saflufenacil and glyphosate may provide better control of hairy fleabane.

Effect of Postemergence Herbicides and Application Time on Small Grain Injury and Yield

[1]Gerardo Banuelos, [2]Steve Wright, [1]Anil Shrestha, [2]Sonia Rios, [2]Kelly Hutmacher, [2]Katie Wilson, [2]Jaime Changala, [2]Nancy Loza, [3]Walter Martinez
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Abstract

Often times both broadleaf and grassy weeds are problematic in cereal production requiring the use of two different herbicides with different application timing. To cut costs, growers are interested in combining applications. However, crop safety with herbicide combinations is a concern, and the appropriate application timing for different herbicides and herbicide combinations was not well tested. Research was conducted in the San Joaquin Valley area of central California to evaluate weed control and crop safety with selected new and standard herbicides applied alone and in combination at two different growth stages (3-5 and 6-8 leaf stage). In general, herbicide treatments with Puma (*Fenoxaprop*), Axial (*Pinoxaden*), or Axial + MCPA had little to no crop injury at any site. The differences in crop injury between tank mixes were minor at one site with the exception that when Axial was used the injury increased. The wheat (*Triticum aestivum*) injury that did occur with some of the tank mixtures typically disappeared after four to five weeks and there was no significant difference in bushel weight, protein, or yield between any of the treatments.

All of the treatments gave excellent control of wild oats (*Avena fatua*) at both timings, except for treatments with only ET (*Pyraflufen*) or Shark (*Carfentrazone*). Simplicity (*Pyroxsulam*) gave fair to good control of wild oats and some broadleaves. All treatments controlled Shepherd's-purse (*Capsella bursa-pastoris*) at both timings, except for treatments with only Puma or Axial. All treatments gave good to excellent control of common chickweed (*Stellaria media*) at both timings, except for treatments with Puma or Axial alone. All of the treatments with Shark, Osprey (*Mesosulfuron*), or Simplicity gave excellent control of coast fiddleneck (*Amsinkia menziesii*). All of the treatments except Puma or Axial alone gave excellent control of burning nettle (*Urtica urens*). The results of this research supported 2012 label change to allow tank mixing of Axial + MCPA.

Horseweed (*Conyza canadensis*) Control in Almond Orchards with Pre- and Postemergence Herbicides in the Southern San Joaquin Valley

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In recent years, populations of horseweed (*Conyza canadensis*) have been observed more frequently in orchards in the Southern San Joaquin Valley. Since glyphosate-resistant (GR) biotypes of this species were confirmed in 2007, alternative integrated techniques are needed to manage GR and glyphosate-susceptible horseweed populations and to prevent further development of herbicide resistance. A field experiment was conducted in January, 2012 in Tulare County to control horseweed with various pre- and post-emergence herbicides labeled for use in almond orchards. Herbicides included glufosinate (82 fl oz/ac), flumioxazin (8 oz/ac), rimsulfuron (4 oz/ac), oxyflurazon (3 pts/ac), isoxaben (1.33 lbs/ac), penoxsulam (3 pts/ac), indaziflam (5 fl oz/ac), saflufenacil (1 oz/ac), and pendimethalin (2 qts/ac). These herbicides were applied either pre- or post-emergence with a CO_2 backpack sprayer at rates labeled for almonds. The experiment was designed as a randomized complete block with four replications. Evaluations on survival or control of the horseweed plants were taken at 7, 14, and 50 days after treatment (DAT). Results indicated that at the 7 and 14 DAT saflufenacil at 1oz/ac provided significantly better control of horseweed than the other treatments. However, at 50 DAT, all treatments were similar and provided excellent control of horseweed. Therefore, this study showed that any of the herbicides tested could be used to control horseweed effectively but rapid early control could be obtained with saflufenacil.

Weed Population Dynamics In Overhead And Subsurface Irrigated No-Till Cotton Cropping Systems

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Water is a limiting factor for agriculture in California's San Joaquin Valley, and therefore irrigation efficiency is highly important. Drip irrigation systems have become increasingly popular, and overhead (OH) systems (such as linear and center pivot) are being experimented with to increase irrigation efficiency. These OH irrigation systems are much more common in mid-western U.S. than in California, but in recent years their mechanization, ease of use, as well as compatibility with minimum tillage systems, is drawing attention of researchers and growers. A field study was conducted at the University of California West Side Research and Extension in 2011 and 2012. The experimental design was a randomized complete block and treatment comparisons included sub-surface drip (SSDI) and OH irrigation in no-till Roundup Ready 'Acala' cotton. An application of glyphosate was made one month after cotton planting. The crop was irrigated with the same volume of water, and was monitored throughout the growing season for several parameters. In this report, only information on weed populations is being presented. In both years, weed densities were similar early in the season but in July the densities were higher in the OH than in the SSDI treatment. Weed biomass at crop harvest was greater in the OH than in the SSDI plots. Seedbank samples showed that, although weed densities were lower mid-season in the SSDI plots, more viable seeds were present in this treatment indicating that the seeds failed to germinate because of lack of moisture at the soil surface. The growth, development, and yield of the crop were similar in both systems. Though crop growth and yield was not affected, plots with OH irrigation may require two weed control operations during the growing season to prevent weed seed return whereas one weed control application may be sufficient in SSDI systems.

Can The Activity Of Rimsulfuron Be Enhanced With Aquatrols® (Soil Surfactant) In Transplanted Fresh Market Deficit Irrigated Tomatoes?

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Shortages of water have led to research on regulated deficit irrigation (RDI) and use of soil surfactants such as Aquatrols IrrigAid Gold® that potentially improves water infiltration. We hypothesized that this soil surfactant may also improve the distribution and thus the efficacy of a soil-applied pre-emergence herbicide such as rimsulfuron (Matrix). A field study was conducted in 2012 at the California State University, Fresno farm to evaluate the efficacy of rimsulfuron when applied with Aquatrols IrrigAid Gold® on weed control and to see if reduction in irrigation increased weed competition. The fresh market tomato variety 'Quali T 47' was transplanted on 60 inch beds in late-May. The experimental design was a split-split plot with 3 irrigation regimes (100%, 80%, and 60% of the daily ET) as the main plot. Soil surfactant applied at the rate of 4 oz/ac or no-surfactant were the sub-plots. Rimsulfuron applied at 0, 1, 2, and 4 oz/ac were the sub-sub-plots. Irrigation and fertilizer was applied through a sub-surface drip irrigation system buried 6 inches deep. The soil surfactant and rimsulfuron were applied immediately after transplanting tomatoes and the herbicide was water-incorporated. Data were taken on weed densities, weed biomass, and crop growth, yield, and quality. Irrigation levels did not affect weed density or crop yield but weed biomass was lowered and fruit maturity was delayed as irrigation was reduced. The soil surfactant had no effect on any of the weed or crop parameters. Presence of herbicide affected both weed and crop parameters but the herbicide rate did not. Weed density, biomass, and crop yield was lower when no herbicide was applied. In conclusion, under RDI better weed control may be required as presence of weeds delayed fruit maturity and lowered the yield more so in the 60% ET plots than in the other plots.

Screening for Natural Product Herbicides

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Natural products have long been used to manage pests, particularly as insecticides and fungicides. However, their usefulness as herbicides has been limited. Only one commercial herbicide is a natural product and a handful of others are natural product-like. However, the continuing emergence of herbicide resistant weeds has renewed the interest for new herbicide chemical classes with new potential molecular target sites. There are a number of advantages in utilizing natural products for the discovery of new herbicides, but there are also a number of problems or limitations associated with using such compounds (Table 1).

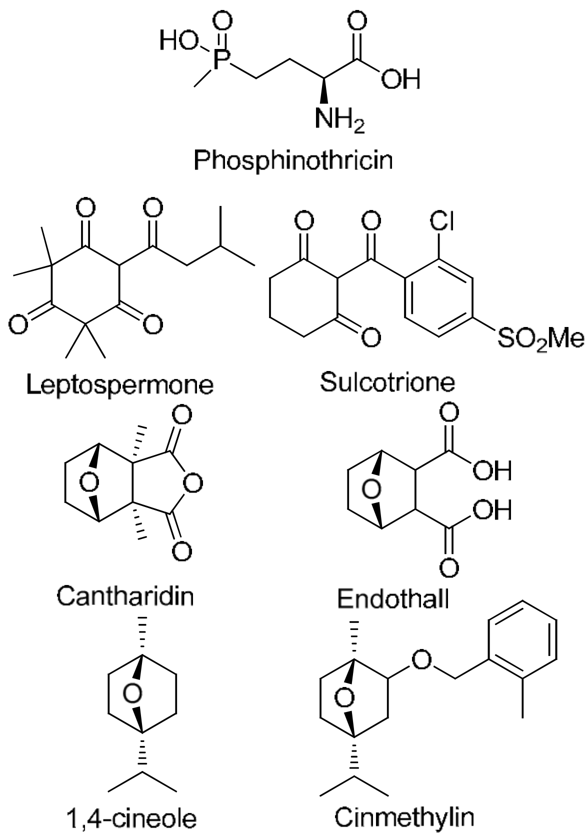
Table 1. Advantages and limitations of using natural products as a source of new herbicides or new modes of action.

Advantages	**Limitations**
New structural backbones extending to unexplored chemical spaces	Complicated structures that may be too expensive to synthesize
New molecular target sites	May have high general toxicity problems
Evolved biological activity increase the likelihood of discovering relevant structures	Structure may already be optimized for activity but have inadequate physicochemical properties
Improved instrumentation makes identification easier and requires smaller amounts	Rediscovery of known compounds is costly and sourcing may be limiting
Generally environmentally friendly	Too short environmental half-life
Better public acceptance	Public expects low rate use
May be cheaper to register	Patent protection may be limited

Investigating natural products as herbicides is advantageous because many secondary metabolites have been selected over time to address specific biological stresses. Therefore, it is likely to lead to the discovery of biologically active compounds that often have new target sites. Additionally, natural products tend to have unique scaffolds that are rich in oxygen and nitrogen molecules, and possess more chiral centers than synthetic pesticides. Such structures explore chemical spaces not exploited by their synthetic counterparts. These features, however, can sometimes be a problem because many natural product target sites may be unsuitable for a herbicidal mode of action due to general toxicity.

Determination of the mode of action of phytotoxins is a challenging endeavor due to the multitude of potential molecular targets. This short review will describe commercial herbicides that are either natural products or natural products-derived, and approaches to screening natural products for herbicides.

Bialaphos, a tripeptide analog of phosphinothricin (Figure 1), is the only natural broad-spectrum post-emergence herbicide (Figure 1). This fermentation product from *Streptomyces hygroscopis* cultures is marketed as a herbicide in eastern Asia. Bialaphos is a proherbicide that is bioactivated into phosphinothricin by plants before exerting its herbicidal action as a glutamine synthetase inhibitor. There are no other commercial herbicide with this mode of action. The commercial version of phosphinothricin is commercialized as glufosinate.



The triketone herbicides were derived from leptospermone (Figure 1), a herbicidal natural triketone component produced by bottlebrush (*Calistemon* spp.). Triketone herbicides inhibit *p*-hydroxyphenylpyruvate dioxygenase (HPPD), disrupting biosynthesis of carotenoids and causing bleaching (loss of chlorophyll).

Endothall (Figure 1) is a natural product-like herbicide that resembles cantharidin, a toxin produced by the blister beetle (*Epicauta* spp.). Endothall and cantharidin are strong inhibitors of plant serine/threonine protein phosphatases. This herbicidal mechanism of action is unique to endothall.

Figure 1. Phosphinothricin (the only natural product herbicide) and the similarity between some natural products (left) and their structurally related commercial herbicides (right).

Cinmethylin (Figure 1) is a structural analog of 1,4-cineole, a monoterpene present in the essential oils of many aromatic plants. The benzyl ether moiety was added to the monoterpene to lower the volatility of the natural product. A physionomics investigation of the mode of action of cinmethylin discovered a novel mechanism of action for herbicides, namely inhibition of plant tyrosine aminotransferase.

Screening for Natural Product for Herbicide Discovery

The successful examples mentioned above provide a good rationale for screening natural products to discover new herbicides. Investigating compounds from exotic organisms is a fairly common strategy. Phytotoxins from microbial origin are particularly interesting because large scale fermentation enables the production of sufficient amounts of toxins for agricultural use. Rediscovery of compounds is fairly common but the process is much faster with newer dereplication processes integrating analytical instrumentation and informatics. New interfaces between HPLC, mass spectrometry (MS) and nuclear magnetic resonance simplify the isolation and identification of natural products. Commercial, public and private databases of natural products as also available to identify previously known compounds.

The outcome of the isolation process is dependent on the sorts of bioassays used. These can range from enzymatic assays to whole organism assays. In general, target site-specific assays can be automated and miniaturized for high-throughput screenings but are likely to miss a large number of potential herbicidal compounds. We prefer miniaturized whole organism bioassays. These are slower but may be more suitable for natural product-based discovery processes. Indeed, bioassay-guided fractionation protocol based on *in vivo* responses minimizes the risk of missing active compounds (that would be overlooked in site-specific assays), and maximizes the possibility of discovering new molecular sites of action.

Carefully planned dose-response experiments that use whole organisms can yield important qualitative and quantitative information in evaluating the effect of the inhibitor, and also may offer some hints as to the possible sites targeted by the compound. We currently use the free statistical software R with the DRC module developed by Streibig and Ritz in Denmark. This program easily calculates the concentration necessary for any level of inhibition as well as calculating the selectivity index.

A great number of natural products with interesting phytotoxic profiles have been discovered but very few have been studied to the extent necessary to be considered as candidate compounds. Table 2 summarizes some of the better natural products to have been considered as herbicides.

Table 2. Relevant information on the natural products mentioned in the text.

Compound	Mode of action	Unique	Patent for herbicide use
Microbial source			
Thaxtomin A	Cellulose synthesis	New	Yes
Cyperin	Enoyl-ACP Reductase	New	No
Actinonin	Peptide deformylase	New	Yes
Phaseolotoxin	Ornithine carbamoyl transferase	New	No
Hydantocidin	Adenylosuccinate synthetase	New	Yes
Albucidin	Adenylosuccinate synthetase	New	No
Tentoxin	CF1 ATPase	New	No
Pyridazocidin	Photosystem I electron acceptors	No	No
Cinnacidin	Jasmonic acid-mimic	New	No
Ascaulitoxin	Unknown	New	No
Plant source			
Pelargonic acid	Removal of cuticles	New	Yes
Sarmentine	Removal of cuticles	New	Yes
Citral	Microtubule polymerization	New	Yes

Thaxtomin A (Table 2) is a phytotoxic cyclic dipeptide analog produced by *Streptomyces scabies* and other *Streptomyces* species, the causative agents of common scab disease in potato and other taproot crops. Thaxtomin inhibits cellulose synthesis by affecting the formation of the cellulose synthase complexes on the outside of the plasma membrane. This mode of action is different from that of known cellulose biosynthesis inhibiting herbicides such as dichlobenil and isoxaben, though the symptoms of the plants are similar.

Cyperin (Table 2) is produced by several fungal plant pathogens. This phytotoxic natural diphenyl ether that causes light-independent membrane degradation. We recently discovered that cyperin inhibits enoyl (acyl carrier protein) reductase (ENR). ENR is the molecular target site of the diphenyl ether triclosan which is commonly used as a component of antimicrobial soaps, but this enzyme has not been targeted by any commercial herbicide to date.

Actinonin (Table 2) is a naturally occurring hydroxamic acid pseudopeptide produced by a soil actinomycetes. It inhibits metallopeptidase peptide deformylase involved in initiating protein translation in prokaryotes by removing the *N*-formyl group from *N*-formyl methionine. Actinonin effectively controls a wide range of plants, including many agriculturally important and difficult-to-control weed species. This compound has been patented for herbicide use but no commercial product has been developed to date.

Phaseolotoxin (Table 2) is a sulfodiaminophosphinyl peptide produced by *Pseudomonas syringae* pathovars, the causal agent of halo blight on legumes. It is a competitive inhibitor of ornithine carbamoyl transferase.[51] Ornithine carbamoyl transferase is a key enzyme in the urea cycle which converts ornithine and carbamoyl phosphate to citrulline. No commercial herbicides have been developed to target this enzyme.

Hydantocidin (Table 2) is produced by different *Streptomyces* strains and has been the subject of intense research. It was at one time seriously considered as a natural herbicide,[52,53] but the cost of synthesis appeared prohibitive. Hydantocidin is a proherbicide that must convey bioactivity via phosphorylation in order to inhibit adenylosuccinate synthetase, and enzyme involved in purine biosynthesis.[54] The toxicological implications of this molecular target site may also have deterred development of a herbicide with this target site.

Albucidin (Table 2) was isolated from *Streptomyces albus*. The compound is a very potent nucleoside toxin that induces chlorosis and bleaching. Albucidin has moderate levels of pre-emergence activity, with broadleaf weeds being more sensitive than grasses. Pre-emergence herbicidal activity implied that the mechanism of action may involve metabolic perturbation not limited to bleaching, as the development of the majority of affected plants was halted at the cotyledonary stage. Post-emergence activity was broad spectrum. .

Tentoxin (Table 2) is a cyclic tetrapeptide produced by *Alternaria alternata* that causes extreme chlorosis of the foliage of sensitive species by inhibiting chloroplast development. Tentoxin inhibits the energy transfer of the chloroplast-localized CF1 ATPase. Tentoxin also interferes with the transport of the nuclear-coded enzyme polyphenol oxidase into the plastid of sensitive plants, but does not affect the transport insensitive species. The linked relationship between the effect of tentoxin on the β subunit of proton ATPase and polyphenol oxidase processing is not understood.

Pyridazocidin (Table 2) was purified from cultures of *Streptomyces*. Post-emergence application of pyridazocidin produced necrosis at high concentration and chlorosis at lower application rates. Pyridazocidin is positively charged and appears to act like bipyridinium herbicides (e.g. diquat) but disrupting photosystem I electron transport, resulting in rapid membrane lipid peroxidation.

Cinnacidin (Table 2) was isolated from a fungal fermentation extract of *Nectria* sp., a plant pathogen that causes cankers on many tree species. Cinnacidin causes stunting and chlorosis that spread throughout the foliar tissues. Its mode of action may be similar to that of coronatine and acts as a hormone-like herbicide by mimicking the role of jasmonic acid.

Ascaulitoxin has been isolated from the plant pathogen *Ascochyta caulina*. This natural product is already patented as a mycoherbicide. Its activity is associated with the production of the phytotoxin ascaulitoxin and its non-protein amino acid aglycone (2,4,7-triamino-5-hydroxyoctanoic acid) (Table 2). The mode of action is unknown but appears to be novel, possibly involving amino acid amino acid transporters.

Sarmentine (Table 2) is an example of the ethnobotanical approach to herbicide discovery from natural products. The fruits of long pepper (*Piper longum* L.) have been used in traditional medicine for the treatment of several diseases and ailments. Therefore, it is likely that this plant possesses a number of bioactive compounds. The bioassay-guided purification of the crude extract of long pepper led to isolation of the broad-spectrum contact natural herbicide sarmentine. The phytotoxicity of sarmentine matched that of herbicidal fatty acids such as pelargonic acid (Table 2). These molecules are broad-spectrum, foliar-applied, post-emergent herbicides that lead to plant desiccation and burndown.

Citral (Table 2) is a diterpene component of many plant essential oils that can account for up to 80% of the steam distillate, as in lemongrass (*Cymbopogon citratus* Stapf.). Citral is patented as a herbicide and is the active ingredient of a number of lemongrass oil-based natural herbicides. Citral disrupts plant microtubule polymerization rapidly. The phenomology of citral action on microtubule is distinct from that of well known mitotic inhibitors used as herbicides, such as oryzalin, suggesting that it may have a novel target site in disrupting mitosis.

Suggested Literature

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Career Opportunities for Weed Scientist

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There has probably never been a more important time to consider a career in the agricultural sciences, especially Weed Science! As we face the future, we'll have little choice but to face the age-old problems of hunger and resource limitations, but now on a global scale. To begin to meet this need, we must recognize that the solutions of the past just won't bring us any further than they already have. We are rapidly approaching a point where we, as a people, will no longer be insulated by the apparent abundance of food and as we approach the future, there are going to be greater and greater demands for agricultural output; this can't happen without an embrace of all forms of agriculture and a deep commitment to technology and innovation. We need to be producing more food, not less, to meet the needs of an expanding population. While the scale of this challenge is a bit intimidating, these difficult circumstances also bring us enormous opportunities to do things in new ways and this will require dedicated scientist, technicians and agricultural practitioners with new ways of seeing the world.

Here are several facts that should make you uncomfortable (and this is just a small subset of what's really going on!)!

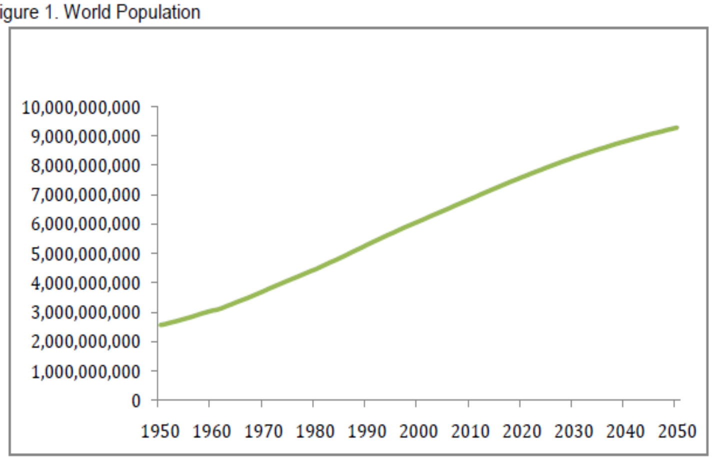
- In late 2007, several factors pushed up the price of grains consumed by humans as well as used to feed poultry and dairy cows and other cattle, causing higher prices of wheat (up 58%), soybean (up 32%), and maize (up 11%) over the year.
- Food riots took place in several countries across the world (Morocco, Yemen, Mexico, Guinea, Mauritania, Senegal, Uzbekistan and Pakistan). Contributing factors included drought in Australia and elsewhere, increasing demand for grain-fed animal products from the growing middle classes of countries such as China and India, diversion of food grain to biofuel production and trade restrictions imposed by several countries.
- An epidemic of stem rust on wheat caused by race Ug99 is currently spreading across Africa and into Asia and is causing major concern.
- Approximately 40% of the world's agricultural land is seriously degraded. According to UNU's Ghana-based Institute for Natural Resources in Africa, if current trends of soil degradation continue, the continent might be able to feed just 25% of its population by 2025,
- Water deficits, which are already spurring heavy grain imports in numerous middle-sized countries, including Algeria, Iran, Egypt, and Mexico, may soon do the same in larger countries, such as China or India.

The Moral Imperative for a Career in Agriculture:

The world is getting smaller and crowded! By 2050, the world's population is expected to grow to nearly nine billion (figure 1) – the equivalent of two more Chinas – and all the while, the ratio of agricultural land to population continues to decrease. The UN FAO predicts that global food production must double by 2050, and 70 percent of the world's additional food needs can be produced only with new or adapted agricultural technologies.

We've all seen charts like figure 1 below which depicts the projected rate of global population growth. And we know that this increase in population also means an increased demand for food, water, land, and other resources. Simply put: we will need to produce more food to feed more people.

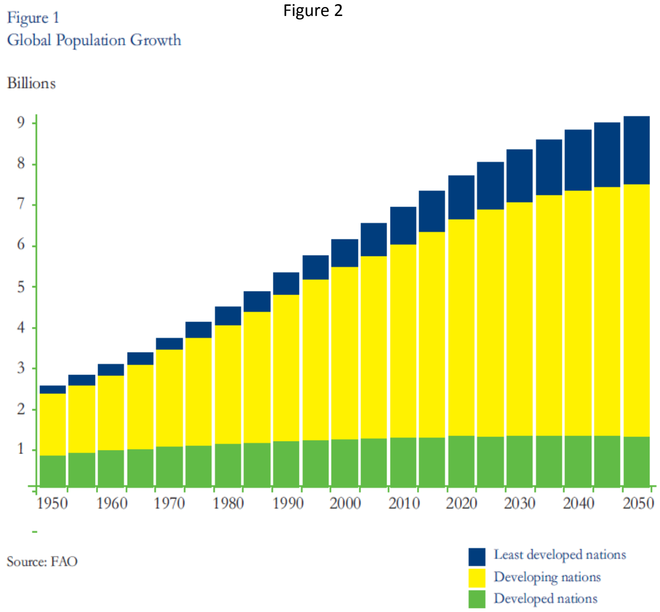
Figure 1. World Population



Source: U.S. Census Bureau. International Database. (Retrieved September 16, 2010). Available from: www.census.gov/ipc/www/idb/region.php

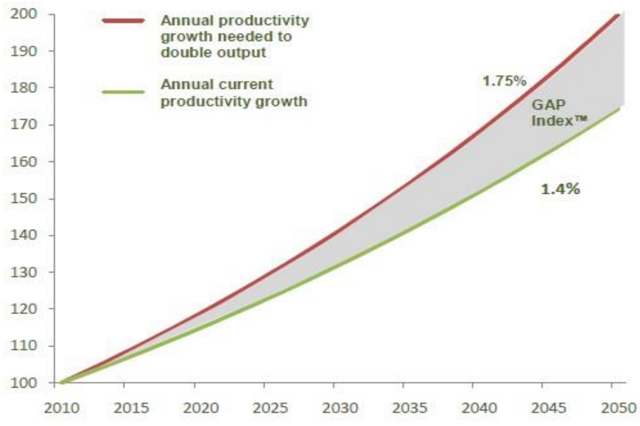
But this is a simple view. Let's add just one layer of complexity to this graph (figure 2).

Figure 2



This view breaks down the same projections by economic standing. At the bottom of the chart are the developed countries – such as the United States and much of Western Europe – which will show little growth and will, in fact, dip slightly over the next 40 years. At the top of the chart are the least developed countries – countries like Ethiopia, Liberia, and Tanzania in Africa, as well as Bangladesh, Cambodia, and Yemen in Asia, Samoa in the Pacific, and Haiti in the Caribbean. They will grow significantly within their category, but it's the middle of the chart where there's a cause for concern: developing nations, such as China, India, Egypt, and much of Eastern Europe, will continue to be the largest population and will also see dramatic growth over the next 40 years.

Figure 3. The Global Agricultural Productivity Index™



Source: Farm Foundation, NFP calculations (2010) based on USDA ERS data.

Figure 3 shows the gap between the current annual productivity growth rate (the bottom line) and the rate of growth needed to double production (the top line) without additional land resources.

What it boils down to is that we must increase the rate of productivity growth an average of 25% every year over the next 40 years just to meet the needs of the global population growth.

From even this simplest of viewpoints, there's already a projected gap of 1/3%, that's as of this morning.

There are many opportunities to contribute to the growth in productivity we need and Weed Science is just one, but it's a critical one! Weeds cause severe yield losses in arable and horticultural crops, which may be more than 34% worldwide. Weeds compete with crops for water, nutrients, light and space reducing crop yields. Weeds also contaminate seeds, foul milk, slow tillage, and interfere with harvesting practices as well as harboring diseases, insects and nematode pests. Additionally, weeds poison livestock, interfere with transportation, create fire hazards, block waterways, obstruct power lines and reduce land values. When the costs of weeds are combined with the cost of their control, the economic impact was calculated to be over $34 Billion[i].

Weed Scientist are called upon by growers, homeowners, and private or public agencies to provide information on Weed Biology and Management. Though the goals for industry academia do differ, there is substantial overlap, the objectives of each group are:

- Industry Scientist:
  - ❑ Generate new knowledge on herbicide Mode-of-Action and in chemistry, biochemistry and formulations science
  - ❑ Create, develop and make available new technology and vegetation management solutions
  - ❑ At the practitioner level, we apply these solutions to increase productivity.
- University Scientist (all roles) are expected to:
  - ❑ Train students in the art and science,
  - ❑ Generate and make public new knowledge on the biology, ecology, spread, and control of weed species in agriculture, aquatics, urban environments, parks and other recreation areas
  - ❑ Generate new knowledge on the interactions of taxa involved in natural and managed ecosystems.
  - ❑ Transfer that knowledge and technology to the practitioner

Weed Scientist have "new" and critical global issues trends that must be addressed, these will drive the future of the discipline and the define job opportunities in the twenty first century:

1. Serious problems with herbicide resistance require a re-thinking of weed management strategies in all crops
2. Impressive growth in the Agricultural Science Companies driven primarily by the development of transgenic crops with input and output traits require highly trained scientists and technicians
   a. Weed scientists, plant physiologists, molecular biologists, plant breeders, entomologists, plant pathologists, etc.
3. And the Organic Growers are desperate for solutions.

There are demographic trends in Weed Science that must be addressed if we are going to be able to populate the discipline:

- Will there be enough highly qualified Weed Scientists to satisfy demand in the public and private sector in the next 5 to10 years?
- Many Weed Scientist in academia and industry are expected to retire in the next 5-10 years (median age $\geq$ 55-58 years)
- In 2009, there were almost 5-times as many graduate students in entomology (1032) and 3-times as many in plant pathology (624) compared to Weed Science (220)[ii].

Qualifications!

- To work as a Weed Scientist in the greenhouse or field, you should:

- ❑ *Be fascinated by weed science* (including taxonomy and plant ecology), soil science, and agriculture.
- ❑ Have a minimum of a Bachelor's degree in a field such as agronomy, plant science, horticulture, range science, soil science, chemistry, biochemistry, genetics, or Ag engineering.
- ❑ For a laboratory research career you'll need a degree in chemistry, biochemistry, plant science, genetics or plant physiology.
  - *For research positions past technician, you'll need a Graduate degree.*
- ❑ To work in business, you should have an interest in sales, marketing, and economics plus a BA degree in business with emphasis on agribusiness or agricultural economics.
  - An MBA is helpful, but best with some on-the-job experience.

The jobs categories for Weed Scientists are only limited by your creativity, but here are a few!

- University Weed Scientist
- Farm Advisor, Extension Agent or Specialist
- Government Researcher (USDA ARS)
- Crop Protection Industry (at many levels)
- Pest Control Advisor or Certified Crop Advisor
- Professional Applicator
- Federal Regulatory (EPA) or State (DPR)

More-or-less typical University Weed Scientist job description:

- Responsibilities may include 55% research, 40% teaching, plus 5% advising and university service.
- Expected to develop an externally funded program in some area of plant production or agroecological research including specialty crops and teach classes in the same subject area.
- Develop research publications in peer-reviewed journals, teach and direct undergraduate and graduate students
- Create timely technical publications, training materials and programs for county extension staff, producers, agribusiness firms and other agencies
- Work independently and as a member of an interdisciplinary team to provide leadership for planning and implementing a statewide education programs.
- May also need to develop a strong extension and applied research program to evaluate new cultivars and agricultural technologies.

More-or-less typical Extension Weed Science Specialist job description:

- Leads in planning, implementing, and evaluating educational programs to *transfer weed control technologies.*
  - ❑ Knowledgeable in a broad range of weed control methods, chemical to cultural or mechanical.
  - ❑ Ability to explain the economic and environmental aspects of each option.

- Work with Farm Advisors, other Extension Specialists, faculty, land managers and the industry to conduct research on unmet State and local weed management needs.
- Develop a nationally competitive research program and obtain extramural grant funds.
- Minimum qualifications include:
  - Evidence of ability to communicate orally and in writing,
  - Ability to work effectively in a team environment with Extension and agribusiness personnel
  - Ability to effectively instruct undergraduate and graduate students
  - Skills regarding the effective use of electronic media in education and communication of technical information.

Weed Science Careers in USDA Agricultural Research Service:

- ARS is the principal research agency of the USDA charged with extending scientific knowledge and solving agricultural problems.
- Weed Scientist career options exist in two programmatic areas:
  - Natural Resources and Sustainable Agricultural Systems and
  - Crop Production and Protection.
- Program goals include research to improve strategies for cost-effective management of native and invasive weed pests, while minimizing impacts on the environment and human health.
- Careers span a variety of disciplines - chemistry, plant physiology, plant pathology, genetics, microbiology, engineering, soil science, and agronomy.
- Grade levels for research scientist positions in ARS are set using the Research Position Evaluation System (RPES).
  - The RPES is a peer review system based on the "person-in-the-job" concept and scientists have open-ended promotion potential based on their personal research and leadership accomplishments, this can change the complexity and responsibilities of their positions.

Careers as a California Pest Control Advisor

- A**ny person who offers a recommendation** on any agricultural use of a pest control product or technique and presents himself/herself as an authority on any agricultural use, or solicits services or sales for any agricultural pest control tool is a **Pest Control Adviser (PCA)**.
- **PCAs are tested to insure they're knowledgeable and proficient in all aspects of crop production and management.**
  - Exams are given (approximately) each month.
- **To become a PCA,** you must meet specific educational requirements, pass the laws, regulations, and basic principles exam, and pass an exam in a pest control area.
  - **Educational requirements:** At least 45 college-level semester units (67.5 quarter units) of required courses in the biological, agricultural, and pest management sciences.
- **California requires continuing education (CE)** for PCAs and pesticide applicators prior to license renewal.

There are many Weed Science roles in Industry, here's just a few:

- Field research scientist
- Discovery scientist (biologist, chemist, biochemist, molecular biologist)
- Characterization leader for discovery technology
- Technical expert to support commercial products
- Technology transfer

Opportunities in Industry don't preclude academic involvement and industry Weed Scientists have the opportunity to:

- Publish with academic scientists
- Accept Adjunct professorships
  - Stay involved with professional societies and participate and Associate Editors for scientific journals and act as Scientific Society Officers

Industry Field Research Scientist job description:

- Thrives in a fast-paced working environment as a part of a research and development team.
- Collaborates with other R & D team members to shape and meet product development goals
- Plans and conduct field, greenhouse and laboratory based experiments to evaluate plant health and herbicide efficacy.
- Generates, collect and prepare experimental data for presentation both internally and at regional and National scientific meetings.
- Coordinate with field and greenhouse staff to properly prepare fields and obtain permits and supplies necessary for research.

OK, I'm a field scientist… what's next???

- The opportunities moving forward are diverse and plentiful!
  - People leadership?
  - Regulatory?
  - Discovery?
  - Project leader?
  - Commercial?
  - Career field scientist?

Opportunities in Industry progress through a Variety of Roles and Work Experiences…

- Within a job, will likely work on a variety of projects over time and train in other disciplines
- Job change can be good to maintain enthusiasm and stimulate learning
- Job change does not necessarily require a geographical move

Non-technical competencies are important in any and every role! Non-technical competencies are:

- The basis for personal and professional effectiveness
- Transferable from one project, job/role to another
- Provide evidence of sustainable ability and flexibility
- For recruiting and hiring purposes, serve as strong discriminating factors when evaluating a large pool of available technical talent
  - ❑ Note: Non-technical skills are seldom formally taught in graduate school

Examples of Non-technical skills (Also called Key competencies)

- Leadership
- Teamwork
- Embraces Change
- Initiative/Accountability
- Interpersonal effectiveness
- Innovation & Value creation

These skills form basis of an employee performance review in almost any position!

In summary, Weed Science Careers are:

- Interesting, rewarding, important and diverse careers
- Can be found within Academia, Government, Multi-national crop protection companies and at the local level
- Continuous learning and improvement combined with flexibility are essential for personal growth
- Non-technical "soft skills" are critical for success and interpersonal effectiveness

There's never been a better time to be in the Agriculture Sciences!

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[i] Pimentel D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52 (2005) 273– 288

[ii] Derr J. and A. Rana. 2011. Weed Science Research, Teaching, and Extension at Land-Grant Institutions in the United States and its Territories. Weed Technology 2011, 25:277-291

The Three Fs: Filaree, Fluvellin, Fleabane
(Actually The Two Fs and a W: Filaree, Fluvellin and Willowherb)

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I will begin with an explanation of the title. While 'Filaree, Fluvellin, Fleabane' are all problem weeds and it makes an intriguing title, hairy fleabane [*Conyza bonariensis* (L.) Cornq.] is not yet established as a serious weed of vineyards in California's North Coast vineyards where I conduct my research. Conversely, Panicle willowherb [*Epilobium brachycarpum* C. Presl] is well established in this area.

Several weeds have become established in vineyards due to the changing management practices adopted by a majority of growers in the North Coast (mainly Napa and Sonoma, but also Lake, Mendocino, Solano and Yolo). The change from heavy cultivation (French plow or disk) under the vines every year, to much lighter cultivation, or in many cases to 'no-till' and a dependence on glyphosate, or 'Roundup only' has changed the species that make up the major weed problems in vineyards.

I will summarize three experiments that effect the population of these weeds. The first experiment conducted in the winter of 2008 shows the effect of accumulated grapes on herbicide efficacy and resulting reduction in control of filaree [a combination of two species: Whitestem filaree (*Erodium moschatum*) and redstem filaree (*Erodium cicutarium*)] and panicle willowherb. The experiment was conducted in a mature Merlot grape vineyard in Rutherford, Napa County, California. Initially eight sets of paired treatments were established (One paired plot was eliminated because the vines in the plot were recently replanted allowing more sunlight to reach the ground, unlike the other plots). Each plot was 4 vines (24 feet) long. The pair treatments were: 1. Leaves in vine row removed; or 2. Leaves in vine row left in place. The grape leaves in the leaves removed plots were raked by hand within 1 hour before herbicide application. All plots were then treated with 10 oz of Chateau(flumioxazin) +24 oz Roundup(glyphosate) (product on a per acre basis)using a OC02 Off -center nozzles sprayed from both sides of row.

Table 1.	March 1		June 12	
% Leaf Cover	% Filaree Cover		% Willowherb control	
	Raked	Not	Raked	Not
60	5	50	100	70
50	7	30	100	50
50	15	40	90	40
40	3	20	90	50
40	5	10	100	70
33	1	15	90	70
25	5	20	100	70
AVE	8.30%	28%	96%	60%

The left column denotes the percentage of area under the vine covered by grape leaves. This area was determined visually in a .5 by 1 meter area. The amount of weed cover or control (filaree and willowherb) was also determined by visual evaluation. Due to the time of year, biology of filaree, and postemergence nature of the Roundup plus Chateau application, filaree was evaluated by percent coverage. Willowherb was evaluated 180 days after application and was evaluated on percent control.

Weed control in all raked treatments was improved in each paired plot. The differences were greater in the plots where raking was compared with the highest percent leaf cover. Because this operation, done commercially with sweeper or blower, would increased equipment costs, and possibly an additional pass through the field and may not be warranted at leaf cover percentages at 30 % and below.

In a second trial conducted in 2011 at the UC Davis Oakville Research Station to test several herbicides for their ability to control fluvellin (*Kickxia elatine*).

Treated 12/8/11		3/8/12		5/22/12			7/9/12			8/7/12	
Treatment[1]	Rate[2]	FLU		OA[3]	FLU[4]		OA	FLU		OA	FLU
1.UTC		9.75		1.0	9.25		6.75	8.88		4.75	7.25
2.Rely 280 (glufosinate)	2 qt	8.0		5.0	7.0		4.50	5.75		6.75	7.5
3.Roundup WM (glyphosate)	2 qt	7.25		6.25	6.75		4.25	4.75		7.0	9.88
4.Trellis (isoxaben)	1 lb	9.75		7.50	9.63		8.25	9.25		7.0	8.75
5.Chateau(flumioxazen)	12 oz	10.0		8.75	9.25		8.50	8.50		6.25	7.0
6.Goal 2X (oxyflourfen)	3 qt	9.37		6.50	6.25		5.63	5.88		3.75	4.75
7.Shark (carfentrazone)	2 oz	7.25		6.0	6.5		5.0	5.0		8.25	9.5
8.Venue (pyraflufen ethyl)	4 oz	7.25		5.5	6.25		5.0	5.75		7.75	9.5
9.Zeus (sulfentrazone)	12 oz	7.87		6.5	7.25		5.0	5.25		3.5	3.75
10.Matrix (rimsulfuron)	2 oz	8.25		7.5	7.25		4.50	4.75		2.75	2.75
11.Alion (indaziflam)	5 oz	9.87		8.25	8.75		7.38	7.50		6.50	6.75

[1] All treatments, except Rely 280 were applied with added 2 qt/acre Roundup Weather Max.
[2] Rate is in amount of product per acre.
[3] OA = Overall weed control rating on a 1-10 scale (1 no control; 10- complete control)
[4] Flu = Fluvellin weed control on a 1-10 scale (1 no control; 10- complete control)

This trial was conducted in an area of the Oakville research station not planted to grapes. Applications were made to plots 10ftx 10ft with a 3 nozzle boom using 8002 XR nozzles delivering 30 GPA. The area was heavily infested with fluvellin. Fluvellin was present but not actively growing at the time of application. All treatments except Rely 280(glufosinate) contained 2 qts/acre of Roundup WeatherMax (glyphosate) for postemergence activity. Treatments 2, 3, 7, and 8 (all postemergence only treatments) were reapplied on July 10, 2012)

Because fluvellin is capable of germinating very late in the growing season it is important that preemergence treatment last long enough to control germination. The purpose of this trial is to determine which of the preemergence herbicides can control fluvellin throughout the season and which postemergence treatments are the most effective.

Fluvellin appears to germinate best in clean (no weed growth), warm soil. Practically this means that if a grower uses a preemergence herbicide to provide weed control the herbicide must last throughout the season, or make a second postemergent application, to insure that the fluvellin is controlled.

Analyzing the results show that Trellis (isoxaben), Alion (indaziflam) and Chateau (flumioxazin) were the best preemergence herbicides in this trial, providing nearly season-long control. It is interesting that the untreated control plot had almost no fluvellin which equates to control equal to, or better than, both the Alion and Chateau treatments. This is true because of the abundance of other weeds, especially annual fescue that was established in this area. Fluvellin does not grow well in areas where there are other competitive plants growing. I feel this is due first to competition, and to the fact that the soil will be cooler longer into the season when compared to 'clean' soil.

The third study is a preliminary evaluation of a long-term study comparing three weed control methods: 1. Cultivation; 2. Postemergent weed control only; 3. Post+premeregence herbicide treatment. Future evaluation may include measuring water penetration and other differences between the three treatments. This study is being conducted at the UC Davis Oakville Research station in a vineyard that has been treated with a tank mix of post+ preemergence herbicide for the last five years. This is important because of the demonstrative differences in weed composition in the three treatments within one year.

Percent 'hits' in transect[1]							
Treatment	Willowherb	Blando Brome	Bristly Oxtongue	Zorro Fescue	Fluvellin	Field Bindweed	Bur Clover
Cultivate	2.2	23.0	0.7	51.8	0.4	1.7	3.3
Glyphosate	29.3	1.9	6.5	0.8	7.8	0.3	0.2
Glyphosate + Chateau	0.7	0	0	0	0	4.0	0

[1] Ratings are based on average of 4 replications of the percent of transect hits recorded every 6 inches for 128 feet directly under the vinerow of the middle row of each 3 row plot

Treatments were applied by a commercial management company using a Clemens (cultivator) and ATV applicator using a single OC02 nozzle for herbicide application. Cultivation was done on December 5, 2011 and May 2, 2012. The herbicide applications were made December 14, 2011. The postemergence only treatment was Roundup (glyphosate) 2 quarts/acre of product and the post + preemergence treatment was Roundup at 2 quarts + Chateau (flumioxazin) 10 oz/acre of product.

Readings taken with a transect in the middle row of the three row plots (126 ft- read every 6 inches) show that the composition of weeds has quickly changed. Willowherb is by far the most prevalent weed in the glyphosate only treatment, with fluvellin being the second most abundant. The grasses Blando Brome and Zorro fescue were predominate in the cultivated plot with willowherb and fluvellin found in only 2.2 and 0.4% of the points respectively. In this trial there were almost no weeds in the post + preemergence treatment. These preliminary results show that there is a major difference in weed composition after only one year after changing weed management practices and that acceptable weed control for multiple years with preemergence herbicides does not necessarily mean that a grower can switch to a postemergence herbicide and expect any residual control.

Post-emergence Weed Control Options in Tree Nut Orchards

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Herbicides are the primary means of vegetation management in tree nut orchards in California. Among registered herbicides, post-emergence (POST) materials, like glyphosate, are the most widely used in tree crops because of low cost and broad weed control spectrum. However, herbicide resistance has compromised the efficacy of POST only herbicide programs in many parts of the state. Most cases of resistance in orchards are glyphosate-resistant hairy fleabane, horseweed, ryegrass, and junglerice. To manage resistant weed species, pre-emergence (PRE) herbicides can be applied during winter before weeds emerge; however, PRE herbicide use can be limited by cost and the need for rainfall to incorporate them. Even when PRE herbicides are used, most orchards will need a POST treatment to control weed escapes and to prepare the orchard for harvest operations.

One approach to optimize control of late emerging or glyphosate-resistant weeds is to use alternate herbicides, mixtures, rates, or more appropriate application timing. The objective of this project was to evaluate POST control of hairy fleabane and yellow nutsedge with different herbicides combinations.

Methods

Field experiments were conducted in a three year-old almond orchard infested with hairy fleabane and yellow nutsedge. The orchard was located in a sandy soil area in Merced County, and irrigated with solid set sprinklers. The area is known to be infested with glyphosate-resistant hairy fleabane. Hairy fleabane had been mowed for 3 to 4 times during season and allowed to regrow to six inches in height (bolting) before the treatments were applied. Nutsedge was still at vegetative stage with 8 to 12 leaves. Other species also found sparsely distributed at the site were three-spike goosegrass, large crabgrass, spotted spurge, and cut-leaf evening primrose.

Hairy fleabane treatments were applied to 20 by 7.5 ft plots between the tree rows on July 23 and August 21, 2012 for the first and second hairy fleabane trials, respectively (table 1). Spray equipment was a CO_2-pressurized back pack sprayer using TT11002 (Teejet) nozzles and calibrated to deliver 25 gallons per acre. Percent visual control (%), weed density (plants per square meter), and plant biomass (g m^{-2}) were recorded 28 days after treatment (DAT). ANOVA analysis indicated no differences between experimental runs therefore data were combined.

The yellow nutsedge trial was conducted within the tree rows, and percent visual control (%) was recorded 35 DAT. Treatments were applied on August 21, 2012 using the previously described equipment. Treatments included herbicides known to have activity on nutsedge as standard comparison; however, not all tested treatments are registered for use in almonds (table 2).

Results – hairy fleabane trials

Hairy fleabane was not controlled with glyphosate (trt-2), carfentrazone (trt-3), or the tank mix of both herbicides (trt-4) 28 DAT. These treatments were not significantly different than untreated control in percent control or biomass (table 1, figure 1). Glyphosate and glyphosate + carfentrazone treatment reduced biomass of other species present at the site, but not biomass of hairy fleabane supporting the reports of glyphosate resistance in this population.
Good (>85%) to excellent (>95%) control of hairy fleabane was provided by treatments that included glufosinate (trt 5, 6 & 9), saflufenacil (trt 7, 8, 9 & 17), 2,4-D (10, 11, & 12), or paraquat (13, 14, & 19). The majority of these treatments completely eliminated hairy fleabane plants by 28 DAT (figure 1). These treatments could be used during pre-harvest weed control, when bare ground is desired, provided that their use follows label recommendations for pre-harvest interval.

Effective treatments for hairy fleabane control are also needed for other weed species, but not all tested treatments succeeded in both duties. Saflufenacil (trt 7) and 2,4-D (trt 10) treatments provided no control of other species, mainly grasses, present in the site. These herbicides are not active in grass species, and for this reason are recommended with burndown partners herbicides like glyphosate. Tank mixes of glyphosate + saflufenacil (trt 7) and glyphosate + 2,4-D (trt 11) provided excellent control of all species as indicated by biomass accumulation (figure 1). Mixtures of herbicides with different mode of actions, as the case of these treatments, are a good strategy to delay the onset of herbicide resistance and manage existing resistant species. Another approach for managing glyphosate-resistant weeds is the sequential herbicide application, as the case of glyphosate followed by paraquat (trt 14). In this treatment, the initial glyphosate application was followed 14 days later with a paraquat treatment. Excellent control of all species was provided by this treatment, but not statistically different than the paraquat treatment (trt 13). The sequential application has the disadvantage of additional application costs.

The residual herbicides penoxsulam/oxyfluorfen (trt 15), rimsulfuron (trt 16), and flumioxazin (trt 18) with glyphosate did not provide acceptable POST control of established hairy fleabane. These herbicides are effective for pre-emergence and early post-emergence control of hairy fleabane and many other weed species. When mature weeds are present, it is necessary to tank mix these herbicides with post-emergence herbicides such as glyphosate. However, the addition of glyphosate did not improve control of the glyphosate-resistant hairy fleabane in advanced stage of development. Tank mixes of glyphosate + rimsulfuron + saflufenacil (trt 17) or paraquat + flumioxazin (trt 19) provided excellent control of all species. These results indicate the importance of post-emergence herbicides to complement pre-emergence herbicide programs. Likewise it reiterates the importance of preserving the post-emergence herbicides for the long term to avoid onset of new resistance. Populations of hairy fleabane resistant to both glyphosate and paraquat are present in the state. The management of multiple-resistant populations would be greatly limited by the loss of paraquat susceptibility.

Yellow nutsedge trial

Best activity on nutsedge was provided by treatments including flumioxazin (trt 4), halosulfuron (trt 13), rimsulfuron (trt 12), and penoxsulam/oxyfluorfen (trt 9) (table 2, figure 2). Best POST activity (greater than 95% control) was observed up to three weeks after application (data not shown), and control started to decline at 35 DAT. Flumioxazin, rimsulfuron, and penoxsulam/oxyfluorfen are registered for almonds. These treatments did not provide acceptable post-emergence control of hairy fleabane, but did control yellow nutsedge up to 35 DAT thus may be a promising alternative for suppressing nutsedge.

Glyphosate, glyphosate + saflufenacil, glyphosate followed by paraquat, or glyphosate + glufosinate provided only initial suppression of nutsedge. The burndown activity of these treatments were only visible for the first three weeks (data not shown), and would require multiple application during the season in order to continue suppressing nutsedge growth.

Conclusion

There are herbicides to control hairy fleabane and yellow nutsedge. Mixtures of herbicides with different mode of action were, in some instances, superior to single herbicide application due to greater spectrum of weed control.

The success of post-emergence activity is dependent on the species present at the time. Some pre-emergence herbicides tested also provided good burndown activity in selected species, but the long-term activity was not evaluated in this trial. Additional research is required to evaluate timing of application for the pre-emergence material in order to explore its maximum potential of burndown and residual activity. However, because post-emergence herbicides will still be required to complement pre-emergence program, it is important to preserve post-emergence active ingredients for effective, season-long weed control in orchards.

Table 1. Hairy fleabane visual control (%) with herbicide combinations 28 days after treatment.

Trt #	Treatment	Rate per acre		Control %	(SE)
1	untreated control			0	(0.0)
2	Roundup Powermax (glyphosate) + NIS + AMS	27.6	fl oz	3	(1.6)
3	Shark EW (carfentrazone) + NIS + AMS	2	fl oz	1	(1.3)
4	Roundup Powermax (glyphosate) + NIS + AMS	27.6	fl oz	14	(5.3)
	Shark EW (carfentrazone)	2	fl oz		
5	Rely 280 (glufosinate) +AMS	69	fl oz	88	(4.1)
6	Roundup Powermax (glyphosate) + AMS	27.6	fl oz	82	(12.6)
	Rely 280 (glufosinate)	69	fl oz		
7	Treevix (saflufenacil) + AMS + MSO	1	oz	96	(2.6)
8	Roundup Powermax (glyphosate) + AMS + MSO	27.6	fl oz	92	(3.4)
	Treevix (saflufenacil)	1	oz		
9	Rely 280 (glufosinate) + AMS + MSO	69	fl oz	95	(2.5)
	Treevix	1	oz		
10	Dri-Clean (2,4-D)	27	oz	85	(9.6)
11	Roundup Powermax (glyphosate)	27.6	fl oz	99	(0.7)
	Dri-Clean (2,4-D)	27	oz		
12	Rely 280 (glufosinate) + AMS	69	fl oz	100	(0.3)
	Dri-Clean (2,4-D)	27	oz		
13	Gramoxone SL (paraquat) + NIS	4	pt	99	(0.6)
14	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	98	(1.2)
	[1]Gramoxone SL (paraquat) + NIS	2	pt		
15	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	54	(5.0)
	Pindar GT (penoxsulam/oxyfluorfen)	1.5	pt		
16	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	43	(5.0)
	Matrix (rimsulfuron)	2	oz		
17	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	94	(2.5)
	Matrix (rimsulfuron)	2	oz		
	Treevix (saflufenacil)	1	oz		
18	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	11	(2.3)
	Chateau (flumioxazin)	6	oz		
19	Gramoxone SL (paraquat) + NIS	4	pt	100	(0.1)
	Chateau (flumioxazin)	6	oz		
		Tukey's critical value		30	

[1]paraquat applied 14 days after glyphosate treatment

abbreviations: NIS – non-ionic surfactant R-11 at 0.25% v/v; SE – standard error; AMS – ammonium sulfate Pro AMS plus at 10 lb/100 gal; MSO – methylated seed oil Monterey MSO at 1 % v/v

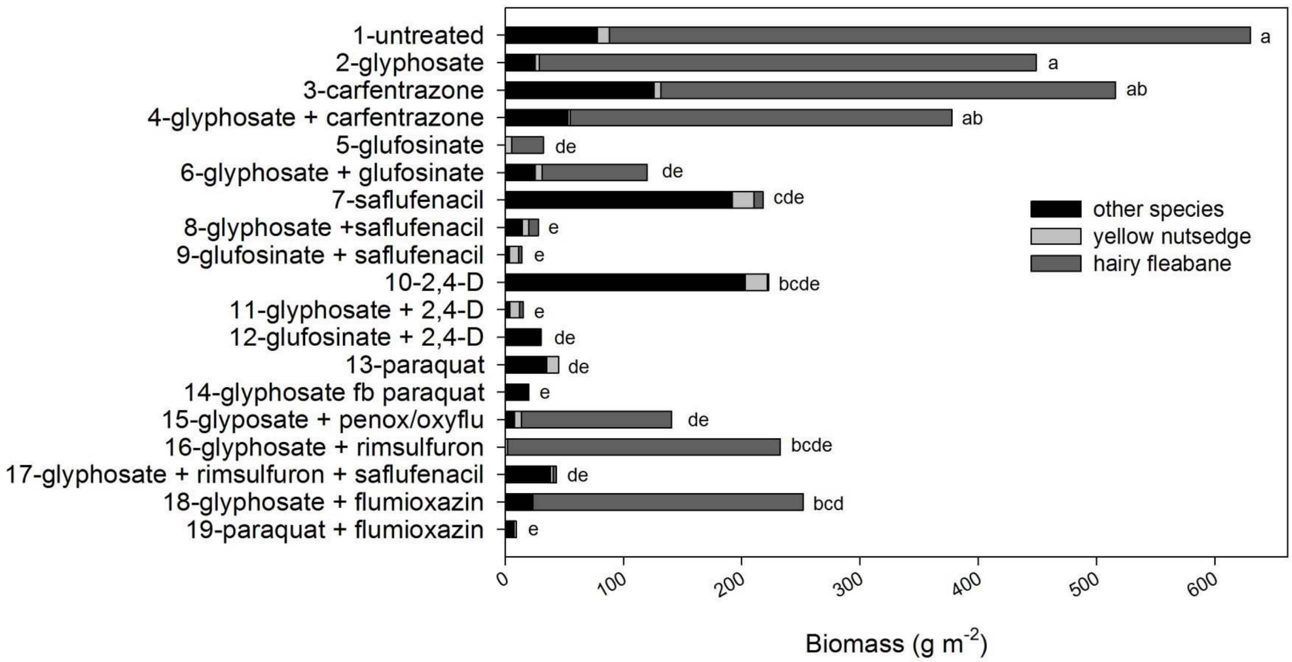

Figure 1. Weed dry biomass 28 day after herbicide treatment. Biomass of sparsely distributed species such as cut-leaf evening primrose, large crab-grass, three spiked goosegrass, and spotted spurge, were combined and are represented as black bars. Bars followed by the same letters are not statistically different according to Tukey's test ($p<0.05$).

Table 2. Yellow nutsedge visual control (%) with herbicide combinations 35 days after treatment.

Trt #	Treatment	Rate per acre		Control %	(SE)
1	Untreated			0	(0)
2	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(8.6)
3	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	20	(4)
	Treevix (saflufenacil)		oz		
4	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	89	(3.1)
	Chateau (flumioxazin)	12	oz		
5	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(8.6)
	Goal 2XL (oxyfluorfen)		oz		
6	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	50	(10.8)
	Goal 2XL (oxyfluorfen)		oz		
7	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	48	(7.5)
	Goal Tender (oxyfluorfen)		oz		
8	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	65	(8.6)
	Tangent (penoxsulam)	1.67	oz		
9	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	70	(7)
	Pindar GT (penoxsulam/oxyfluorfen)	2.5	pt		
10	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	55	(9.6)
	Zeus (sulfentrazone)	6	oz		
11	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	55	(8.7)
	Matrix (rimsulfuron)	2	oz		
12	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	70	(0)
	Matrix (rimsulfuron)	4	oz		
13	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	75	(6.5)
	Sandea (halosulfuron)	1	oz		
14	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	80	(0)
	Outrider (sulfosulfuron)	1.33	oz		
15	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(9.5)
	Rely 280 (glufosinate)	48	fl oz		
16	Roundup PowerMax (glyphosate) + MSO + AMS	28	fl oz	43	(8.5)
	[2]Gramoxone SL (paraquat)	48	fl oz		
	Tukey's critical value			39	

[1]glyphosate rate is expressed as acid equivalent (ae); [2]paraquat applied 14 days after glyphosate treatment

abbreviations: NIS – non-ionic surfactant R-11 at 0.25 % v/v; SE – standard error; AMS – ammonium sulfate Pro AMS plus at 10 lb/100 gal; MSO – methylated seed oil Monterey MSO at 1 % v/v

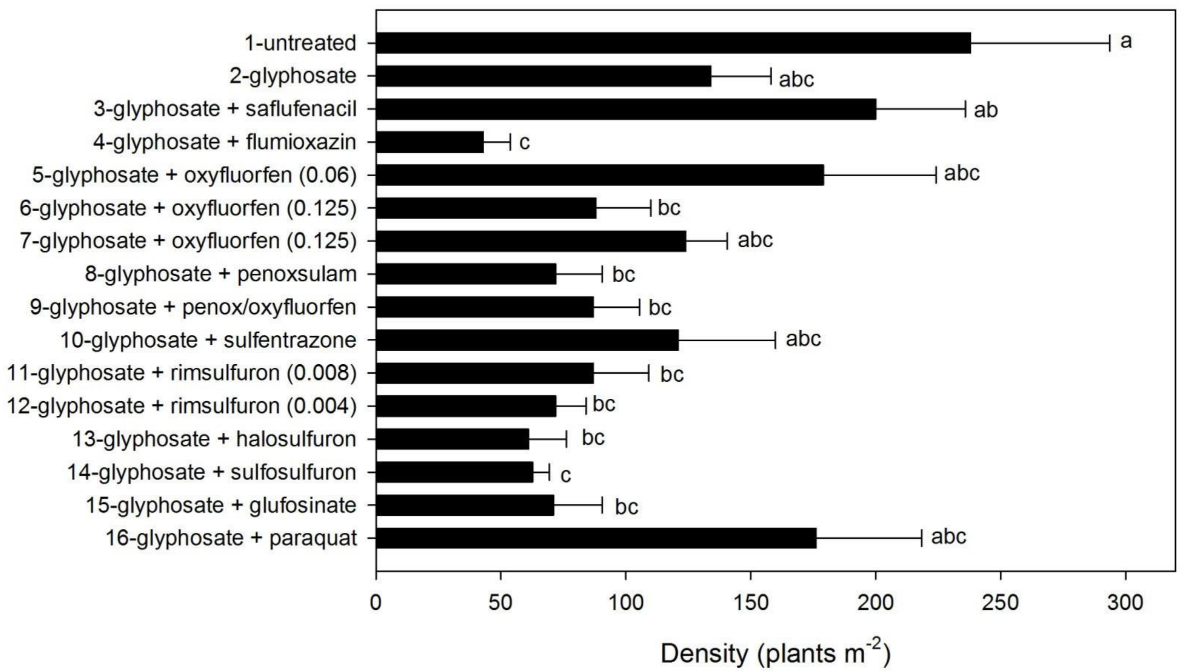

Figure 2. Yellow nutsedge plant density 35 days after herbicide treatment. Bars followed by the same letters are not significant different according to Tukey's test (p<0.05).

New Herbicide Uses for California Tree and Vine Crops

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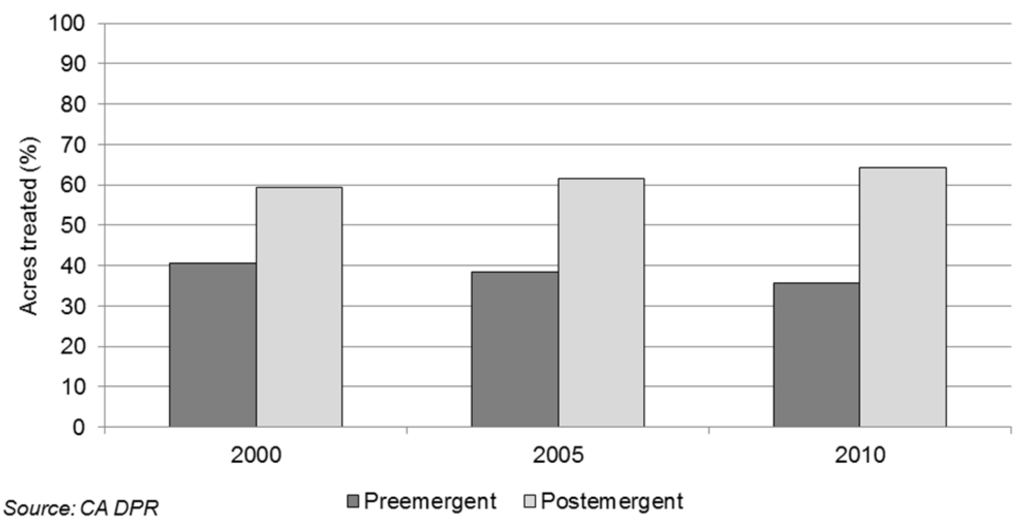
For decades, herbicides have been used for weed management in perennial tree and vine crops in California. When used under the right conditions, herbicides provide effective control of a large variety of weeds and aid crop growth and productivity. While both pre- and postemergent herbicides are widely used, there has been a trend towards greater reliance on postemergent materials in recent years, particularly glyphosate (Figure 1). Between 2000 and 2005, growers relied mostly on five herbicide active ingredients (glyphosate, oxyfluorfen, paraquat, oryzalin, and simazine) for weed control in tree nuts, stone fruits, and grapes (Figure 2). In 2010, more than 80% of the acreage in the state was treated with three herbicide mode of actions (MOA), with over 40% attributed to a single MOA; the EPSP synthase inhibitor, glyphosate (Figure 3).

Widespread reliance on glyphosate in postemergent-only programs has contributed to glyphosate-resistant horseweed, hairy fleabane, rigid ryegrass, and junglerice in the state. Also, the implementation of regulated groundwater protection areas (GWPA) in 2004 contributed to this increase in glyphosate use as growers replaced using preemergent herbicides, like simazine, bromacil, and norflurazon (sensitive to runoff and leaching in GWPA), with safer alternatives, including glyphosate.

Figure 1. Herbicide use in trees and vines in CA
(by herbicide type in tree nuts, stone fruits, and grapes)



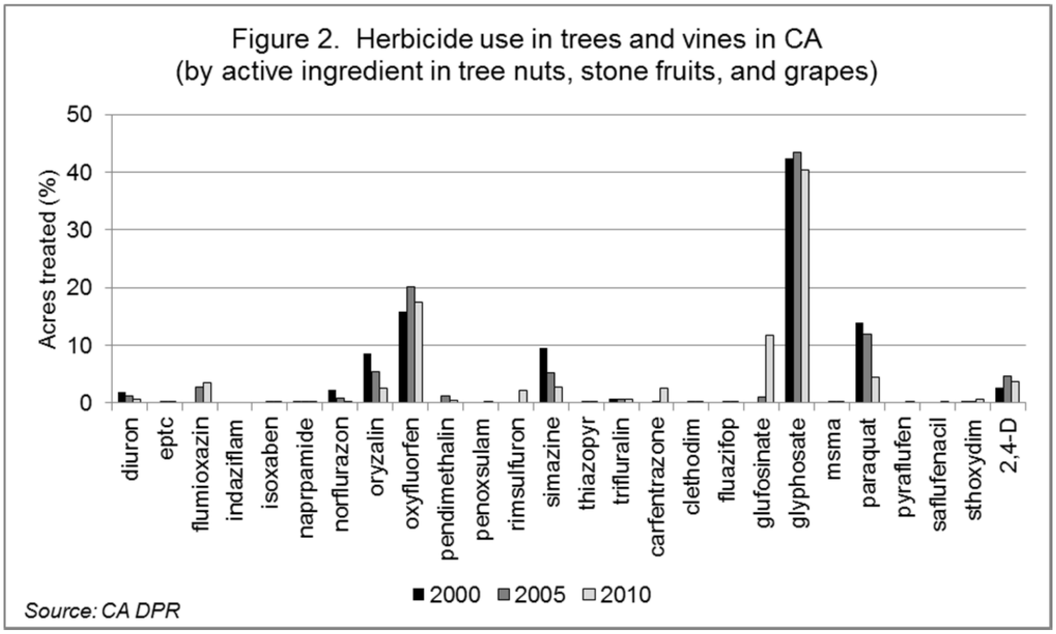


Figure 2. Herbicide use in trees and vines in CA
(by active ingredient in tree nuts, stone fruits, and grapes)

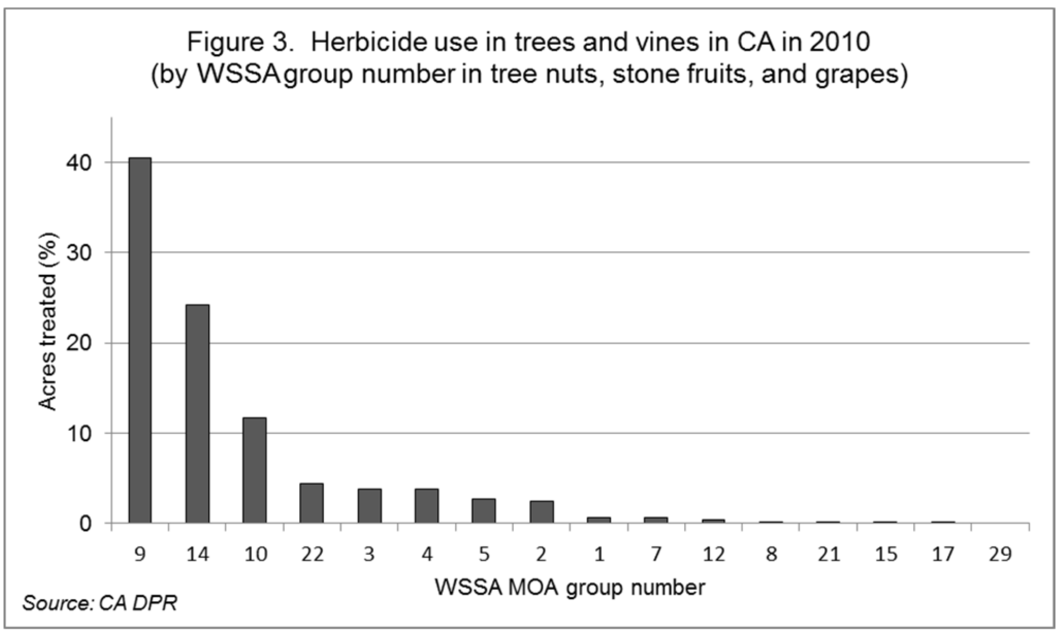


Figure 3. Herbicide use in trees and vines in CA in 2010
(by WSSA group number in tree nuts, stone fruits, and grapes)

Currently, there are about 30 herbicide active ingredients with 16 different MOAs (by WSSA group number) registered for use in the various perennial tree and vine crops in California (see table). Since 2004, eight new herbicide active ingredients with three new MOAs were registered for use. These materials were developed, in-part, in response to a need to find safer alternatives that could be used on farms located in GWPAs and offer control of a wide-array of weeds, including those resistant to glyphosate. While these newer herbicide have only been available a few years, they are already having a positive impact on the ability of growers to manage glyphosate-resistant weeds and others. These herbicides are not available for use in all tree and vine crops grown in the state, but each has its own fit in a particular set of crops. With the addition of these new herbicides, growers have been more diligent in rotating or tank-mixing herbicides with different MOAs to help maintain weed control and combat weed resistance.

Herbicides currently registered in perennial tree and vine crops in California

WSSA	HRAC	Herbicide mode of action	Herbicide active ingredient	Activity
1	A	Acetyl CoA carboxylase inhibitor	clethodim, fluazifop-p-butyl, sethoxydim	POST
2	B	Acetolactate synthase inhibitor	rimsulfuron*, penoxsulam*	PRE
3	K1	Microtubule assembly inhibitor	oryzalin, pendimethalin, thiazopyr, trifluralin	PRE
4	O	Synthetic auxin	2,4-D	POST
5	C1	Photosystem II inhibitor	bromacil, simazine	PRE
7	C2	Photosystem II inhibitor	diuron	PRE
8	N	Lipid synthesis inhibitor	EPTC	PRE
9	G	EPSP synthaseinhibitor	glyphosate	POST
10	H	Glutamine synthase inhibitor	glufosinate*	POST
12	F1	Carotenoid biosynthesis inhibitor	norflurazon	PRE
14	E	Protoporphyrinogen oxidase inhibitor	flumioxazin*, oxyfluorfen carfentrazone*, flumioxazin*, oxyfluorfen, pyraflufen*, saflufenacil*	PRE POST
15	K3	Cell division inhibitor	napropamide	PRE
17	Z	Unknown (Organoarsenicals)	MSMA	POST
21	L	Cellulose biosynthesis inhibitor	isoxaben	PRE
22	D	Photosystem-I-electron diversion	paraquat	POST
29	L	Cellulose biosynthesis inhibitor	indaziflam*	PRE
*Registered for use in California since 2004				

In California, preemergent materials are mainly applied during the winter dormant period to take advantage of winter rainfall for incorporation and activation and to improve crop safety. Here, newer materials like flumioxazin, rimsulfuron, penoxsulam, and indaziflam are providing good residual weed control. Postemergent herbicides, like glyphosate, glufosinate, and 2,4-D are added to the spray tank to control weeds that are emerged at time of treatment. Combinations of preemergent products (i.e. flumioxazin plus pendimethalin, indaziflam plus rimsulfuron, etc.) with different MOAs are often used to provide long-term control of a wide-array of weeds like hairy fleabane, horseweed, and ryegrass. In many cases, residual control with the newer materials last six months or more. Efficacy is usually improved where leaves and other trash are mechanically blown from the soil surface before the herbicides are applied. As the newer preemergents become more widely used, growers should see improved overall weed control and a need to rely less on postemergent materials for control.

Since about 2005, glufosinate has been an important herbicide for the control of established horseweed, hairy fleabane, grasses and other weeds not readily controlled with glyphosate. Glufosinate is often combined with glyphosate to control a large number of weeds, including nutsedge. To date, no weeds have shown resistance to glufosinate. However, lack of glufosinate availability in California since 2011 has caused growers to turn to other alternatives for burn-down control efforts, like using saflufenacil in tree nut crops. Since saflufenacil does not control grassy weeds, it too is usually combined with glyphosate to help control grassy species. A selective grass herbicide, like sethoxydim, is sometimes used to control glyphosate-resistant junglerice if glufosinate is unavailable. Paraquat continues to be an important player in postemergent weed control efforts. However, since it is a Restricted Use Pesticide, it requires a permit to purchase and use, a closed system for delivery, and special protective clothing during mixing, loading, and application, which sometimes discourages its use.

Tree and vine growers in California are fortunate to have a fairly large number of herbicide active ingredients and MOAs to select from to help manage weeds. Selecting and using these herbicides in a manner that considers weed species present, weed resistance, crop safety, and the environment is essential for their long-term viability. While no one herbicide can be expected to control all the weeds in any particular field, each one can play an important role when used appropriately.

Introduction to Adjuvants

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Introduction

Questions about adjuvant selection are common. Adjuvants are not regulated by the EPA or any other regulatory agency allowing an unlimited number of adjuvants. Adjuvants are composed of a wide range of ingredients which may or may not contribute to herbicide phytotoxicity. Results vary when comparing specific adjuvants, even within a class of adjuvants. POST herbicide effectiveness depends on spray droplet retention, deposition, and herbicide absorption by weed foliage. Adjuvants and spray water quality (Paragraph A6) influence POST herbicide efficacy. Adjuvants are not needed with PRE herbicides unless weeds have emerged and labels include POST application.

Spray adjuvants generally consist of surfactants, oils and fertilizers. The most effective adjuvant will vary with each herbicide, and the need for an adjuvant will vary with environment, weeds, and herbicide used. Adjuvant use should follow label directions and be used with caution as they may influence crop safety and weed control. An adjuvant may increase weed control from one herbicide but not from another. To compare adjuvants and determine adjuvant enhancement, herbicide rates should be used at marginal weed control levels. Effective adjuvants will enhance herbicides at reduced rates and provide consistent results under adverse conditions. However, use of below labeled rates exempts herbicide manufacturers from liability for nonperformance.

Surfactants (nonionic surfactants = NIS) are used at 0.25 to 0.5% v/v (1 to 4 pt/100 gal of spray solution) regardless of spray volume. NIS rate depends on the amount of active ingredient in the formulation, plant species and herbicides used. The main function of a NIS is to increase spray retention, but at a lesser degree, may function in herbicide absorption. When a range of surfactant rates is given, the high rate is for use with low herbicide rates, drought stress and tolerant weeds, or when the surfactant contains less than 90% active ingredient. Surfactants vary widely in chemical composition and in their effect on spray retention, deposition, and herbicide absorption.

Silicone surfactants reduce spray droplet surface tension, which allow the liquid to run into leaf stomata (“stomatal flooding”). This entry route into plants is different than adjuvants that aid in absorption through the leaf cuticle. Rapid entry of spray solution into leaf stomata from use of silicone surfactants often does not result in improved weed control. Silicone surfactants are weed and herbicide specific just like other adjuvants.

Oils generally are used at 1% v/v (1 gal/100 gal of spray solution) or at 2 pt/A depending on herbicide and oil. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum (PO) or methylated vegetable or seed oils (MSO) plus an emulsifier for dispersion in water. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of an oil adjuvant. Oil adjuvants enhance POST herbicides more than NIS and are effective with all POST herbicides, except Liberty and Cobra, and will antagonize Roundup. The term crop oil concentrate (COC) is used to designate a petroleum oil concentrate but is misleading because the oil type in COC is petroleum and not a crop vegetable oil.

MSO adjuvants greatly enhance POST herbicides much more than NIS and PO adjuvants. MSO adjuvants are more aggressive in dissolving leaf wax and cuticle resulting in faster and greater herbicide absorption. The greater herbicide enhancement from MSO adjuvants may occur more in low humidity/low rainfall environments where weeds develop a thicker cuticle. MSO adjuvants cost 2 to 3 times more than NIS and PO adjuvants. The added cost of MSO and increased risk of crop injury when used at high temperatures have deterred people from using this class of adjuvants. Using reduced herbicide rates with MSO adjuvants can enhance weed control while lowering risk of crop injury.

Some herbicide labels restrict use of oil adjuvants and recommend only NIS alone or combined with nitrogen based fertilizer solutions. Follow label directions for adjuvant selection. Where labels allow use of oil additives, PO or MSO adjuvants may be used.

NDSU research has shown wide difference in adjuvant enhancement of herbicides. However, in many studies, no or small differences occur depending on environmental conditions at application, growing conditions of weeds, rate of herbicide used, and size of weeds. For example, under warm, humid conditions with actively growing weeds, NIS + nitrogen fertilizer may enhance weed control to the same level as oil adjuvants. The following are conditions where MSO type additives may give greater weed control than other adjuvant types:

1. Low humidity, hot weather, lack of rain, and drought-stressed weeds or weeds not actively growing due to some stress condition.
2. Weeds larger than recommended on the label.
3. Herbicides used at reduced rates.
4. Target weeds that are somewhat tolerant to the herbicide. (buckwheat, lambsquarters, ragweed to Pursuit or Raptor, or yellow foxtail to Accent).
5. When university data supports reduced herbicide rates. Most herbicides, except Roundup, give greater weed control when used with MSO type adjuvants.

Oil adjuvant applied on a volume or area basis - Labels of many POST herbicides recommend oil adjuvants at 1% v/v. At water volume of 15 or 20 gallons per acre (GPA), 1% oil adjuvant will provide a minimum adjuvant concentration (1% v/v PO in 17 gpa = 1.4 pt/A). The optimum rate of a PO is 2 pt/A. State surveys show common spray volumes are 10 gpa or lower. PO at 1% v/v in 8.5 gpa = 0.68 pt/A and does not provide an sufficient amount of oil adjuvant. Further, in aerial applications at 5 GPA, PO at 1% v/v will not provide sufficient adjuvant. For example, Pursuit and Raptor labels require oil adjuvants to be added at 1.25% v/v or 1.25 gal/100 gal water for aerial application at 5 GPA.

Some herbicide labels contain information on adjuvant rates for different spray volumes. To insure sufficient adjuvant concentration, add oil adjuvant at 1% v/v but no less than 1.25 pt/A at all spray volumes. Surfactant at 0.25 to 1% v/v water is sufficient across all water volumes.

High surfactant oil concentrates (HSOC) were developed to enhance lipophilic herbicides without antagonizing glyphosate. HSOC adjuvants contain at least 50% w/w oil plus 25 to 50% w/w surfactant, are PO or MSO based, and are usually applied at ½ the oil adjuvant rate (area basis). Glyphosate must be applied with other herbicides to control glyphosate tolerant weeds and crops and to delay resistant weeds. Glyphosate is highly hydrophilic, is enhanced by NIS and nitrogen fertilizer surfactant type adjuvants, and is antagonized by oil adjuvants. Postemergence herbicides preferred by growers to mix with glyphosate to increase weed control are lipophilic (Select, Banvel, Laudis, others) and require oil adjuvants for optimum herbicide enhancement. Surfactants are less effective in enhancing lipophilic herbicides. Oil adjuvants, including PO and MSO adjuvants, may antagonize glyphosate. NDSU research has shown wide variability among PO based HSOC adjuvants with many performing no different than common PO adjuvants. However, MSO based HSOC adjuvants enhance both glyphosate and the lipophilic herbicide. MSO based HSOC adjuvants can enhance lipophilic herbicides more than PO based HSOC, MSO and PO adjuvants.

Some water pH modifiers are used to lower (acidify) spray solution pH because many insecticides and some fungicides degrade under high water pH. Most solutions are not high or low enough in pH for important herbicide breakdown in the spray tank. A theory has long been postulated that acidifying the spray solution results in greater absorption of weak-acid-type herbicides. pH-reducing adjuvants (water conditioners/AMS replacment) were developed under this belief. However, low pH is not essential to optimize herbicide absorption.

Many herbicides are formulated as various salts, which are absorbed as readily as the acid. Salts in the spray water may antagonize formulated salt herbicides. In theory, acid conditions would convert the herbicide to an acid and overcome salt antagonism. However, herbicides in the acid form are less water soluble than in salt form. An acid herbicide with pH modifiers may precipitate and plug nozzles when solubility is exceeded, such as with high herbicide rates in low water volumes. Antagonism of herbicide efficacy by spray solution salts can be overcome without lowering pH by adding AMS or, for some herbicides, 28% UAN.

Acidic AMS replacement (AAR) adjuvants (see page 130) contain adjuvants including monocarbamide dihydrogensulfate (urea and sulfuric acid) and some adjuvants in this class are similar to NIS + AMS in enhancing glyphosate and other weak-acid herbicides. The sulfuric acid forms sulfate when reacting with water and can prevent herbicide antagonism with salts in water. The conversion of urea to ammonium is slow but the ammonium formed can partially enhance herbicides. AAR adjuvants must be applied at 1% v/v or greater to achieve the same level of herbicide enhancement as AMS.

Basic pH blend adjuvants are blends of nonionic surfactant, fertilizer, and basic pH enhancer and are used at 1% v/v regardless of spray volume. Data indicate basic blend adjuvants at 1% v/v from 5 to 20 GPA will provide adequate adjuvant enhancement for similar weed control.

Basic pH blend adjuvants are surfactant based, increase spray solution pH, and contain nitrogen fertilizer to enhance herbicide activity. They contain a surfactant to aid in spray retention, spray deposition, and herbicide absorption, and a buffer to increase water pH. Basic pH blends adjuvants increase water pH to near pH 9 which increases water solubility of some herbicides and can increase herbicide phytotoxicity. Within the sulfonylurea chemistry the magnitude of solubility from high spray solution pH can increase from 40 fold (Harmony GT) to 3,670 fold (UpBeet). The solubility of herbicides in other chemical families increase with high pH: Achieve (1-Dim), florasulam (2-TPS), Everest (2-SACT), Sharpen (14), and diflufenzopyr (19), Callisto and Laudis (27-triketone), and pyrasulfatole and Impact (27-pyrazolone) (numbers represent herbicide mode of action).

Some herbicides degrade rapidly in high pH spray solution. Cobra (diphenylether), Resource and Valor (N_phenylphthalimide), and Sharpen (pH 9) degrade within a few minutes in high pH water but are stable for several days at low pH. Optimum use of pH adjusting adjuvants requires some knowledge of herbicide chemistry or experience. Research has shown that basic pH blend adjuvants may enhance weed control similar to MSO adjuvants and can be used in situations where oil adjuvants are restricted.

Commercial adjuvants differ in effectiveness with herbicides. Data from the table below are from experiments conducted at six NDSU R&E Centers in ND from 1992 through 1995 and repeated in 2005 and 2006 comparing commercial adjuvants with Roundup. In 1993-95, Roundup was applied at 1 to 1.5 oz ae/A to 16 grass and broadleaf weed species. In 2005-06 Roundup was applied at 1 to 4 oz ae/A to 26 grass and broadleaf weed species (272 averages). Higher rates were used in western ND because of low activity in low humidity.

Spray carrier water quality

Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Clay inactivates paraquat, diquat, and glyphosate. Organic matter inactivates herbicides. Hard water cations or micronutrients such calcium, magnesium, manganese, sodium, and iron reduce efficacy of all weak-acid herbicides. Cations antagonize glyphosate efficacy by complexing with glyphosate to form salts (e.g. Glyphosate-Ca) that are not readily absorbed by plants. Antagonistic minerals can inactivate the activity of most POST herbicides, including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Ignite. The antagonism is related to the salt concentration. At low salt levels, loss in weed control may not be noticeable under normal environmental conditions but will occur when weed control is marginal because of drought or partially susceptible weeds. The precise salt concentration in water that causes a visible loss in weed control is difficult to establish because weed control is influenced by other factors.

ND water often contains a combination of sodium, calcium, magnesium, and iron and these cations generally are additive in the antagonism of herbicides. Water in ND, SD, and MT is often high in sodium bicarbonate which does not normally occur in other areas of the U.S. Calcium levels above 150 ppm and sodium bicarbonate levels above 300 ppm in spray water can reduce weed control in all situations. Water with 1600 ppm sodium bicarbonate can occur in ND, but total hardness levels can exceed 2,500 ppm.

Ammonium nitrogen increases effectiveness of most weak-acid herbicides formulated as a salt. Fertilizers should always be used with herbicides unless prohibited by label. Ammonium ions greatly enhance herbicide absorption and phytotoxicity even in the absence of antagonistic salts in the spray carrier. However, enhancement of Roundup* and most other POST herbicides from ammonium is most pronounced when spray water contains large quantities of antagonistic cations. Herbicide enhancement by nitrogen compounds appears in most weed species but is most pronounced in species like volunteer corn and species that accumulate antagonistic salts on or in leaf tissue (lambsquarters, velvetleaf, and sunflower).

AMS enhances phytotoxicity and overcomes salt antagonism for weak-acid herbicides formulated as a salt including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Ignite. The antagonism may be overcome by increasing the glyphosate concentration relative to the cation content or by adding AMS and some water conditioners to the spray solution. Effective water conditioners include EDTA, citric acid, AMS, and some acidic AMS replacements. Of these, AMS has been the most widely adopted. When added to a spray solution, the ammonium (NH_4^+) ion complexes with the glyphosate molecule and reduces glyphosate interaction with the hard_water cations, and the sulfate (SO_4^{2-}) ion complexes with the hard_water cations (e.g. calcium sulfate), causing the salt to precipitate from solution. This combined effect increases absorption and efficacy. Natural sulfate in water can be disregarded but can reduce antagonism if the sulfate concentration is at least three times the calcium concentration.

Antagonism of Roundup by calcium in a spray solution was overcome by sulfuric but not nitric acid, indicating that the sulfate ion was important, but not the acid hydrogen ion. The importance of the sulfate ion explains the effectiveness of ammonium sulfate, and not 28% UAN, in overcoming calcium antagonism of glyphosate. Other herbicides that become acid at a higher pH than Roundup may realistically benefit from a reduced pH as has been shown for Poast. However, Poast does not require a low pH for efficacy. pH of 4 has overcome sodium antagonism of Poast, but nitrogen fertilizer or AMS also will overcome sodium antagonism of Poast without lowering the pH. The ammonium ion provided by these fertilizers is apparently the important ion.

AMS is recommended at 8.5 to 17 lb/100 gal spray volume (1 to 2%) on most Roundup* labels. However, AMS at 4 lb/100 gal (0.5%) is adequate to overcome most salt antagonism but more than 4 lb/100 gal may be required to fully optimize herbicides. AMS at 0.5% has adequately overcome antagonism of glyphosate from 300 ppm calcium. Use at least 1 lb/A of

AMS when spray volume is more than 12 gpa. The amount of AMS needed to overcome antagonistic ions can be determined as follows:
Lbs AMS/100 gal = (0.002 X ppm K) + (0.005 X ppm Na) + (0.009 X ppm Ca) + (0.014 X ppm Mg) + (0.042 X ppm Fe).
This does not account for antagonistic minerals on or in the leaf tissue in species like lambsquarters, sunflower, and velvetleaf which may require additional AMS.

AMS may contain contaminants that may not dissolve resulting in plugged nozzles. Use spray grade AMS to prevent nozzle plugging. Commercial liquid solutions of AMS are available and contain approximately 3.4 lbs of AMS/gallon. For 8.5 lbs of AMS/100 gallons of water add 2.5 gallons of liquid AMS solution.

28% UAN fertilizer is effective in enhancing weed control and overcoming mineral antagonism of most POST herbicides, but not calcium antagonism of Roundup. Sodium bicarbonate antagonism of Poast is overcome by 28% UAN and AMS. AMS or 28% UAN does not preclude the need for a oil adjuvant with lipophilic herbicides. Generally, 4 gal of 28% UAN/100 gal of spray has been adequate. AMS and 28% UAN enhance herbicide control of most weeds even in water without antagonistic salts. Nitrogen fertilizer/surfactant blends may enhance weed control of most herbicides formulated as a salt.

The Effects of Adjuvants on Herbicide Efficacy

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Abstract

Spray adjuvants generally consist of surfactants, oils and fertilizers. The main function of a NIS is to increase spray retention, but at a lesser degree, may function in herbicide absorption. Surfactants vary widely in chemical composition and in their effect on spray retention, deposition, and herbicide absorption. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum (PO) or methylated vegetable or seed oils (MSO) plus an emulsifier for dispersion in water. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of an oil adjuvant. Oil adjuvants enhance POST herbicides more than NIS and are effective with all POST herbicides, except Liberty and Cobra, and will antagonize Roundup. MSO adjuvants greatly enhance POST herbicides much more than NIS and PO adjuvants. MSO adjuvants are more aggressive in dissolving leaf wax and cuticle resulting in faster and greater herbicide absorption. The greater herbicide enhancement from MSO adjuvants may occur more in low humidity/low rainfall environments where weeds develop a thicker cuticle. MSO adjuvants cost 2 to 3 times more than NIS and PO adjuvants. The added cost of MSO and increased risk of crop injury when used at high temperatures have deterred people from using this class of adjuvants. Using reduced herbicide rates with MSO adjuvants can enhance weed control while lowering risk of crop injury. Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Hard water cations or micronutrients such calcium, magnesium, manganese, sodium, and iron reduce efficacy of all weak-acid herbicides. Calcium levels above 150 ppm and sodium bicarbonate levels above 300 ppm in spray water can reduce weed control in all situations. Ammonium nitrogen increases effectiveness of most weak-acid herbicides formulated as a salt. Fertilizers should always be used with herbicides unless prohibited by label. Ammonium ions greatly enhance herbicide absorption and phytotoxicity even in the absence of antagonistic salts in the spray carrier. However, enhancement of Roundup* and most other POST herbicides from ammonium is most pronounced when spray water contains large quantities of antagonistic cations. Herbicide enhancement by nitrogen compounds appears in most weed species but is most pronounced in species like volunteer corn and species that accumulate antagonistic salts on or in leaf tissue (lambsquarters, velvetleaf, and sunflower). AMS enhances phytotoxicity and overcomes salt antagonism for weak-acid herbicides formulated as a salt including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Ignite. The antagonism may be overcome by increasing the glyphosate concentration relative to the cation content or by adding AMS and some water conditioners to the spray solution. Effective water conditioners include EDTA, citric acid, AMS, and some acidic AMS replacements. Of these, AMS has been the most widely adopted.

Broad Spectrum Weed and Algae Control in Irrigation Canals Using Endothall

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Irrigation canals are a major source of water for agricultural production in the western United States. Control of aquatic vegetation and algae in irrigation canals is crucial for efficient water delivery in irrigation canals. While aquatic weeds can have a significant impact on water flow, the tools available to canal managers for control are limited. The In 2010, two endothall formulations were labeled for use in irrigation canals. Cascade is the dipotassium salt of endothall, and works to control a range of aquatic weed species. Teton is an amine formulation of endothall that can control both submersed plants and algae. Since their introduction in 2010, Cascade and Teton have been successfully incorporated into the programs of many irrigation districts. Sago pondweed [*Stuckenia pectinata*] was the main target species identified during the development of endothall for irrigation canals. During their first three seasons of use, differential susceptibility was identified, with some species being more difficult to control. Eldoea [*Elodea canadensis*] is one species that has been difficult to control. Additional studies conducted on elodea have indicated that Teton applied at 2 ppm or greater can significantly reduce elodea biomass, with longer exposure time resulting in greater control. Chara [*Chara spp*.] is an algae species that commonly occurs in the West, and is often difficult to control in flowing water systems. A trial evaluating chara control using Teton indicated that a concentration of 0.5 ppm for a minimum of 4 hrs can provide excellent control. These and other trials have been used to refine use rates for irrigation canals. Results from field applications and these ongoing trials indicate that Cascade and Teton provide a safer and more effective tool for controlling aquatic weeds and algae in irrigation canals compared to alternative control methods.

Management of Western Watermilfoil in the Friant-Kern Canal

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Background of the Friant-Kern Canal

The Friant Water Authority (Authority) oversees the Operation and Maintenance (O&M) of the Friant-Kern Canal (FKC). A principal feature of the Central Valley Project, the 152 mile long FKC conveys critical supplies of water to Water Contractors (Contractors) along the eastern side of the lower San Joaquin Valley. These Contractors utilize their supplies for agricultural, municipal/industrial, and groundwater recharge purposes within their service areas. Approximately 1,000,000 acres of highly productive farmland in the counties of Fresno, Tulare, Kern, and Kings are served by water supplied from the Friant-Kern Canal. This acreage is owned and cultivated by nearly 15,000 mostly small family farming operations. In addition, several municipalities including Fresno, Orange Cove, and Lindsay rely on water conveyed by the FKC for some or all of their domestic water supply

Myriophyllum Hippuroides or Western Watermilfoil. Source: Lars Anderson

Background of Invasive Weed

Friant Water Authority first noted the existence of a “new” invasive aquatic weed growing in the FKC in 1998. The location of the initial identification was near the transition from concrete lined to earthen canal at FKC MP 34.94. Over the past 14 years, the invasive weed has spread to entire sections encompassing 22.37 miles of earthen canal in Tulare and Fresno Counties, a 2.01 mile earthen section adjacent to Woollomes Equalizing Reservoir in Kern County, Woollomes Equalizing Reservoir, areas of the FKC that are concrete lined and contain silt accumulation, and numerous facilities including canals, laterals, and recharge basins operated by Contractors who take delivery of water from the FKC.

Identification of Western Watermilfoil

Efforts to identify the invasive weed began in 2001 and continued through 2004. Participants involved in the identification process included Friant Water Authority, United States Bureau of Reclamation, California Department of Food and Agriculture, University of California at Davis, and the United States Department of Agriculture - Agricultural Research Service. Ultimately, the invasive weed was identified as *Myriophyllum hippuroides* or western watermilfoil (WWM). Western watermilfoil is a perennial aquatic plant. Most of the plant grows submerged below the water surface, but stems which bear reproductive structures do penetrate the water surface. The plant is rooted in earthen sections of the FKC and on a more limited basis where silt has accumulated in concrete lined sections. Vegetative growth can be extensive, with plants having multiple stems of ten or more feet in length. WWM forms roots which store nutrient reserves to support the spread of vegetative growth in the water column. In addition to spreading by root growth, stem fragments that break off from plants can settle on the substrate. These fragments subsequently root and generate new plants. Spread by sexual reproduction is less common than by vegetative means.

Impacts on Friant-Kern Canal and Water Users

Infestation of WWM in the FKC causes many issues that impact proper operation of the facilities. Within the FKC, WWM's growth and spread has led to an approximately 10% reduction in capacity during peak flow periods which greatly affects the ability to convey flows to both agricultural and municipal/industrial contractors. Further, as WWM breaks apart, the fragments are transported in the water column to Contractors' turnouts. These fragments regularly impair deliveries as they accumulate on the face of Contractors' turnout trash racks. In some cases, WWM fragments have reduced deliveries by up to 50% in a 24-hour period. Such flow impediments restrict the Contractors' ability to deliver water to their customers.

Infestation of WWM also impacts distribution systems of Contractors who derive their supplies from the FKC. Contractors report that WWM has taken root in distribution canals, laterals, lift ponds, and groundwater recharge basins. Agricultural Contractors report WWM fragments delivered in the water supply regularly clog delivery meters, pumps, and micro irrigation equipment. Municipal contractors report lowered efficiencies of treatment plants, increased downtime, and additional maintenance due to WWM.

Western Watermilfoil in the Friant-Kern Canal Adjacent to a District Turnout. Source: Friant Water Authority

Past Management Efforts

FWA has undertaken efforts to manage WWM in the FKC. Since 2003, on one occasion for each control chemical, FWA has applied diquat, glyphosate, and triclopyr on various limited and broad based control efforts. Observations of the treated areas suggested that existing WWM plants were only minimally affected, reportedly responding to the contact herbicides only by leaf-tip and terminal "burning and dieback"; complete dieback and plant death did not occur. Significant projects to remove silt accumulations which provide a substrate for WWM have been completed. Furthermore, intensive mechanical extraction efforts by hand and machine have aimed to remove WWM from the FKC. These efforts have had limited impact on the infestation of WWM in the FKC.

Past Mechanical Extraction of Western Watermilfoil. Source: Friant Water Authority

Further Research

Due to the spread of the weed, lack of successful control, impact to the FKC, impacts to Contractors, FWA sought to further evaluate WWM. In 2009, FWA entered into a research agreement with the United States Department of Agriculture - Agricultural Research Service at UC Davis. Dr. Lars Anderson headed the project in order to further understand WWM's life cycle, means of reproduction, growth characteristics, and susceptibility to various control chemicals.

Western Watermilfoil Chemical Trial Tanks. Source: Lars Anderson

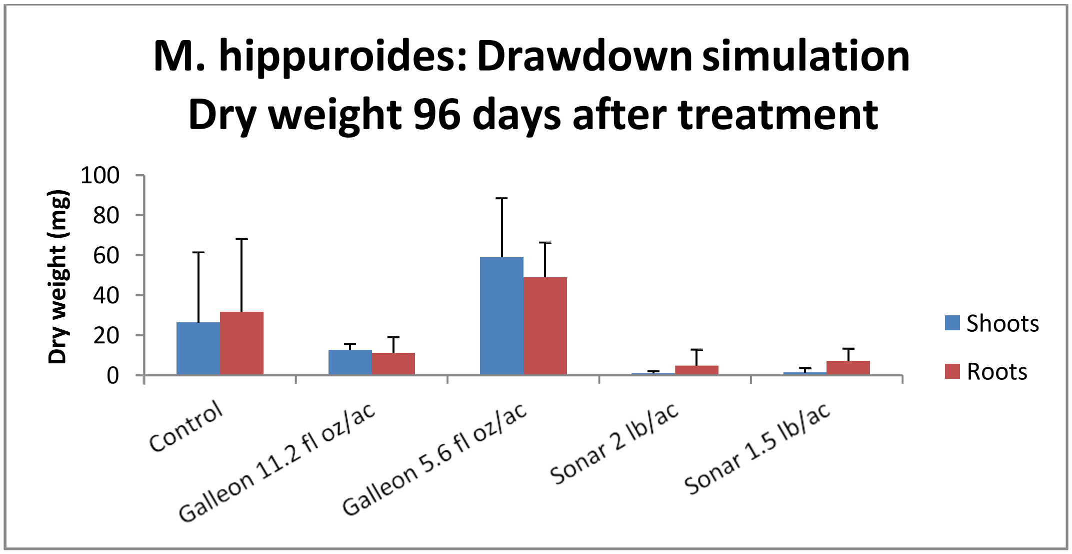
Further Management Options Presented

Chemical control options to address WWM while keeping the FKC in operation were presented to the FWA Advisory Committee for review in 2010 and 2011. The committee determined there was not sufficient consensus to pursue such an application given the varied interests served by the FKC. In 2011 and 2012, FWA staff pursued the potential permitting and introduction of triploid grass carp with the California Department of Fish and Game in order to utilize a non-chemical means of WWM control in the FKC. As a result of these efforts it was determined FWA would not be eligible to receive the necessary permits for the introduction of triploid grass carp in the FKC. In mid-2012, FWA staff presented to the Operation and Maintenance Committee and Board of Directors options related to potential chemical control options to address WWM during a drawdown of the FKC. This potential treatment was presented in order to address continued concerns and requests by Contractors to address the WWM issue in the FKC.

Chemical Treatment 2012/2013

The treatment in the drawdown FKC employed the use of fluridone and imazamox. Fluridone was identified by Dr. Anderson as having notable effect on WWM and imazamox was identified as having successful control on other watermilfoil species by SePRO Corporation.

FWA consulted with SePRO on the potential use of these chemicals in the FKC to determine if the chemicals would fit the uses and needs demanded by the water users. Fluridone, trade name Sonar Genesis, is manufactured and distributed by SePRO Corporation. Imazamox, trade name Clearcast, is manufactured by BASF and distributed by SePRO Corporation. Both are FIFRA labeled, EPA approved, and approved by the California Department of Pesticide Regulation for pre-emergent control of aquatic weeds in canals that are drawn down. Both chemicals are labeled for use in agricultural and domestic water systems with limited restrictions and limitations.



Effectiveness of Chemicals in Drawdown Simulation. Source: Lars Anderson

Consultation with Governing Agencies and Stakeholders

FWA submitted the WWM treatment plan to all Contractors on the FKC for input and comment. The plan was further submitted to the California Department of Public Health, United States Bureau of Reclamation, along with the Agricultural Commissioners of Fresno, Tulare, and Kern Counties. The California Department of Pesticide Regulation was consulted related to the acceptability of use and registration of the products. Contractors and regulating entities provided their respective comments, confirmation, and approval of the WWM treatment plan.

Location and Timing of the Application

Sonar Genesis and Clearcast herbicides were applied to the drawn down FKC invert and embankments beginning at MP 34.94 through MP 61.99 excluding intermittent concrete lined areas and siphons. Applications took place the last two weeks of 2012. Both labels call for a minimum 14 day hold time prior to reintroduction of water. FWA utilized hold times of roughly 30 days in order to allow for proper incorporation into the FKC embankments.

Herbicide Application

Sonar Genesis was applied at a rate of 2.0 lbs. active ingredient (ai) per acre or 4.0 gallons per acre. Clearcast was applied at a rate of 0.50 lbs. ai per acre or 0.50 gallons per acre. The two chemicals were tank mixed prior to application. Application to the FKC embankments was completed using truck mounted booms and the invert was sprayed by truck mounted boom, hand wand, and a spray highline suspended by two vehicles on opposite sides of the FKC. A spray solution of 30-120 gallons per acre was applied depending on the application method.

Herbicide Label Limitations on Domestic and Agricultural Uses

Requirements on the specimen labels for Sonar Genesis and Clearcast have limited use restrictions, precautions, and limitations. Sonar Genesis and Clearcast are approved by the EPA and the State of California Department of Pesticide Regulation for agricultural and drinking water use. The California Department of Public Health provided limitations on any residual levels of treatment agents However, Sonar formulations have been used extensively for over a decade to combat invasive aquatic weeds in the Sacramento-San Joaquin Delta by the California Department of Boating and Waterways.

Safety Protocols

As the FKC was in a dewatered state, the Contractors' turnouts were not in service. The FKC control structures within the treatment area were closed then locked and tagged out and a series of secondary containment was installed downstream of the treatment zone. Additionally, the turnout of the one municipal Contractor within the treatment zone was also locked and tagged out as an added precaution.

Canal Re-Watering, Depuration, and Water Quality Monitoring

SePRO was consulted by FWA to determine anticipated levels of depuration which may be expected upon reintroduction of water in the FKC. In their experience, depuration rates of 10% - 20% have been observed. Several calculations utilizing different refill scenarios were run to determine anticipated residuals. Upon reintroduction of water in the FKC, water quality will be monitored. Samples to determine any residual levels of the active ingredients found in Sonar Genesis and Clearcast will be collected. Samples will be taken from within the application zone 1 day (d), 2d, 5d, and 7d after water reintroduction. Water samples will also be taken at the site of municipal Contractors' turnouts within the treatment area and extending through Tulare County. Samples will be tested by SePRO's laboratory along with a third party laboratory. Water will not be released for use by Contractors until label restrictions are met.

Integrated Vegetation Management in Flood Control and Urban Creek Settings

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Introduction

Maintenance of urban creeks and flood control channels is a valuable and challenging activity. Proper maintenance of these facilities protects people, property, wildlife, and the environment. The challenge for agencies tasked with maintaining these resources is to successfully protect these assets while at the same time adhering to regulatory and permit conditions. Resource limitations (labor, equipment, contractors, funding) and public concerns are additional factors that managers must consider in their decision making process.

Discussion

There are significant differences between water conveyance facilities, and urban creeks and streams. The water level of conveyance systems can often be modified, and in some cases even de-watered as part of an integrated vegetation management plan. This method is not available when maintaining creeks and flood control facilities. Obtaining the necessary permits to de-water a creek or flood control facility is too time consuming and expensive to use for vegetation management.

While there is overlap, the spectrum of problematic weeds is usually different in each of these areas. Weed control in urban creeks and streams usually targets emerged, marginal, and riparian vegetation. Managers of water conveyance facilities focus most of their weed management on submerged and true aquatic vegetation.

Water conveyance facility slopes are often armored with concrete or rock to minimize erosion and water loss, and are seldom vegetated. Urban creek and stream slopes are usually vegetated, and only armored where necessary. The habitat and wildlife value of creek and flood control facilities is usually quite high compared to many (but certainly not all) water conveyance facilities.

The primary reason for active maintenance of urban creeks and streams is flood protection. In California, most counties make flood-related disaster declarations at least once a decade. Private property and infrastructure are often located adjacent to these resources, incurring heavy losses during even short duration flood conditions. Flood related losses in excess of $1 billion occur at least once a decade in California (California OES).

High flow events can damage flood control channels and slopes as well. High speed flow, often combined with debris, can erode and undercut slopes. Slope repairs and re-establishing low-flow channels to their original design is expensive and requires a lengthy permit process.

There seems to be no correlation between flood events and either El Nino or La Nina conditions (California OES). Since there is no way to know when heavy rain events will occur, maintenance of creeks and flood control facilities must be done to preserve maximum flood protection each year. Most flood events are associated with short duration, high intensity storms, and not necessarily with an above-average rain season.

Fuel load, or fire risk, is another concern for managers of these facilities. Homes and buildings are often located adjacent to urban creek and flood control facilities. Therefore, managers must reduce probability that a fire will escape from their facility. Local fire districts usually have fairly strict fuel abatement guidelines. These guidelines don't always take plant biology into account.

Re-vegetation projects in these facilities, while beneficial to the environment, make maintenance more expensive and time consuming. Maintenance crews need good training and close supervision to prevent damage to desirable vegetation. Maintenance activities need to be altered and adjusted as this vegetation matures.

In addition to maintaining flood capacity, 24 hour/365 day access for crew and equipment should be preserved to allow for quick response to storm-related problems. A clear line of sight of slopes and flow should be preserved as much as possible, allowing inspectors to quickly identify damage and blockages.

Another challenge faced by managers is associated with property rights. Many creeks have private maintenance in some sections, and public maintenance in others. Two or more agencies may have maintenance responsibilities in the same creek or watershed. This is especially challenging when conducting invasive weed control. Privately maintained creeks can be a source of excess organic debris, increasing the risk of blockages.

Most flood control facilities have O&M manuals (operation and maintenance). These give guidance for how much vegetation and silt can be allowed without compromising flood protection. This type of guidance is very helpful in urban creek maintenance. Visual aids and written plans can be used by maintenance crews and the general public.

Invasive weed exclusion and eradication is difficult near water. Once established, they can spread easily throughout the creek or facility. Permits are often required by the Regional Water Resources Control Board, and a limited number of compounds have aquatic registration in California. Introduction of these weeds can be from upstream sources or adjacent property owners. It is helpful to know where these sources are located when trying to limit their spread.

Public perception of pesticides, including herbicides, is decidedly negative. Fears regarding impacts on health are common. Choosing materials with low human and environmental toxicity, and making that information public, can reduce concerns. Political and regulatory opposition to the use of herbicides is difficult to answer effectively. Having written information available on training, licensing, safety precautions can be helpful. Creating an integrated vegetation management plan specific to each area you maintain can help to educate these groups as to the complexity of managing these resources.

Documenting maintenance costs, by method, can be helpful in the education process. It is important to capture all costs when making these calculations. Labor, benefits, equipment, contractors, supervision, inspection, contract administration and administrative overhead are all components of the total cost of maintenance.

Deferred maintenance should be documented and communicated to the managers who have the authority to allow or prohibit specific vegetation management techniques. The underlying reasons for deferred maintenance should be documented as well. Don't assume that elected officials or district managers know and understand all of the reasons for deferred maintenance.

Grazing, manual mowing or removal, machine mowing, and the use of herbicides are all common tools used in urban creek and flood control channel maintenance. Disking is usually not appropriate due to sedimentation concerns. Much is only appropriate when used near or at the top of bank. Fabric barriers can be useful when placed around desirable plants, but is difficult to install correctly and often washed away during high flow events. The use of competitive plantings can be effective in certain circumstances but requires high amounts of labor to maintain during establishment.

A NPDES permit may be required for the use of herbicides in urban creeks and flood control facilities. And depending on how close and what type of application method is used, aquatically approve herbicides may be required as well. Permits may be required by other regulating agencies as well. This can complicated the use of herbicides and increase overhead costs.

The use of low impact application methods (cut-stump, basal bark, low-volume foliar, and directed/spot applications) are often preferable to broadcast applications when treating invasive plants. These methods limit damage to surrounding vegetation. Selective herbicides are also helpful when trying to control specific or closely related weeds species.

Plant species requiring control share some or all of the following characteristics:

- Spread rapidly via fruit or vegetative reproduction
- Grow rapidly in riparian habitats
- Produce large amounts of biomass
- Growth habit impedes the flow of water
- Crowd out native species and/or form a monoculture
- Produce a high fuel load or present a high fire hazard
- Spread easily from urban and suburban landscape

Conclusion

- ❖ Thorough record-keeping is essential

- Know the plants in each facility which require control
- Outline your decision-making process to inform management and public
- Document the risks of not managing vegetation
- Tailor management and treatments to fit each resource
- Review and alter management techniques as needed
- Keep records of resource limitations and deferred maintenance

Integrated Herbicide Program for Control of Aquatic Weeds and Algae in Irrigation Canal Systems

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Herbicides are an effective part of integrated aquatic plant management programs. Aquatic vegetation management has been slow to change over the years, due in part to the inherent difficulty in finding new molecules that will have effective control on aquatic weeds while remaining selective to desirable species and still allowing the use of the treated water body for irrigation, recreation or domestic use. Since 2007, **Sonar® AS** has been registered for use on dry or de-watered irrigation canals in an off-season application. In an effort to increase the range of control options and mode-of-action portfolio available to the irrigation market, there has been a recent expansion of available pre-emergent aquatic herbicide products for this use.

This presentation will discuss a short history of aquatic weed control. From mechanical to in-season applications. Best Management Practices that have shown by utilizing a pre-emergent program followed by in-season treatment products as needed, either stand alone or in combination, has improved overall efficacy while reducing maintenance costs for irrigation system operators.

Management of algae will also be discussed. Reduction in submersed aquatic weeds has increased the need to do algae control independently during the irrigation season.

Best Management Practices for Aquatic Weed Control in Canals

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Weed control specialists must consider many factors when deciding on the management practices to utilize for control of aquatic weeds in irrigation canals. Management practices are generally limited to mechanical removal, hand removal and herbicide treatments. However the factors that need to be considered when adopting a management practice can be very diverse and unique for each canal system. These factors include the standard of control that is required, minimization of environmental impact, the customers that the canal services, the resources that are available, employee and public safety and cost. In addition, historical records of past practices are important for refining and revising management practices as conditions or weeds species change. As new herbicides are introduced into the market, the weed control specialist must determine if the herbicide has a place in their "tool box," based on the many factors unique to the situation. This presentation will highlight the decision making process in development of best management practices for aquatic weed control in canals at Solano Irrigation District.

Biopesticides Role in Organic Weed Control

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Abstract

Surveys of organic growers indicate that weed control is the number one cost of organic production. Conventional grower surveys are inhibited from transitioning to organic production due to the cost and difficulty of weed control. As such there is an unmet need in the market for companies to discover and develop more effective and cost effective alternatives for weed control in organic production. Marrone Bio Innovations (MBI) was founded with one of its core focus areas discovering, developing and marketing natural products for weed control. After entering and exiting the market with products based on essential oils, MBI embarked on discovery and in-licensing of novel microorganisms and plant extracts that produce natural compounds with novel modes of action that control weeds. This talk will discuss MBI's herbicide discovery and development process and also three products in MBI's pipeline, Opportune (tm) (MBI 005) cellulose biosynthesis inhibitor, MBI 011 burndown herbicide and MBI 010 systemic herbicide. These products have potential for both organic and conventional production. The speaker will also provide an overview of the biopesticide market and the drivers behind double digit growth of biopesticides and the intense interest by large agrichemical companies and growers in this fast growing sector.

Organic Herbicides Performance in Field Trials

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In recent years, several organic herbicide products have appeared on the market. These include Weed Pharm (20% acetic acid), C-Cide (5% citric acid), GreenMatch (55% d-limonene), Matratec (50% clove oil), WeedZap (45% clove oil + 45% cinnamon oil), and GreenMatch EX (50% lemongrass oil), Final-San-O (22% ammoniated soap of fatty acids), Biolink (80% Caprylic-Capric acid), among others. These products are all contact-type herbicides and will damage any green vegetation they contact, though they are safe as directed sprays against woody stems and trunks. These herbicides kill weeds that have emerged, but have no residual activity on those emerging after application. Additionally, these herbicides can burn back the tops of perennial weeds, but perennial weeds recover quickly.

Organic herbicides only kill contacted tissue; thus, good coverage is essential. Initial greenhouse studies found that spray volumes of 70 gallons per acre (gpa) were superior to 35 gpa, regardless of the organic herbicide tested. In test comparing various spray volumes and product concentrations, we found that high concentrations at low spray volumes (20% concentration in 35 gallons per acre) were less effective than lower concentrations at high spray volumes (10% concentration in 70 gallons per acre). Applying these materials through a green sprayer (only living plants are treated), can reduce the amount of material and thus the application and material cost (http://www.ntechindustries.com/weedseeker-home.html).

Also, we observed that adjuvant addition improved organic herbicide performance. Among the organic adjuvants tested thus far, Natural wet, Nu Film P, Nu Film 17, and Silwet ECO spreader have performed the best. The Silwet ECO spreader is an organic silicone adjuvant which works very well on most broadleaf weeds, but tends to roll off of grass weeds. The Natural wet, Nu Film 17 and Nu Film P work well for both broadleaf and grass weeds. Although the recommended rates of these adjuvants is 0.25 % v/v, we have found that increasing the adjuvant concentration up to 1% v/v often leads to improved weed control, possibly due to better coverage.

Field testing has further confirmed greenhouse observations. These products are effective in controlling weeds when the weeds are small and the environmental conditions are optimum. In a large field study, we found that weeds in the cotyledon or first true leaf stage were much easier to control than older weeds (Tables 1 and 2). Broadleaf weeds were also found to be easier to control than grasses, possibly due to the location of the growing point (at or below the soil surface for grasses), or the orientation of the leaves (horizontal for most broadleaf weeds) (Tables 1 and 2).

Because organic herbicides lack residual activity, repeat applications will be needed to control new flushes of weeds or to further suppress perennial weeds. Perennial weeds wre found to recover after a single treatment with an organic herbicide. However, treating a second time 15 to 21 days after the initial application resulted in almost complete top kill of the perennial (field bindweed or yellow nutsedge), and slowed recovery.

Temperature and sunlight have both been suggested as factors affecting organic herbicide efficacy. In several field studies, we have observed that organic herbicides work better when temperatures are above 75F. Weed Pharm (acetic acid) is the exception, working well at temperatures as low as 55F. Sunlight has also been suggested as an important factor for effective weed control. Anecdotal reports and our own observations indicate that control is better in full sunlight. However, in a greenhouse test using shade cloth to block 70% of the light, it was found that weed control with WeedZap improved in shaded conditions (Table 3). The greenhouse temperature was around 80F. It may be that under warm temperatures, sunlight is less of a factor, or that cool, shaded conditions, the products are less effective.

Organic herbicides are expensive at this time and may not be affordable for broadcast applications in cropping systems. However, for spot treatments, they may have a fit. Mulches are a common method used to control weeds in organic crop production systems. Mulches are generally effective for the first year or so after installation, but weed growth on or next to the mulch can reduce its value. In small field test, we found that wood chip mulches could be kept in good condition by periodic spot treatment of weeds with organic herbicides. Organic herbicides were able to kill the weeds growing on the mulch without disturbing the mulch.

Table 1. Broadleaf (pigweed and black nightshade) weed control (% control at 15 days after treatment), when treated 12, 19, or 26 days after emergence.

	-----------------Weed age---------------------		
	12 Days old	19 days old	26 days old
GreenMatch Ex 15%	89	11	0
GreenMatch 15%	83	96	17
Matran 15%	88	28	0
Acetic acid 20%	61	11	17
WeedZap 10%	100	33	38
Untreated	0	0	0

Table 2. Grass (Barnyardgrass and crabgrass) weed control (% control at 15 days after treatment), when treated 12, 19, or 26 days after emergence.

	-----------------Weed age---------------------		
	12 Days old	19 days old	26 days old
GreenMatch Ex 15%	25	19	8
GreenMatch 15%	42	42	0
Matran 15%	25	17	0
Acetic acid 20%	25	0	0
WeedZap 10%	0	11	0
Untreated	0	0	0

Table 3. Weed control with WeedZap (10% v/v) in relation to adjuvant, spray volume and light levels. Plants grown in the greenhouse in either open conditions or under shade cloth, which reduced light by 70%.

	Pigweed control (%)		Mustard control (%)	
	Sun	Shade	Sun	Shade
WeedZap + 0.1%v/v Eco Silwet (10 gpa)	31.7	93.3	26.7	35.0
WeedZap + 0.5%v/v Eco Silwet (10 gpa)	31.7	48.3	43.3	71.7
WeedZap + 0.5%v/v Natural Wet (70 gpa)	26.7	94.7	26.7	30.0
Untreated	0.0	0.0	0.0	0.0
LSD.05*	5.7		11.5	

* Values for comparing any two means. Pigweed and mustard were each analyzed separately.

Evaluation of Options for Weed Control in Organic Vineyards, Vegetables, and Berry Cropping Systems

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Abstract: Studies were conducted in organic vineyards, broccoli, spinach, blackberry, and strawberry cropping systems. Treatment comparisons included steam, plow, cultivator, and an organic herbicide in the vineyards; white mustard and soybean seed meal at 0.5 and 2 t/ac in broccoli and spinach; recycled paper mulch of two thicknesses (1 and 2 mm) in blackberry; and recycled paper mulch and black plastic mulch in strawberry. In the vineyards, the mechanical weed control treatments were the most cost-effective. In the broccoli and spinach study, mustard seed meal at 2 tons/ac provided considerable weed control and reduced hand weeding time compared to the other treatments. In the blackberry study, the recycled paper mulch provided up to two months of weed control. In the strawberry study, both plastic and recycled paper mulch provided similar weed control. However, the soil temperature under the paper mulch was on average 1° C cooler than under the plastic mulch.

Introduction: Weed management in organic cropping systems is a challenge due to the lack of registered herbicides that are effective and economic as in conventional cropping systems. Therefore, alternative tools for weed management need to be evaluated in organic cropping systems. These tools include mechanical and thermal weed control, use of mulches, and use of allelopathic substances to name a few. Similarly, there are a few new postemergence broad-spectrum herbicides labeled for use in organic cropping systems. However, the efficacy and economics of these tools have not been tested adequately in field studies. This paper will summarize the findings of several separate field studies conducted in organic vineyards, spinach, broccoli, blackberry, and strawberry cropping systems.

Materials and Methods, Results, and Discussion:

Organic vineyards**:** Studies were conducted in 2010 and 2011 in organic raisin and wine grape vineyards in Fresno and Madera County, respectively. Treatment comparisons included non-weeded control, two mechanical weed control methods (French plow and Bezzerides tree and vine cultivator), steam, and an organic herbicide (d-limonene; Greenmatch®). The experiments were designed as split-plots with these treatments as main-plots followed by an additional weed control treatment one month later as sub-plots. By far, the greatest level of weed control was provided by the mechanical treatments. When the plots were hand hoed as the sub-plot treatment, compared to the time required for hoeing in the non-treated plots, the plowed plots required 55 to 75% less while the cultivated plowed plots required 30 to 60% less time to hoe in the raisin grape vineyards. Similarly, in the wine grape vineyard, hoeing time was reduced by 50 to 75% in the cultivated plots compared to those non-treated plots. Such differences did not occur in the herbicide or steam treated plots as the time required to hoe the plots with these treatments was generally similar to the non-treated control. However, none of the treatments affected vine growth, grape yield, or quality in either of the vineyards indicating that established vineyards had a higher threshold for weeds. Total weed control costs in the plowed, cultivated, steam-treated, and the herbicide-treated plots in the raising vineyard was approximately $80, $85, $170, and $250/acre, respectively. In the wine grape vineyard, the total weed control costs in the cultivated, steam-treated, and herbicide-treated plots were approximately $55, $125, and $200/ac, respectively. Therefore, the mechanical treatments were by far the best weed control treatment and may remain the most cost-effective weed control method in organic vineyards till better alternatives are developed.

***Organic blackberries*:** Studies were conducted in 2011 and 2012 in the certified-organic plots at the Fresno State University farm. The objective of the study was to compare recycled paper mulch (EcoCover LLC, Huntington Beach, CA 92647) of two thicknesses (1 mm and 2 mm) with non-treated plots during blackberry establishment phase. Square mulch mats measuring 0.2 m^2 were placed around each blackberry plant on the soil surface immediately after crop planting in April and staked. The plants were surface drip irrigated and the mats were placed on top of the drip tape. Weekly measurements on plant height, soil water content and soil temperature (at 12 cm depth) were taken. At the end of each month, weed density and weed biomass was evaluated.

Weed biomass in May (one month after planting) was 51% and 49% lower in the 2 mm and 1 mm mulch, respectively compared to the plots without mulch. Weed densities in June (two months after planting) were also lower by 72% and 65% in the 2mm and 1mm mulch, respectively compared to no mulch. However, there were no differences in weed density or weed biomass between the two mulch types. There were no differences in weed density or biomass between any of the treatments thereafter. Therefore, the mulches were successful in providing weed control during the first few months of this experiment. Weed emergence in all the plots was very low after June, hence no differences were found between the treatments. Although data was not taken on weed control, the mulch was still intact till the end of the year providing some level of weed control. Therefore, it is possible that the paper mulch will provide weed control for a longer period of time.

***Organic broccoli and spinach*:** Studies were conducted in 2010 and 2011 in the certified-organic plots at the Fresno State University farm. The objective of the experiment was to compare the effects of white mustard and soybean seed meals on weed control in broccoli and spinach. Mustard and soybean seed meals were soil-incorporated at two rates (0.5 and 2 tons/ac) two weeks prior to crop planting. Weed densities and hand-weeding time were recorded twice during the growing seasons and weed biomass was determined at crop harvest. Total weed emergence was reduced by approximately 50 to 95% and 40 to 45% 3 and 6 weeks after planting (WAP) of broccoli and spinach, respectively, in the 5 ton/ac mustard meal treated-plots compared to the 0.5 ton/ac soybean seed meal-treated plots. Time required for hand-weeding at 3 and 6 WAP was also reduced by up to approximately 80% and 50%, respectively with the 2 ton/ac mustard meal compared to the 0.5 ton/ac soybean seed meal treatment. Although the mustard seed meal provided substantial weed control, the treatment still will have to be supplemented with other weed control methods for season-long weed control.

***Organic strawberries*:** Studies were conducted in 2012 in the certified-organic plots at the Fresno State University farm. The objective of the study was to compare recycled paper mulch (EcoCover LLC, Huntington Beach, CA 92647) with black plastic mulch. Each plot was covered with either black plastic or recycled paper mulch. Both these materials were staked to the ground. Some plots were left without any mulch for comparative purposes. The experiment was designed as a randomized complete block. The plants were surface drip irrigated and the tapes were placed under the mulch. Weekly measurements on soil temperature and water content (measured at 12 cm depth) were taken in early part of the growing season and in late summer. Weed density and weed biomass was taken several times during the growing season.

Both mulch types provided complete control of weeds except for a few weeds next to the plants in the planting holes. Differences in soil temperature and moisture content were observed at various timed during the growing season (Fig. 1). Soil temperature under the recycled paper mulch was generally lower than under the plastic mulch or the non-mulched plots on average by about 1° C. Soil moisture content was generally similar between the two mulch systems, but in late summer the soil moisture under the plastic mulch was much lower than in the other treatments (Fig. 1). These differences in soil temperature and moisture, however, did not affect crop yield as there were no differences between the two mulch systems in berry yield over the growing season.

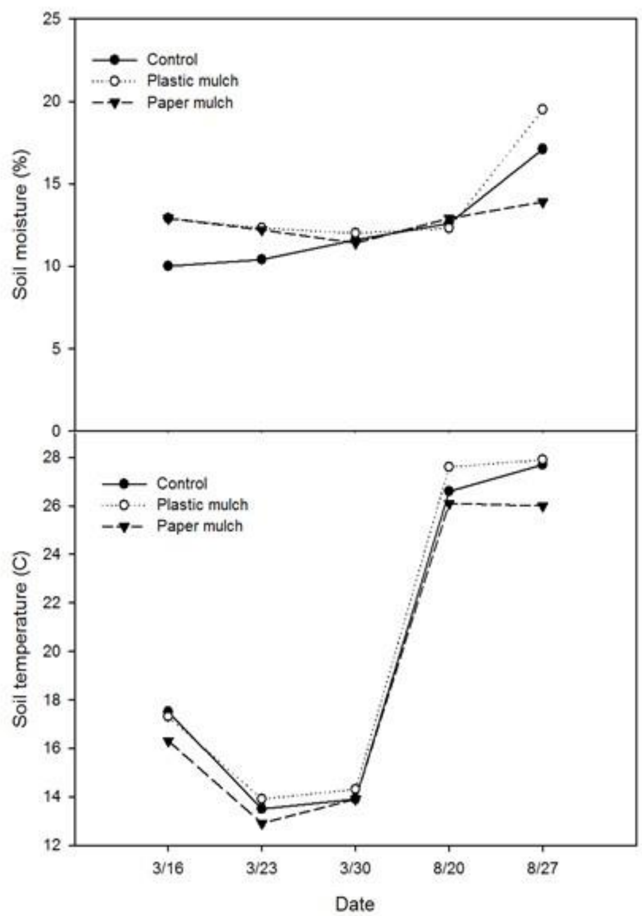

Figure 1. Soil moisture and temperature at 12 cm depth in the various treatments at various times of the year.

Manuka Oil as a Potential Natural Herbicide

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In 1977, Gray observed that bottlebrush plant (*Callistemon citrinus*) repressed the growth of plants in its surroundings. Crude extracts from this plant caused the bleaching of grass weeds. He identified the active component as leptospermone, a natural triketone structure with no known biological activity that had been reported in a number of Australasian shrubs. Leptospermone was moderately active in greenhouse tests, controlling mostly small-seeded grass weeds. This natural product and a small number of synthetic structural analogs were patented as herbicides in 1980. A few years later, a separate group at the Western Research Center was generating analogs of the cyclohexanedione herbicide sethoxydim, an inhibitor or acetyl-coenzyme-A carboxylase. Some of the second generation herbicidal derivatives with a dimedone backbone caused bleaching symptoms similar to leptospermone. Combination of the syncarpic acid of leptospermone to this chemistry ultimately served as the basis for the development of the triketone synthetic herbicides (Fig. 1).

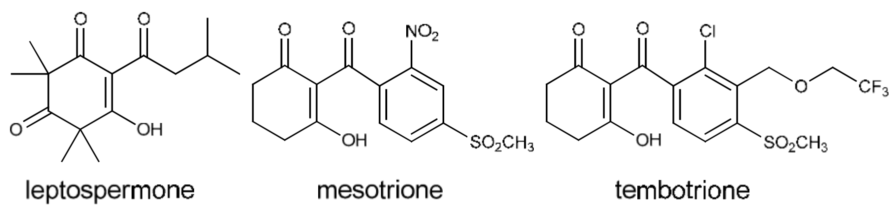

Fig. 1. Structures of the natural triketone leptospermone and two synthetic analogues that are sold as commercial herbicides.

Natural β-triketones are common in many Australasian woody plants (e.g., *Leptospermum*, *Eucalyptus*, *Melaceuca*, etc...). Steam distilled manuka oil account for 0.3% of the dried weight of *L. scoparium*. However, the amount of β-triketone present in these oils varies wildly across New Zealand. Some chemotypes contain as little as 0.1% triketone while others can accumulate up to 33%.

β-triketone herbicides (e.g., sulcotrione and mesotrione) cause bleaching of newly emerging tissues. This symptom was traditionally associated with inhibitors of phytoene desaturase but triketone herbicides do not inhibit this enzyme. It was later found that these herbicide inhibit *p*-hydroxyphenylpyruvate dioxygenase (HPPD), a key enzyme involved in the biosynthesis of prenyl quinones and tocopherols. Plastoquinone (a prenylquinone) is an essential cofactor for phytoene desaturase. In the absence of plastoquinone, phytoene desaturase activity is reduced which results in bleaching of young foliage and accumulation of phytoene typically observed with phytoene desaturase inhibitors develop (Fig. 2). Chlorophyll levels are also affected because the photosynthetic apparatus is no longer protected from the reactive oxygen species generated under high light intensity.

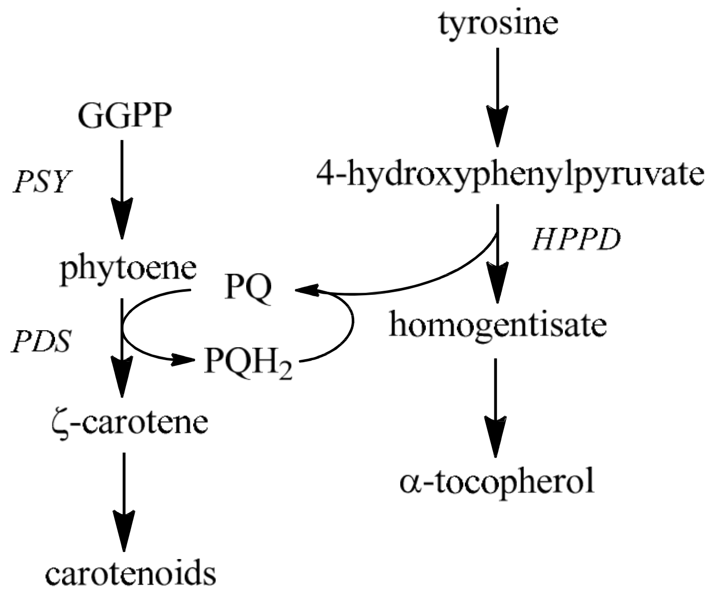

Fig. 2. Mechanism of action of leptospermone. *PSY* = phytoene synthase; *PDS* = phytoene desaturase' *HPPD* = p-hydroxyphenylpyruvate dioxygenase; PQ = plastoquinone.

Gray observed that leptospermone also caused bleaching of plant tissues. Work with the bioactive components of manuka oil demonstrated that some natural β-triketones also inhibit plant HPPD. Most of the activity of manuka oil was due to leptospermone because it was the most abundant triketone in the oil. However, grandiflorone, a minor constituent with has a more lipophilic side chain, was much more active on HPPD. Conversely, the short methyl side chain of flavesone nullified the activity. The important role of the lipophilicity of the side chain was confirmed with a structure-activity study with a series of natural and synthetic leptospermone analogs.

Manuka oil is active both when applied on the foliage and on the soil surface. While most essential oils have little to no soil activity, preemergence application of manuka oil controlled the growth of large crabgrass at a rate of 3 L/ha. The soil activity of manuka oil is due in part with the relatively slow dissipation of leptospermone, which remained active in soil for at least two weeks.

Triketones and other phytotoxic natural products are often produced and stored in specialized structures which may serve in part as a mechanism to prevent autotoxic effects. In the leaves of members of the Myrtaceae family, which encompasses most of the known herbicidal triketone-producing species, specialized schizogenous glands (Fig. 3). In the genus *Leptospermum*, the gland is covered by two to four cells which have thin, straight walls and are generally of the same approximate size. These cells are encircled by five to 14 unspecialized epidermal cells in a spiral orientation. Schizogenous formation proceeds by the division of single cells within the epidermis or mesophyll layer with the oil cavity forming as an intracellular space. The schizogenous cavity is lined with a single layer of 4 to 6 epithelial cells that are thought to be responsible for the production of the volatile oils stored within the cavity.

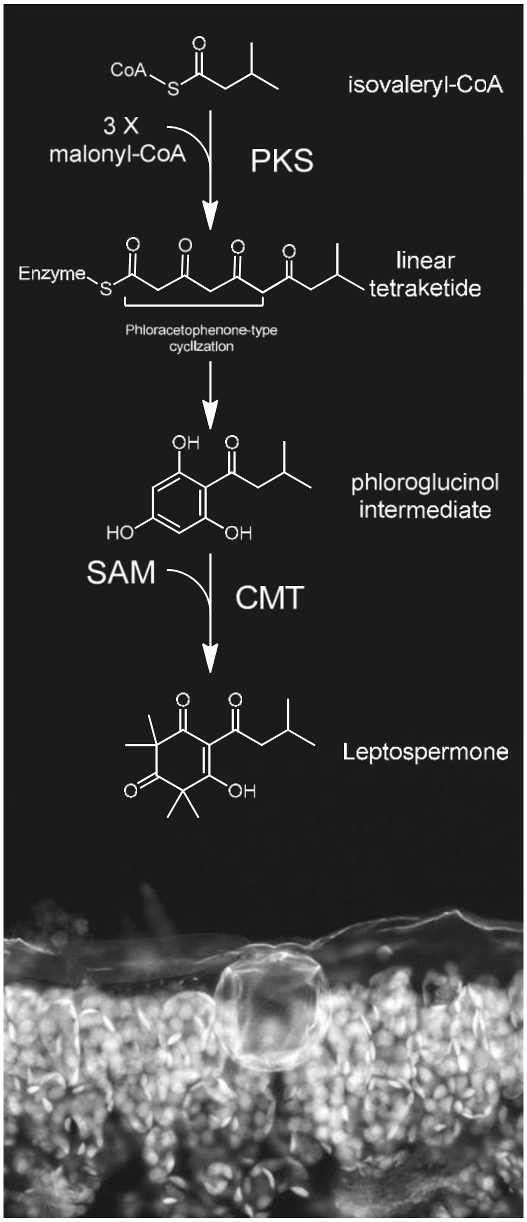

Fig. 3. Proposed biosynthesis of leptospermone (top) and micrograph of a representative *Leptopermum scoparium* (manuka) schizogenous gland connected to the cuticle and extending into the mesophyll.

The chemical synthesis of natural β-triketones has been well studied, but much work remains to unravel the *in vivo* biosynthesis of these molecules. Although an *in planta* biosynthetic route has yet to be established, a hypothetical pathway can be proposed based on the structure of the final compounds (Fig. 3). In a series of conversions analogous to the well-examined chalcone synthase enzyme, a type III polyketide synthase (PKS) sequentially condenses three malonyl CoA molecules into a polyketide chain extending from an isovaleryl CoA starter molecule. The enzyme subsequently cyclizes the linear tetraketide intermediate via a Claisen type condensation to generate a phloroglucinol intermediate. A PKS enzyme, valeropenone synthase (VPS), with this activity has been purified to homogeneity and biochemically characterized from *Humulus lupulus* L. (hops) cone glandular hairs. VPS is thought to be involved in the production of the beer flavoring iso-acids of hops which have been shown to contain a β,β-triketone moiety. Subsequently, a gene for this enzyme has been identified and characterized. Efforts are currently underway to isolate and characterize enzymes homologous to VPS from *Leptospermum scoparium* as an initial effort to characterize the leptospermone biosynthetic pathway.

After the production of the phloroglucinol intermediate, the compound would be proposed to undergo spontaneous keto-enol tautomerization, and subsequently to undergo methylation by an as-of-yet unidentified C-methyltransferase (CMT). Early work with methionine-methyl-C^{14}

labeled adult *Dryopteris marginalis* ferns, demonstrated that the C- and O-methyl substituents of isolated phloroglucinols were derived from methionine. If these findings are consistent with leptospermone, the biosynthetic methyltransferases are likely to be similar to S-adenosylmethionine using CMTs identified in other species.

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Tracking Herbicide Movement- Post Application

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Introduction – Explain Caltrans' Policy and Objectives of IVM, Integrated Vegetation Management. Emphasis is to suggest Post and Pre-Emergent Application Considerations for weed, tree, brush and growth management, suppression, and/or control, to help avert possible problems. Caltrans' primary focus is for safety of applicators, support crews, and traveling public, and the environment.

By using sound 'Application Objectives and Considerations' before applications, the idea is to help enhance overall application efficacy. This may reduce mitigation issues, and help avoid "Off Site" movement, and then the subsequent need to track herbicide movement 'off target'.

Caltrans IVM- Integrated Vegetation Management/ IPM:

Includes biological, cultural, mechanical, and other methods when "Practical, Feasible, and Economically sound". Thus resulting in the proposed chemical a.i. reduction. The current focus is for lowering pesticide usage for the Caltrans A.I. Reduction "Plan", now in it's peak of the 20 year proposal to reduce chemical usage by 80%. These commitments are for maintenance and vegetation management for landscaped areas and roadsides. This includes esthetics, fire control and suppression, and reduced water usage. Again, the focus is to enhance development of reduced worker and public exposure to chemicals, and reduce possible adverse environmental aspects. There is a strong emphasis on "stormwater" contamination reduction.

"I.V.M Plan" objectives:

Introduce lower a.i. chemicals, manage use and include surfactants for efficacy,

Modify cultural and mechanical practices to enhance efficacy, ie, mowing, mulching, other physical weed suppression, hardscapes, mats, cobble, concrete, etc.,

Advance planning and design to limit safety issues and increase efficacy through design.

Presentation includes suggestions for tracking herbicide movement "post application". If "issues, accusations, or complaints" arise, the objective is to repudiate 'blame' if complaint is not valid, analyze actual causes, or minimize subsequent settlement, and/or fines and violations. Also expecting to reduce monetary, environmental, or "collateral damages". This would help reduce "reputation issues", and help plan to avoid reoccurrence and reduce problem potentials in the future. The subsequent need for tracking and calculating "off-site" movement will be mitigated or reduced with prior assessment, planning, and precise documentation of chemical applications.

Documentation is imperative, as proper applications, safety and protective devices, and overall knowledge of the specific chemicals and their potential, will help divert "accusations" by presenting fact. The appropriate appearance and implementation of care and safety, from the viewpoint of regulatory entities, and may help mitigate further losses, in event the problem becomes a ‘misfortune’.

If an actual ‘misapplication’ occurs, or consequences from factors like weather conditions, which are out often of your control, better results of the events and attempted mitigation to avoid inherent problems, may help result in a more positive outcome.

For tracking evidence and damages, research into adjacent areas or other local applications from use reports, making observations of surroundings and layout or topography, and sampling and history of affected plant physiological, soils, and other factors may be useful. If a claim is filed for crop loss or damage with the State, D.P.R., or local County Agricultural Commissioners’ Office, samples will be evaluated due to regulations. That may or may not work in your favor. The manufacturer of the product in question will help mitigate, take samples, or help investigate to avoid perceived product negativity, loss of the product(s) registration, or counter-suits and monetary damages. These companies have long running expertise and advisors for these situations. Note: Not everyone is aware of the time and costs necessary to research, develop, and register new products, and keeping them on the market is vital to the industry. Continued or sporadic problems with these products may result in revised registrations or research costs, re-registration, or complete removal from the market. Farm Advisors and other crop and soil experts also shine a light on problems that may not be chemical related. UC Davis and other scholastic entities have some sharp people along with other associated institutions, so reach out! Don’t be afraid to ask, …they can only say NO! There is a possibility of negative response for assistance though, as there may be affiliation issues with people not wanting to “cross” anyone or get involved.

Conclusion: All said factors and implementation, as seen before, will likely reduce need for tracking of chemical movement post application, but the presentation will include case history.

The Basics of Herbicide-Resistant Weeds

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My program at UC Davis is focused on management of weeds, especially herbicide-resistant weeds, in orchard and vineyard cropping systems. So, how does that apply to this California Weed Science Society session dedicated to managing weeds in roadsides, utilities, and industrial sites? Simple, although the details may differ slightly, the concepts of herbicide-resistance are pretty much the same regardless of whether herbicides are used in annual crops, perennial crops, or non-crop sites!

Herbicides can provide impressive levels of weed control in many crop and non-crop situations; however, not all weedy species are equally controlled due to varying levels of natural tolerance or evolution of herbicide-resistant weed biotypes. Herbicides impose a great degree of "selection pressure" on weed populations and if the same herbicide or herbicides with the same mode of action are used repeatedly, herbicide-resistant or -tolerant species can build up in the population after several generations

Herbicide tolerance and weed shifts: Weedy plants can be tolerant of herbicides due to a variety of temporal, spatial, or physiological mechanisms. For instance, a weed that emerges after a burn down herbicide is applied or completes its lifecycle before a post-emergence herbicide is applied may avoid control efforts. Similarly, large-seeded or perennial weeds can emerge from deeper in the soil and may avoid germinating in soil treated with a preemergence herbicide. Other weedy species have physiological mechanisms of tolerance and avoid control through reduced herbicide uptake or translocation, rapid detoxification, or insensitive target sites. Regardless of the mechanism of tolerance, repeated use of an herbicide can lead to "weed shifts" in which weed populations become dominated by species that are not affected by the weed control measures used.

Herbicide resistance: Herbicide resistance in weeds is an evolutionary process and is due in large part to selection with repeated use of the same herbicide or products with the same mode of action. Herbicides do not "cause" resistance; instead they select for naturally occurring resistance traits. On a population level, organisms occasionally have slight natural mutations in their genetics; some of these are lethal to the individual, some are beneficial, and some are neutral. Occasionally, one of these chance mutations affects the target site of an herbicide such that the herbicide does not affect the new biotype. Similarly, mutations can affect other plant processes in a way that reduces the plant's exposure to the herbicide due to reduced uptake or translocation or through more rapid detoxification. Whatever the cause, under continued selection pressure with the herbicide, resistant plants are not controlled and their progeny can build up in the population. Depending on the initial frequency of the resistance gene in the population, the reproductive ability of the weed, and competition, it may take several (or many) generations until the resistance problem becomes apparent.

Target-site resistance: Herbicides usually affect plants by disrupting the activity of a specific protein (enzyme) that plays a key role in plant biochemical process. Target site resistance occurs when the target enzyme becomes less sensitive or insensitive to the herbicide. The loss of sensitivity is usually associated with a mutation in the gene coding for the protein and can lead to conformational changes in the protein's structure. These physical changes can impair the ability of one or more herbicides to attach to the specific binding site on the enzyme; thus reducing or eliminating herbicidal activity. Certain herbicide groups are particularly vulnerable to developing target site resistance, because resistance can be endowed by several mutations, thus increasing the probability of finding resistant mutants in weed populations - even in those not previously exposed to that herbicide group. For example, specific mutations resulting in seven different amino acid substitutions in the acetolactate synthase (ALS) gene are known to confer resistance to ALS-inhibiting herbicides in weed biotypes selected under field conditions. Something similar occurs with the grass herbicides that inhibit the enzyme acetyl coenzyme A carboxylase (ACCase) for which at least five point mutations causing amino acid substitutions within the gene are associated with cross-resistance patterns observed at the whole plant level involving four classes of ACCase inhibiting herbicides. The existence of so many mutations conferring resistance is reason resistance to these herbicides is frequently found and can evolve rapidly. Resistance to glyphosate can also be target-site mediated in some cases.

Non-target-site resistance: Several mechanisms confer resistance to herbicides without involving the active site of the herbicide in the plant. Of these, the best known is the case of metabolic resistance due to an enhanced ability to metabolically degrade the herbicide. Non-target-site resistance can evolve from the intensive use of diverse and unrelated selective herbicides that are similarly effective on a certain weed species and share a detoxification pathway or a mechanism precluding their accumulation at the target site (exclusion or sequestration) that is relatively common in plants. The management of non-target-site herbicide resistance often represents a greater challenge than target-site resistance because a simple change in herbicide mode of action may not alleviate the problem. Reduced herbicide absorption and/or translocation can contribute to resistance in certain biotypes. These have generally been accessory mechanisms that contribute towards resistance in addition to a major resistance mechanisms. However, recent evidence suggests that changes in absorption and/or translocation are an important contributor to glyphosate resistance in several weed biotypes.

Current status of herbicide-resistance in weeds: Herbicide resistant weeds are an issue around the world; but the greatest problems with resistance tend to be found in countries with highly industrialized agricultural cropping systems due to greater reliance on herbicides. Herbicide resistant weed biotypes have been reported in at least 60 countries and include about 396 unique species-herbicide group combinations worldwide. Herbicide resistant weeds around the world and throughout the U.S are dominated by the photosystem II inhibitors and by ALS inhibitors due to the widespread use of these diverse herbicide classes in broad acreage cereal and grain crops. Some of the most troubling herbicide resistant biotypes are multiple resistant biotypes – one population of rigid ryegrass in Australia is reported to be resistant to 9 different modes of action!

Management of herbicide-resistant weeds: A number of factors affect the degree of selection pressure for herbicide resistant weeds. However, if preventive measures are taken to reduce selection pressure, herbicide resistance can be avoided or delayed. As outlined previously, repeated use of the same herbicide or herbicides with the same mode of action can select for weeds that are resistant or tolerant to that mode of action. As an herbicide controls the susceptible biotypes, with repeated use of the same herbicide, the resistant biotype gradually builds up in the population. Therefore, a major goal of herbicide resistance management is to reduce selection pressure. In this context, herbicide rotation and tank mixes become important resistance management tools and often are used as the first line of defense against the selection of herbicide-resistant weeds.

Non-crop areas such as roadsides, canal banks, and industrial sites have few crop rotational alternatives. Therefore, in these systems, rotation or tank mixes of herbicides with different modes of action should be a part of the management plan to prevent the buildup of weeds that are resistant to that particular mode of action. When herbicides with different modes of action are used in rotation or mixtures, the selection pressure for any one herbicide is reduced. Thus, the weeds will have difficulty adapting to this continuous alteration in selection pressure.

Studies have found that the selection pressure on susceptible weeds from herbicides with longer residual activities is higher than that from herbicides with shorter or no residual activities because one treatment can result in exposure of multiple weed cohorts (ie. flushes) to the herbicide. However, when herbicides with no residual activity are used multiple times in a season, selection pressure is equally high and can lead to selection for herbicide-resistant weeds as has been observed with glyphosate-only weed control programs. In fact, short-term residual herbicides in combination with post-emergence herbicides are being recommended for management of glyphosate-resistant weeds in many cropping systems.

Herbicide resistant weed conclusions: Resistance mitigation seeks to diversify weed control methods in order to delay the evolution process by reducing the selection pressure exerted through the use of herbicides. Target-site resistance is conferred by an alteration causing loss of plant sensitivity to herbicides with a specific mechanism of action. It is, therefore, clear that one way of dealing with the problem is by switching to another herbicide effective on the same weed species, but having a different mechanism of action. The use of herbicide mixtures or sequences involving herbicides with different mechanisms of action can protect the herbicides and delay the evolution of resistance to both, since mutants with resistance to one herbicide would be controlled by the other herbicide and vice-versa. However, the recurrent use of the same herbicide mixture could theoretically select for biotypes with resistance to both herbicides (multiple resistance).

Non-target-site resistance may involve different herbicides and the enhanced expression of mechanisms that are common in plants and thus easily selected for. If several herbicides share a common degradation route, such as the ubiquitous P450 monoxidation, their use will select for the same mechanism of resistance in biotypes that will be resistance to all even if these herbicides are used in mixtures or sequences with each other. Thus, combining or changing herbicides to control non-target-site-resistant biotypes becomes very difficult. Non-target-site resistance may involve the accumulation of genes contributing partial resistance levels.

From this discussion of resistance mechanisms in herbicide resistant weeds, it should be clear that resistance cannot be mitigated only by switching or combining herbicides in production systems that rely solely on the intensive use of selective herbicides for weed control. Instead, herbicide resistance management requires the integrated diversification of chemical and non-chemical weed control methods to reduce selection pressure for resistant weed biotypes. Herbicides are one of the most effective tools for weed management; however, they must be used judiciously. They should be 'one of the many tools' in a weed management toolbox rather than the only tool, else we are at risk of losing effective herbicides due to the evolution of herbicide-resistant weeds.

For more resistance info: http://www.ipm.ucdavis.edu/IPMPROJECT/glyphosateresistance.html or the UCWeedScience blog at http://ucanr.edu/blogs/UCDWeedScience/index.cfm

Biotic or Abiotic Damage: Herbicide or Something Else

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Herbicide drift occurs when applications are made during suboptimal environmental conditions – generally this means too much wind. When herbicide injury does occur, diagnosis is often difficult since injury symptoms vary considerably in appearance for different herbicides, plant species, amount of drifted material, and application timing. Insects, disease, nematodes, nutrient stress, excess heat or cold, and chemicals other than herbicides can also cause symptoms that appear similar to those caused by herbicides. All too often when injury symptoms are observed, the first question is "What herbicide caused this?" Careful observation can often distinguish the cause of the symptoms and determine if herbicides are at fault. The purpose of this presentation is to describe symptoms of common herbicide and to show how other stresses can look similar. General symptoms of herbicide injury are given and may be of help in eliminating certain herbicides as the probable cause of injury.

ACCase inhibitors

Compounds in this group include fluazifop (Fusilade), fenoxaprop (Whip, Puma), diclofop (Hoelon), cyhalofop (Clincher), sethoxydim (Poast), and clethodim (Select, Prism). Symptoms are generally only observed on grasses since most broadleaf plants are tolerant. Injury has been observed on flowers (reduced petal size and spotting of petals) of broadleaf ornamentals. Cyhalofop has also been observed to spot peach leaves and fruit. The spotting can result in dead spots that form holes in the leaves (somewhat similar to shothole disease). Leaf spotting has also occurred on some azaleas and tip burn on Bar Harbor juniper with fluazifop. Symptoms are temporary and regrowth is normal.

In grasses, the first effect is a cessation of top growth, followed by yellowing (without pattern) in young leaves within 7-10 days. Later the older leaves become yellowish and may show some purple. Internodes just above the node (meristemmatic area) turn necrotic brown and appear to "rot". The young shoot can easily be separated from the remainder of the lower shoot.

ALS inhibitors

The herbicides in this class are used at very low rates and are extremely active in broadleaf plants. The principal ALS herbicides used in California are chlorsulfuron (Glean, Telar), sulfometuron (Oust), bensulfuron (Londax), nicosulfuron (Accent), halosulfuron (Sandea), Mesosulfuron-methyl (Osprey), rimsulfuron (Matrix), imazapyr (Arsenal), imazethapyr (Pursuit), imazamox (Raptor), pyrithiobac (Staple) and bispyribac-sodium (Regiment) and imazamethabenz (Assert). Foliar and root uptake can occur with these herbicides.

Symptoms are generally observed in new foliage. Growth generally slows and chlorosis and necrosis of the meristematic region occurs. In new growth, internode length is shortened and small chlorotic leaves appear in small, sometimes distorted whorls. Purplish pigmentation also sometimes is observed in mature foliage. In new growth, symptoms may appear somewhat similar to glyphosate. When drift occurs on the mature leaves of trees, symptoms may appear the following spring, with new growth having shortened internodes.

Soil residual varies considerably between materials, with some lasting a year or more.

Photosynthetic Inhibitors

This broad group of chemicals blocks photosynthesis and includes materials applied primarily preemergence. However, some materials (metribuzin, linuron, diuron, propanil) have some postemergence activity when used with surfactants or oils. Herbicides in this group include metribuzin (Sencor), prometryn (Caparal), simazine (Caliber 90, etc), hexazinone (Velpar), diuron (Karmex), linuron (Lorox), propanil (Stam, etc.), tebuthiuron (Spike) and bromacil (Hyvar).

In perennial crops such as almonds, apples, walnuts, peaches, grapes, many woody ornamentals, etc., symptoms from low rates of the photosynthetic inhibitors start as a yellowing around the leaf margins on mature leaves. Young leaves do not show symptoms. As time elapses, interveinal areas of leaves also turn yellow. Progressive injury includes marginal leaf necrosis with more interveinal yellowing. Iron chlorosis also causes these symptoms. Symptoms are rate dependent with higher rates giving greater and more rapid symptoms. Perennial plants retain the leaves with symptoms until normal senescence. Excessive rates can be observed to reach new foliage before symptoms of chlorosis occurs in mature leaves. These symptoms appear as a rapid progression of chlorosis followed by necrosis, similar to drought. Another pesticide (metalaxyl – a fungicide) will also give similar symptoms.

Prometryn, Karmex, Hyvar, or Lorox drift results in the reverse of these symptoms. Veins become chlorotic with the intervein remaining green. .

Bromacil is used as preemergence, soil applied material. Since this herbicide is relatively soluble in water (815 ppm), there is a tendency to leach into the root zone of perennial plants. Annual horticultural plants do not tolerate bromacil. The more tolerant plants (citrus, apples, peaches, almonds) show symptoms on mature leaves as a striking veinal yellowing, and less commonly, the leaves will also have blotchy chlorosis. Sensitive trees such as walnuts or figs develop necrotic leaves. This necrosis frequently appears rapidly, with no veinal chlorosis. These leaves normally fall and new leaves are formed. Depending on rate of the material present in the soil these new leaves may be smaller and chlorotic at low rates or they may also drop if high rates are still present. If trees are healthy, they can drop a set of leaves and develop new leaves at least two times in a season. If the trees are not healthy, they may be killed by high rates of these herbicides.

If soil applied (drift or direct application) prior to seeding or seedling emergence, seedlings may germinate and appear to grow normally for a number of days (7-10) before the leaves turn chlorotic and necrotic and the seedlings collapse. In transplants, root uptake occurs until mature leaves show yellowing with some leaves showing a partial leaf chlorosis (blotchy appearance). Depending upon rate and susceptibility of the plant injury can range from crop death to mild chlorosis.

PPO Inhibitors

PPO inhibitors includes oxyfluorfen (Goal, GoalTender), carfentrazone (Shark, Aim), sulfentrazone (Zeus), oxadiazon (Ronstar), and flumioxazin (Chateau). Although these herbicides are used primarily as preemergence herbicides (except for Shark), they all can have some postemergence activity on exposed leaf tissue. Oxyfluorfen symptoms frequently appear on young leaves, apparently due to low wax content in the leaf cuticle. Oxyfluorfen causes tip dieback on new growth in conifer species, while older foliage is not generally affected, except at excessive rates. On a sensitive plant like petunia, silvery spotting and a glazing appearance occurs, somewhat like smog damage. When applied preemergence to crucifer crops such as broccoli the tips of the cotyledon leaves are frequently cupped, as if the leaves are burned, as they push through the treated soil, leaving the cotyledons distorted. Girdling of the shoots of annual plants, principally broadleaves, is common and appears almost as if there is insect feeding at the soil surface. This symptom is sometimes observed on seedlings after rainfall or irrigation moves treated soil in contact with stem tissue.

Chateau can cause foliar symptoms that often appear to look similar to oxyfluorfen or paraquat symptoms. Ronstar or Zeus can cause desiccation and necrosis if they contact foliar parts of the plant. Susceptible plants emerging from the soil turn necrotic and die after exposure to sunlight. Shark drift, at low concentrations, results in necrotic spots on leaves, with the spots dropping out of the leaf. Fruit of plums will show brown spots and gumming from the spots. If sprayed so coverage is uniform it acts as a contact burn on leaves. Shot hole disease looks similar, but does not affect the fruit.

Paraquat, considered a Photosystem I inhibitor, can cause foliar symptoms similar in appearance to the PPO inhibitors. Injury symptoms from paparquat is usually the result of drift, since it is a contact herbicide, and would not be intentionally applied to a desirable plant. Depending upon concentration, chlorotic or necrotic spots may appear on young or mature foliage. These spots normally don't "fall out" of tree foliage thus it should not be confused with "shot hole" disease. Symptoms progress more rapidly on bright, sunny days. Necrotic spots caused by hail or sand blasting may sometimes be confused with the symptoms seen following PPO Inhibitor or paraquat drift.

Auxinic Acids

Phenoxys include 2,4-D, 2,4-DB (Butyrac), MCPA, and mecoprop (MCPP). Dicamba (Banvel, Clarity) is the only benzoic acid in this group. The carboxylic acids currently in use include picloram (Tordon), triclopyr (Turflon, Garlon, Grandstand), and clopyralid (Stinger, Transline). These compounds can be grouped together because of similar symptoms. Though each may have a characteristic symptom on an individual plant and have a greatly different rate response, symptoms generally cannot be differentiated unless directly compared.

With phenoxys, symptoms appear in new growth of broadleaf plants (annual or perennial). The time interval can be 3-10 days after application before symptoms appear. Interval is generally temperature dependent with a faster response at increasing temperature. Leaves lose their planar angle, the petioles twist and there is general disorientation of growth in new foliage. Old leaves and stems in woody plants such as peaches, grapes, etc., do not appear affected. Leaves of broadleaf plants take on various changes in development patterns. Using grapes as an example, leaves become abbreviated at the tips where there are major veins. This may become so extreme as to cause "fan-shape" or "strap" leaves. Veins become very prominent with the reduction or absence of the interveinal area. High rates kill the young tissue causing necrosis. Stems of immature woody plants may develop splits or "corky" zones.

In grape, symptoms of 2,4-D have often been confused with fan-leaf virus. In diagnosis there should be a different field pattern from 2,4-D drift or accidental application as compared to the sporadic occurrence of diseased plants.

Annual broadleaf plants exhibit similar leaf symptoms as perennials; leaf petioles and stems twist severely. In carrots, root growth appears as irregular thickening giving a "warty" appearance or in some cases splitting occurs because of the irregular growth. Splitting alone is not a characteristic symptom of phenoxy damage, because it can be caused by lack of proper water management. San Jose scale can also cause bark to split, which looks similar to phenoxy damage. Leaf bases are enlarged with a reduction of length of new leaves and some twisting of the leaves can be observed following drift from this group of herbicides.

ESPS Inhibitor (Glyphosate)

Symptoms from glyphosate are variable, depending on timing and method of exposure. Exposure must take place through leaves or young, thin or green bark. Soil exposure is minimal to nil if the soil has been tilled before planting or there is soil over roots. In perennial crops, symptoms from a spring to summer exposure (new to maturing growth) have varied from chlorosis with no specific pattern in new growth when sprayed on older leaves to interveinal chlorosis. Overall leaf chlorosis can occur and new growth following exposure to older foliage is commonly distorted, puckered, and glossy small leaves.

Exposure to mature foliage in the fall may not result in symptoms until the following spring when new growth initiates. Trees with glyphosate exposure can have delayed leaf emergence, reduced leaf size, loss of apical dominance and shortened internodes. Depending upon exposure it may appear on one branch or cane or the total plant may show the effect. As growth occurs, depending upon date and amount of exposure, new growth may be normal and even mask the early symptoms. High rates of exposure, however, cause symptoms to persist during much of the season. These symptoms may appear in new foliage each spring for 2 to 3 years without additional exposure. Unless exposure is very high on mature foliage normally a tree or vine survives. This also depends upon the original health of the plant. In grapes it does not appear to reduce fruiting greatly, even though foliage symptoms may be severe. In pines and firs, the new candles or growth tips become necrotic and die forcing secondary whorls.

After exposure to high glyphosate rates, annual plants leaves turn light green and chlorotic about 7 to 14 days after application, depending upon temperature and sunlight, and then the plant collapses. Plants may survive low rates of glyphosate, showing chlorosis in new growth, and possibly some stunting of subsequent growth. Young tomato leaves can show interveinal chlorosis, whereas the mature leaves may not show symptoms. Some glyphosate symptoms (chlorosis of young growth and shortened internodes) could resemble the sulfonylurea or imidazolinone herbicides.

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Use of Less-Toxic Herbicides and Sheet Mulching in Landscapes

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Abstract:

Sheet Mulching and the use of less-toxic herbicides reduce the need for stronger herbicides on commercial landscapes. The way landscapes are commonly designed, built, and maintained favors the growth of weeds. Compaction, the removal of organic matter, excessive turf areas, and salty fertilizers all create an environment that stresses plants and requires many pesticides to maintain. These pesticides, including herbicides, cause collateral damage and help create conditions that require repeat applications. This cycle should be broken by reducing turf areas, building soil through the addition of organic matter, and using less-toxic herbicides. Sheet mulching smothers existing weeds, inhibits new weed growth, helps build soils, and composts existing turf in place. Less-toxic herbicides are continually improving and landscape managers must stay abreast of new and improved products and methods to maximize efficiency. Transitioning turf areas through sheet mulching and the strategic use of less toxic herbicides can help improve return on investment while reducing pollution, improving ecological stability, and naturally inhibiting weed growth.

Commercial landscapes in California are at a huge disadvantage when it comes to weeds. If one were to design and maintain the perfect environment to promote weed growth, it would look much like your typical commercial landscape. Organisms seek out and prefer certain niches in which to establish themselves. The perfect niche habitat for weed growth is one that mimics early trophic level disturbed soils, soils that have had their structure destroyed through compaction or inundation, or those that have had their supporting organisms wiped out by toxins. Weeds are nature's "first responders". They have evolved to be able to quickly establish themselves in disturbed or "injured" habitat situations, heal the soil, and provide an organic cover layer. They quickly establish themselves to inhibit erosion and build up organic matter that provides food for fungal organisms, thus reducing the pH of the soil. This prepares the way for woody perennials to move in and bump the ecology of the niche habitat into the next successional trophic level. Different weeds serve different roles in the process. Leguminous weeds fix nitrogen and deep tap-rooted weeds help to break up compacted soils and bring up mineral nutrients from lower soil horizons. Other weeds are adept at sequestering and/or breaking down toxins. Weeds have a purpose in the landscape ecology.

Weeds put all their efforts into fast, efficient growth and seed production. When they have done their work, and the niche habitat has been "healed", the weed population naturally declines as a healthy, diverse "O" soil horizon is established and woody perennials take over. In doing their important work, weeds actually go against what one would think best in terms of natural selection: they create and promote an environment that decidedly favors against their well-being. If they have done their job well, their seeds may not even be able to germinate in the environment they have created. One has to take a much greater holistic viewpoint to see the genius in their work, and see how their work fits into the scheme of ecological succession. Their purpose is to fix, repair, and heal land that has been abused and then move on to the next crisis, their seeds being able to travel far and wide and/or to remain dormant for long periods of time until their services are needed again.

The abuse of land reaches an apogee in commercial landscapes. To paint a picture of the archetypical situation, we start at the beginning: Whether it is a new development for a sub-division, a shopping center, an office complex, a new HOA, or an apartment complex, the same procedure usually ensues:

First, the land is surveyed and any vegetation or topsoil is removed. More and more, this topsoil is saved for future use, but many times, and certainly historically, it is simply pushed aside or used as non-structural fill. Secondly, the sub soil is compacted, sometimes limed, and "engineered" soils are generated that are fantastic for roads, foundations, and light pole footings.

Thirdly, after the built structures are in place, the landscape installation is awarded to the low bidding landscape contractor. The low-bidding contractor, having likely underbid the project, moves forward using the least amount of effort to decompact the landscape areas, if at all, depending on the specifications. The least amount of top soil is then put in to achieve the target grade. Minimum-sized holes are then dug for the proposed plant material, a thin layer of topsoil is laid under proposed sod areas, and the minimum amount of mulch is applied, and only if specified. To maintain appearance through the establishment period, chemicals such as Oxadiazon (Ronstar) and Oryzalin (Surflan) or perhaps Pendimethalin (Pendulum) are applied.
–Or maybe a mix of Trifluralin (Treflan for grasses) and Isoxaben (Gallery for broadleafs) is used, such as the mixture in Snapshot. Then surviving weeds are hit with Glyphosate and maybe Diquat as in the concoction in QuickPro.

To make matters worse, the plants generally proposed are those that evolved in woodland environments or bred in European gardens. They are better adapted to different soils and climates. The other problem is that many of them will get much larger than the spaces allotted to them on the plans due to the desire to have a quick mature appearance to entice would be tenants into the new development.

Enter the landscape maintenance contractor. After the establishment period, the maintenance contractor adds insult to injury by flooding the phylosphere of the roots of the plants with a toxic mix of salty urea-based fertilizers blended with chelated minerals to make up for the deficiencies shown in the plant material's leaves, usually iron due to the high pH. The plants respond like they're on plant growth drugs and put on fast succulent growth that is immediately attacked by fungal pathogens, mollusks, and insects. The experienced maintenance contractor, however, is already a step ahead of the game and has injected the trees and sprayed the shrubs with Imidicloprid (Merit) and applied the fungicide Mefonoxam (Subdue) to the color beds. The planting areas have been spread with Metaldahyde and any mammalian pests have gotten a dose of Strychnine or several of Diphacinone. The Landscape now looks "Clean & Green", a masterpiece of sterility and order.

Over time, along with a good deal of fossil fuel use and noise pollution, the maintenance contractor then endeavors to blow, rake, vacuum, and remove any and all organic matter from the site. New mulch, since it's not in the maintenance specs and can be expensive to spread, or might be seen as messy or collecting debris, is often not used, or if it is, only "colored bark" is applied at the minimum amounts necessary to cover the ground. Those plants that are outgrowing their allotted space are routinely hedged into neat little boxes and/or spheres, and many times coated with a PGR, or Plant Growth Regular. It might have an exciting name like Methylchlorohydroxyfluorene. These practices can go on for YEARS.

When the plants eventually (or quickly) give in and decline and weeds amazingly get through the onslaught of chemical herbicides, a new, low bidding landscape contractor is selected to "fix the problem" (… something the weeds could have done if allowed the chance and a decade or so). The "revolving doors" of landscape service providers then begins. Any let down in herbicide defenses invites an onslaught of weeds desperate to heal the habitat niches that are so wildly out of balance.

On a side note, but one that is pertinent to this topic is the overuse of turf in commercial landscapes. Here we have a monoculture of a plant that necessitates roughly 75% more water to be happy than the area in which it is grown generally receives. To maintain this water hungry monoculture, we provide roughly 5% of our air pollution by constant mowing, edging, and blowing. The EPA estimates that roughly 18 MILLION gallons of fuel are SPILLED each year in the process of keeping these monocultures of climate inappropriate plants looking "Clean & Green". The "Clean" part of commercial turf involves more than mowing and edging. Weeds are constantly trying to fix the problem presented by the unnatural monoculture. 2,4-D, Dicamba, and Mecoprop are the chemicals of choice to keep these ecowarriors at bay. While very little of these turf areas is used for actual recreation, many commercial landscapes contain many acres of turf for purely ornamental reasons. It is such an obvious target for water conservation that the state of California is actively promoting the removal of turf through incentive programs identified in the WELO or the Water Efficient Landscape Ordinance (AB1881), and many "cash for grass" conservation programs throughout the State.

When you add up the initial soil destruction, the inappropriate plant selection, the systematic removal of organic matter, the compaction, the regular application of salt based fertilizers, and the unintended collateral damage caused by a mix of chemical herbicides, fungicides, insecticides, and even mammalian toxins used on these commercial landscape sites, there is little wonder why nature has sent in the early responders, the weeds, to fix the problem. That's their job! These soils need help and we keep killing the organisms that are there to take care of it. Unfortunately, the process of natural pedogenesis, that of building soil structure, takes time and our culture has developed an aversion to seeing weeds doing their job.

While it is easy to show a Return on Investment in water savings to promote the transition of wasteful turf monocultures to more climate-appropriate plants on efficient in-line drip systems controlled by ET/Weather-based controllers, the process needed a sustainable procedure that would help the soil and new plants. It had to be quick, efficient, and not involve the use of weeds. Sheet mulching is the answer. Many people have used sheet mulching for permaculture projects and home garden areas, and it has been around as a "fringe" landscape tool for generations but the last five years or so have seen a huge increase in the number of large, commercial-scale sheet mulching projects that have been very successful. It is now taught in UC approved Master Gardener Classes, Bay- and River-Friendly Landscaper Qualification courses, and promoted by many preeminent professional landscapers.

Sheet Mulching is a process that can be used to not only transition turf areas, but also ivy and other monoculture perennial beds such as Hypericum. It is also effective to control weeds in other areas. The beauty of the process is that it minimizes the use of chemical herbicides, completes the cycle of the use of post consumer waste paper products, keeps old sod out of the land fills, and composts the old turf in place. With a little grading around hardscape elements, layers of compost, recycled cardboard, and organic wood chip mulch feeds the soil, inoculates it with microorganisms, smoothers the weeds, and provides a chemical-free, biologically diverse environment to promote water conservation, nutrient cycling, and healthy plant growth. It also inhibits weeds because it does the same work as weeds: It quickly covers the area to mitigate erosion, it builds up the organic content of soils, thus promoting fungal populations, the creation of humus, humic and fulvic acids, and thus lowering the soil pH and making nitrogen available as ammonium. It also establishes a healthy, diverse "O" soil horizon.

There are many different ways to Sheet Mulch. Depending on the existing weeds (which could be turf!) that involve a number of variations on the "lasagna" approach to layering compost, cardboard, and mulch. Blackberry, Poison Oak, and even Eucalyptus can be sheet mulched with enough layers of cardboard and a deep enough layer of organic wood chips. Bindweed, Yellow NutSedge, and Bermuda can all be successfully composted in place using this technique –without the use of herbicides, and while building healthy, biologically diverse soils and promoting the healthy growth of perennial woody plants.

The ones that get away, the weeds that still try to do their work on the dirt, can be addressed with less-toxic herbicides. These are natural oils and acids. Over the last decade, many products have tried to fill the niche market for those who want to avoid the common synthetic herbicides such as 2,4-D, or make a stand against Monsanto and their plans to dominate the food production of the planet. The landscape market is based on customer needs and desires. More and more the landscape maintenance contractor is hearing the customer plead "Please don't use pesticides on my landscape anymore." -and many of them are prepared to pay the difference. Municipalities, school districts, parks and rec; they are all getting pressure to reduce or eliminate the use of pesticides. In Canada, where 2,4-D is now not allowed, for example, a strong market has been created for alternative, selective broadleaf weed control.

While some less-toxic herbicide products have done all right, and some have required surfactants to get the job done, several are proving very efficacious. The methods to improve their efficacy are being developed and the landscape maintenance professional who is catering to the desires of the new eco-literate customer are formulating best management practices to implement true IPM that first goes to the cause of the weeds, but also uses multiple control strategies to hit the weeds with a strategic approach using the least toxic controls in effective and cost effective programs. This is a moving target. New products and new methods are being developed while the customers push for cost effectiveness.

There are no organic trans located herbicides. Corn gluten does not work very well on the West coast. No OMRI listed material will kill Bermuda in fescue. There are certainly limits as to what these burn-down products can offer. They are, however, the leading edge in landscape weed management for the customer who increasingly, care. While an intelligent discussion about the aesthetic threshold level can be good for the site manager-landscape service provider relationship, the bottom line is that as our potable water and oil-based fertilizers and maintenance practices get more expensive and huge expanses of turf are looked at more as wasteful instead of bucolic, the trend towards a sustainable, ecologically responsible way to transition them to more climate-appropriate plants on drip with mulch will intensify. The use of less-toxic herbicides as an adjunct to the process as well as to address weeds in recreational turf and shrub beds will continue to be a growing profit center for those landscape service providers who are prepared to meet the challenge.

Chemical Strategies for Overseeding Success

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Overseeding is common practice on desert golf courses for winter color and playability. Yet, many superintendents are faced with transitioning from warm- to cool-season turf at a time of the year that is not favorable to either species. Traditionally, irrigation was withheld and aggressive cultivation practices such as flail mowing and verticutting were employed to slow down bermudagrass growth and encourage cool-season turf establishment. However, these practices can be deleterious and even prohibitive in terms of air quality standards, green waste transportation and management, and spring transition of bermudagrass. A growing trend on golf courses in the Coachella Valley is toward chemical suppression of bermudagrass during overseeding. Triclopyr is commonly used to suppress bermudagrass regrowth "on the other end" of overseeding or during establishment of cool-season turf. Prior to overseeding, a non-selective contact or burn down herbicide could offer several benefits including:

1. Suppression of bermudagrass competition
2. Reduction of green waste
3. Reduction of labor and transportation costs
4. Improvement of air quality
5. No adverse effects on germination/establishment of overseeded species
6. No adverse effects on spring transition of bermudagrass

The objectives of this research were to compare Scythe (pelargonic acid), Reward (diquat), and Finale (glufosinate) alone and in various combinations for bermudagrass suppression [with or without prior application of Turflon Ester Ultra (triclopyr)], green waste reduction, and spring transition vs. flail mowing as a standard control.

Study One: How long do burn down herbicides suppress bermudagrass and how does prior application of triclopyr affect suppression in combination with these herbicides?

Location:	18 North Fairway, Toscana Country Club, Indian Wells, CA
Species:	Tifway II hybrid bermudagrass
Mowing Height:	0.425 inches
Application Dates:	Burn down herbicides (14 Sep 2011)
	Turflon Ester Ultra (16 oz/A 5 days prior to burn down herbicides)
Spray Information:	50 GPA
	Burn down herbicides applied with single, even flat fan 8003 nozzle
Design:	Randomized complete block; 3 replications
	Study was conducted on two areas of turf, one that was pre-treated with Turflon Ester Ultra and the other received no Turflon Ester Ultra

Results:

- ✓ With the exception of Finale, all other burn down herbicides were more effective in suppressing bermudagrass when the turf was pre-treated with Turflon Ester Ultra (Table 1).
- ✓ Scythe>Reward>>Finale for speed of activity.
- ✓ Finale>Reward>>Scythe for longevity of bermudagrass suppression.
- ✓ These results demonstrated that overseeding preparation (scalping and seeding) should take place within 1-2, 2-5, and 5-12 days of application of Scythe, Reward, and Finale, respectively.
- ✓ The study area was not overseeded until 29 Oct 2011 and, during that time, bermudagrass appeared to recover equally well among all treatments.

Study Two: How do burn down herbicides affect green waste, ryegrass germination, and bermudagrass spring transition?

Location:	18 North Fairway, Toscana Country Club
Species:	Tifway II hybrid bermudagrass
Application Dates:	Burn down herbicides (11 Oct 2011)
	Turflon Ester Ultra (16 oz/A 5 days prior to above date)
Mowing Height:	0.425 inches
	0.250 inches (scalping) and/or flail mowing on 13 Oct 2011
Spray Information:	50 GPA
	CO_2-powered sprayer with flat fan 8003 nozzles
Design:	Randomized complete block; 4 replications
Plot Size:	7 ft x 15 ft; 5-ft alleys
Overseeding:	Perennial Ryegrass, 800 lbs/A, 29 Oct 2011

Results:

- ✓ All treatments resulted in significantly less green waste production compared to the flail and scalping control. Consequently, the data were reported as a percent reduction compared to that treatment (Table 2).
- ✓ Although few significant differences in green waste were found among the scalping and chemical treatments, both rates of Reward reduced green waste the most (74% and 76% reduction).
- ✓ After flail mowing and/or scalping and 48 hours after chemical application, Reward or treatments containing Reward provided the best bermudagrass suppression as evidenced by the percentage of brown bermudagrass turf.
- ✓ Overall, the results of these studies suggest that Reward (diquat) is the best burn down herbicide for use on fairways prior to overseeding based on cost, speed of activity, green waste reduction, and bermudagrass suppression. To ensure maximum safety to all

turfgrass species, application of Reward is recommended at 32 oz/A between 2-5 days before scalping and overseeding and not withholding irrigation prior to overseeding.

- ✓ Scythe (pelargonic acid) is tried and true for overseeding preparation on putting greens where cost is less of a factor due to area. Furthermore, it has already been used with success on fairways in the Coachella Valley. Other advantages include its speed of activity, thus shortening the window between times of application and overseeding preparation. However, our results suggest that the other burn down herbicides are more cost effective and equally or more effective in function on fairways and other large areas of turf.
- ✓ Finale (glufosinate) is the least studied burn down herbicide for this application. However, Finale appears to offer the greatest potential for bermudagrass suppression even without pre-treatment with Triclopyr. In the second experiment, Finale was at a disadvantage since it requires a longer period of time than 48 hours to suppress bermudagrass. However, again it provides the longest suppression. And, like Reward, it is very cost effective. The recommended application rate for this function is 32 oz/A.

Study Three: How does application timing of burn down herbicides affect green ryegrass germination and bermudagrass spring transition?

Location:	18 North Fairway, Toscana Country Club
Species:	Tifway II hybrid bermudagrass
Application Dates:	Burn down herbicides (7, 5, and 2 days before overseeding) Turflon Ester Ultra (16 oz/A 5 days prior to application of burn down herbicides)
Mowing Height:	0.425 inches 0.250 inches (scalping) on 17 Oct 2012
Spray Information:	50 GPA CO_2-powered sprayer with flat fan 8003 nozzles
Design:	Randomized complete split block; main plots = burn down herbicide treatments; sub-plots = Turflon Ester Ultra; 4 replications
Plot Size:	7 ft x 14 ft; 4-ft alleys
Overseeding:	Perennial Ryegrass, 800 lbs/A, 18 Oct 2012

Results:

- ✓ There were no adverse effects of Scythe (7% v/v), Reward (32 oz/A), or Finale (32 oz/A) applied 7, 5, or 2 days before overseeding on establishment of perennial ryegrass (data not shown). Herbicide effects on spring transition of bermudagrass will be evaluated in spring 2013.

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Table 1. Percentage of brown bermudagrass turf 5 and 12 days after treatment with burn down herbicides, and with or with pre-treatment of Turflon Ester Ultra at 16 oz/A. Indian Wells, CA.

				5 DAT		12 DAT	
No.	Treatment	Rate	Cost/Acre[1]	Brown Turf (%) + Turflon	Brown Turf (%) - Turflon	Brown Turf (%) + Turflon	Brown Turf (%) - Turflon
1 1	Scythe MSO	5% v/v 1% v/v	$120	72 cde	25 f	48 cdefg	17 gh
2 2	Scythe MSO	5% v/v 0.5% v/v	$115	85 abcd	38 f	65 abcde	34 efgh
3	Scythe	7% v/v	$154	88 abc	60 e	68 abcde	36 efgh
4 4	Scythe MSO	7% v/v 0.5% v/v	$159	90 abc	78 bcde	71 abcde	65 abcde
5 5	Reward NIS	16 oz/A 0.5% v/v	$15	94 ab	65 de	78 abcd	17 fgh
6 6	Reward NIS	32 oz/A 0.5% v/v	$25	96 ab	89 abc	88 ab	44 defgh
7 7	Reward NIS	64 oz/A 0.5% v/v	$45	98 ab	88 abc	91 ab	55 bcdef
8	Finale	16 oz/A	$10	80 abcde	63 e	70 abcde	72 abcde
9	Finale	32 oz/A	$20	98 ab	96 ab	90 ab	93 ab
10	Finale	64 oz/A	$40	99 a	99 a	98 a	97 a
11 11 11	Scythe Reward NIS	5%v/v 16 oz/A 0.5% v/v	$125	97 ab	65 de	84 abc	13 gh
12 12 12	Scythe Finale MSO	5% v/v 16 oz/A 0.5% v/v	$125	96 ab	90 abc	88 ab	65 abcde
13 13 13	Reward Finale NIS	16 oz/A 16 oz/A 0.5% v/v	$25	98 ab	86 abc	92 ab	64 abcde
14 14 14 14	Scythe Reward Finale NIS	3% v/v 8 oz/A 8 oz/A 0.5% v/v	$82	96 ab	62 e	87 ab	8 h

Means followed by the same letter in a column are not significantly different ($\propto = 0.05$).
[1]Cost/acre of all ingredients is approximate and meant for comparison purposes only.
DAT = days after treatment. MSO = methylated seed oil. NIS = non-ionic surfactant.

Table 2. Percentage of bermudagrass green waste reduction and brown turf following flail or reel mowing on 13 Oct 2011. Herbicide treatments were applied 48 hours earlier. Indian Wells, CA.

No.	Treatment	Rate	Cost/Acre[1]	Green Waste Reduction (%)[2]	Brown Turf (%)
1	Untreated Flail + Reel	--	--	0 a	85 ab
2	Untreated Reel	--	--	62 bc	41 d
3 3 3	Scythe MSO APSA 80	5% v/v 0.5% v/v 0.5% v/v	$130	64 bc	71 bc
4 4 4	Scythe MSO APSA 80	7% v/v 0.5% v/v 0.5% v/v	$167	67 bc	86 ab
5 5 5	Scythe Reward MSO	5% v/v 10 oz/A 0.5% v/v	$121	68 bc	94 ab
6 6	Reward NIS	32 oz/A 0.5% v/v	$25	74 c	99 a
7 7	Reward NIS	64 oz/A 0.5% v/v	$45	76 c	99 a
8	Finale	32 oz/A	$20	60 bc	35 de
9	Finale	64 oz/A	$40	66 bc	41 d
10 10 10	Scythe Finale MSO	5% v/v 16 oz/A 0.5% v/v	$125	67 bc	78 ab
11 11 11	Reward Finale NIS	16 oz/A 16 oz/A 0.5% v/v	$25	69 bc	87 ab
12	Flucarbazone	0.6 oz/A	--	54 b	14 e
13	Flucarbazone	1.2 oz/A	--	67 bc	40 d
14	Flucarbazone	2.4 oz/A	--	70 bc	46 cd

Means followed by the same letter in a column are not significantly different ($\propto = 0.05$).

[1]Cost/acre of all ingredients is approximate and meant for comparison purposes only.

[2]Green waste reduction values were calculated as a percentage of clippings harvested from the untreated flail and reel mowing treatment.

MSO = methylated seed oil. NIS = non-ionic surfactant.

Roundup Ready Technology Overview

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Glyphosate was first discovered to have herbicidal activity in 1970 by John E. Franz, while working for Monsanto. Roundup first appeared on the market in 1973. It has been called the herbicide of the century. Glyphosate herbicides eliminate more than 125 weeds and are non-toxic to animals.

Franz spent his entire 36-year career at Monsanto in St. Louis.

From 1960 to 1988, Franz received over 840 patents worldwide, including approximately 50 in the U.S. Franz published more than 40 papers and wrote the book *"Glyphosate: A Unique Global Herbicide.*" In a bit of irony, considering the firestorm ignited by environmental radicals that has swirled around glyphosate and Roundup Ready technology, later in his career he went back to the organic division to concentrate on environmentally friendly products until he retired in 1991.

For you researchers who have had your pockets stuffed with $100 bills from Monsanto just like I have, you might be interested to know that Franz reportedly received $5 for his first patent from Monsanto.

As we all know, this discovery had an incredible impact on weed management, allowing farmers and urban dwellers to easily and effectively control weeds.

I recall interviewing legendary weed scientists Harold Kempen and Bill Fischer in the mid-1970s talking about this new herbicide. Kempen told me it was so safe that Monsanto said you could wear sandals when applying it, but he said he would opt for boots. I also recall the admonition from researchers that Roundup would not work on stressed weeds. I forget where the story originated, but there was a tale about an irrigation ditch that broke or overflowed and some recently glyphosate-treated weeds died when nearby treated, stressed weeds did not. Scientists and growers also marveled at how it translocated into the roots. It was truly the herbicide of the century.

Remember, it cost about $100 per gallon. It was the most stolen agchem product of the day. Retailers and farmers stored it behind alarmed, chain link fence enclosures with razor wire ringing the top or behind bolted doors.

The technology that eventually melded glyphosate and plants began in 1946, when scientists first discovered that DNA can transfer between organisms. The first genetically modified plant was produced in 1983, using an antibiotic-resistant tobacco plant. In 1994, the transgenic tomato was approved by the FDA for marketing in the US--the modification allowed the tomato to delay ripening after picking.

In the U.S. in 1995, a basketful of transgenic crops received marketing approval: modified oil composition (Calgene), (Bt) corn/maize (Ciba-Geigy), cotton resistant to the glyphosate and, Bt cotton (Monsanto), Bt potatoes (Monsanto), soybeans resistant to the glyphosate (Monsanto), virus-resistant squash (Asgrow), and additional delayed ripening tomatoes (DNAP, Zeneca/Peto, and Monsanto). In 2000, with the production of Golden rice, scientists genetically modified food to increase its nutrient value for the first time. At least 25 GM crops have received regulatory approval to be grown commercially.

Genetically modified crops have become the norm in the United States. In the most recent survey I could find, 70% of all the corn that was planted was herbicide-resistant; 78% of cotton, and 93% of all soybeans. Those percentages were likely much higher in 2012.

Biotech crops reached 400 million acres worldwide in 2011, an 8 percent growth, from 2010. 2011 was the 16th year of commercialization of biotech crops. This growth continued after a remarkable 15 consecutive years of increases.

A 94-fold increase in acreage from 4.2 million acres in 1996 to 400 million in 2011 makes biotech crops the fastest adopted crop technology in the history of modern agriculture.

However, problems with glyphosate-resistant weeds may result in a slight reversal of those percentages. Earlier this month I attended the Beltwide Cotton Conferences in San Antonio, where there were many presentations on the subject of how to grow conventional cotton and the use of yellow, pre-plant herbicides. How soon we forget. Guess what's the hottest new piece of equipment in cotton production; hooded row-crop sprayers.

Roundup Ready crops started coming to market in 1995 with RR Canola followed by RR modified soybeans a year later and with RR cotton first available in limited quantities in 1997; RR corn in 1998; RR alfalfa and RR ready sugar beets were released in 2005. However, legal challenges were filed against both beets and alfalfa and seed sales were halted. After exhaustive legal wrangling, RR alfalfa was re-deregulated in 2011 and sugar beets followed in 2012. The legal battle over RR alfalfa continues with a suit in Northern California where opponents claim the USDA did not take into consideration the Endangered Species Act when deregulating RR alfalfa. Oral arguments were heard last October, and we await a decision. However, I am not sure what the impact would be if the opponents win, since I am told 25 percent of the sales of alfalfa seed last year nationwide was Roundup Ready alfalfa varieties. According to Seth Hoyt, respected hay market analyst, 50 percent of alfalfa seed sales in California for planting last fall were Roundup Ready varieties.

There's RR ready wheat. It was put on the shelf in 2004 due to export marketing concerns. There is an effort afoot now to bring it back. There is RR lettuce. I recall reporting on University of Arizona cooperative extension's Kai Umeda's work on RR lettuce probably 10 years ago. Vegetable producers would not touch that one with a 100-foot tractor boom because of consumer concerns, and it went on the shelf. Roundup Ready rice was field tested for a couple of years before it was put on the shelf in 2000, again fearing market backlash from export customers.

Through all this, as I indicated earlier, GMO crop acreage continues to expand and have significant influence over world agriculture.

Robert Wilson, weed specialist at the University of Nebraska Panhandle Research and Extension Center, says “The adoption rate of Roundup Ready crops in the United States has been one of the major changes in agriculture in the last 20 years.”

The use of Roundup Ready crops has changed farming practices throughout the country, he says. No-till or reduced-tillage practices have increased dramatically and are closely associated with the adoption of Roundup Ready crops.

During the first 10 years of growing Roundup Ready crops, growers relied heavily on glyphosate as the only herbicide used for weed management, despite repeated admonitions that this would eventually lead to resistance. However, as long as glyphosate was cheap and easy to use, growers did not listen. Now growers are paying a high price for that, as the respected researchers who follow me will attest.

If growers have had a problem controlling a specific weed, you generally have their undivided attention. However, when glyphosate is working well, it is only human nature to resist change as long as possible. Some growers are not worried about anything but surviving next year and are not thinking about change.

Doug Munier pointed out, as I was putting this talk together, that “Some people talk about super weeds and Roundup resistance, but don’t consider that if Roundup no longer works we are just back to the decades of weed control before Roundup. Super weed implies nothing controls it. Although Roundup resistance is not catastrophic, we will lose the most valuable herbicide ever developed when resistance gets to the point Roundup is no longer used. At some point in the future, growers may look back and say they didn’t know how good we had it when RR crops were effective.”

There is an attitude among farmers that agchem manufacturers will come up with an alternative to glyphosate. I recall several years ago attending a cotton grower tour stop at the Bayer CropScience research facility in Fresno. The growers were from the Mid-South, as part of a producer information exchange program. At a lunch where growers were asked if they had any questions, one grower asked, ”When are you guys going to come up with something to control pigweed?” This was just two years after the resistance issue with palmer amaranth first became widely evident. I am not sure how pervasive that attitude is among growers, but I am afraid it is more widespread than we want to admit.

Switching gears a bit, I find the topic of biotechnology totally fascinating and a bit perplexing at times. As effective as the RR technology has been, to me the insect pest resistance element of GMO is perhaps the most spectacular.

I find it interesting that more than 15 years after the Bt technology was introduced, there has been no field resistance confirmed. Resistance has been confirmed in the lab, but never in a commercial field. What is even more remarkable about this is that much of the refuge specifications initially required have been modified or abandoned to the point where 100 percent Bt cotton was a key element in eradicating pink bollworm from the Desert Southwest and Mexico...and still no field resistance.

I also find it interesting that herbicide resistance--in this case weed resistance to glyphosate—has emerged as somehow a new issue, when weed resistance to herbicides was documented almost 50 years ago.

According to weed science.com, there are 396 Resistant Biotypes, 210 Species (123 dicots and 87 monocots) in more than 670,000 fields.

My question is why did glyphosate resistance became so widespread so quickly, yet there has been no resistance to the Bt biotech technology after almost 20 years of commercial use

I readily acknowledge I am not a scientist and am mixing apples and oranges by comparing weed science to entomology, but it is an interesting comparison.

The gospel of resistance management is not new, either. It is the cornerstone of many pest management strategies, none more than in fungicides for disease control. Some of you may recall Bayleton use in the late 1970s, early 1980s. It was a brand new fungicide that promised to give long term control of powdery mildew in grapes with far fewer trips through the field. It was so successful, growers treated heavily and often. After only two seasons, Bayleton was useless against powdery mildew, due to resistance from the pathogen. Growers experienced powdery mildew fungicide resistance firsthand really for the first time, since Bayleton was the first synthetic fungicides to reach the market. The only product used for mildew control before the fungicides were introduced was sulfur, and there has never been an issue of resistance to sulfur. Bayleton was a rude wake up call.

Since then, resistance management has been the gospel in control of diseases in not only grapes, but all horticultural crops. There are currently more than 20 products registered for disease control in tree and vine crops and six different fungicide classes. Over-use and resistance is still an issue, but it is not widespread. When it is identified, growers usually take a pro-active approach to mitigating it. Yet despite repeated warnings about glyphosate resistance, growers don't seem to take that seriously until it is almost too late.

And finally, people often ask me why I am so passionate in my commentaries and other articles about GMOs. My wife reads my articles before I send them in. She has remarked more than once someone is going to paint a white X on the roof of our home, so the whackos will not miss the target.

I admit to name-calling. I also acknowledge that there are intelligent, educated scientists who have raised issues about GMO technology. However, most of the controversy in the media has

been generated by radicals who simply do not want to accept sound science and are self-serving socialists who are more interested in halting technology than even considering its benefits.
Let me give you an example. Several years ago I received a call from a man who spearheaded the anti-GMO movement that resulted in several northern California counties symbolically banning GMO crops. He asked if he could just visit with me off the record. I said sure. He began his spiel. He was articulate, calm and convincing. Local newspaper reporters loved him and seldom checked his credentials or his facts. He obviously thought he was convincing me. When he finished, I asked him where he got his degree. He said he did not have a degree, but learned about GMO from “going to a lot of classes.”

When it came time for me to respond, I decided it would be a waste of time challenging his facts. Rather, I said let me tell you a story.
When Bt cotton was introduced into Arizona for the first time, I said, PCAs who checked cotton fields would exit Bt variety cotton fields smiling and covered with insect webbing. I asked him if he understood the significance of that. He did not.

I have a long history of writing about Arizona cotton and the history of the pink bollworm. I have seen cotton so devastated by pinkies that the plants were 8 and 9 feet tall with no bolls on them, even after a grower treated every 3 days.

I explained to this so-called environmentalist that the webbing covering the PCAs was from beneficial insects, which had come back into cotton because it was no longer being sprayed with harsh insecticides. He still did not understand nor did he want to understand.
When the GMO controversy began to boil over, Dr. Tom Kerby, then University of California cotton specialist, got in my face one day at a meeting in Visalia, upset at why there was so much angst over Bt cotton. “It’s only protein,” he protested. I told him that that does not hold water with radicals and that if he wanted to defend the technology, he would have to become a junkyard dog. “I cannot do that; I am a scientist,” he said.

As I read about biotechnology, I discovered that scientists were trying to use it to increase the amount of insulin in the whites of chicken eggs to benefit insulin dependent diabetics. My granddaughter has been a Type 1 diabetic since she was 7 years old. She is now 23 and has struggled with diabetes for a long, long time.

When I read about the insulin research, I decided to be the junkyard dog when it came to defending science, defending men and women who are using biotechnology for the betterment of man and the environment.

To me, those radicals who attack biotechnology are no different than those who opposed smallpox and polio vaccines. It is almost criminal what they get printed in the newspapers and reported on television. They do not deserve respect or acknowledgement.
So as long as I am able, I will defend the right of scientists and professionals like most of you here to pursue biotechnology or other scientific endeavors to meet the challenges John Jachetta talked about yesterday in feeding the 9 billon people who will be on this planet in 2050.

Rather than letting the radicals control the future, it behooves us all to defend biotechnology with the words of Nobel Laureate Dr. Norman Borlaug, the father of the Green Revolution, who is credited with saving 1 billion people from starvation by developing higher-yielding wheat and rice varieties that tripled food yields per acre across most of the world after 1960.

"I believe genetically modified food crops will stop world hunger," he said in one interview. That should be on the wall of every university campus ag science building in the world.

Thank you for allowing me to be a little personal and passionate in this presentation.

Glyphosate-Resistant Weeds Worldwide

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The intent of the International Survey of Herbicide-Resistant Weeds is to document practical cases of field selected, genetically inherited resistant weed biotypes that survive a rate of herbicide to which the indigenous population was controlled. This information assists farmers and academics in the development of effective weed control systems for the field and assists herbicide manufacturers in the development of appropriate stewardship programs for their products. The survey currently (1/24/2013) records 396 unique types of herbicide-resistant weeds in 210 weed species (123 dicots and 87 monocots). The herbicide sites of action most prone to resistance are the ALS inhibitors (129 resistant species) the triazines (69 species), and the ACCase inhibitors (42 species). Glyphosate has generally been considered a low risk herbicide for selection of resistance, but low risk does not mean "no risk", and given the massive area treated with glyphosate annually it is not surprising that 24 weed species have evolved glyphosate resistance (Table 1).

In 1996 Roundup Ready Soybeans were introduced in the United States and since then there has been a rapid adoption of Roundup Ready crops (primarily soybean, maize, cotton, canola and sugar beet). Figure 1 shows the correlation between the increase in Roundup Ready crops and the evolution of glyphosate-resistant weeds. Roundup-Ready crops are not entirely responsible for the selection of glyphosate-resistant weeds, 12 weed species have evolved glyphosate-resistance in orchard and non-crop situations.

The USA leads the world in the area planted to Roundup Ready crops and consequently has the highest number of glyphosate-resistant weed species (13) Table 2. Brazil and Argentina also have large areas planted to Roundup Ready Crops and both have 5 glyphosate-resistant weeds. Australia has selected 6 glyphosate-resistant weeds, primarily through the repeated use of glyphosate in summer fallow situations and orchards. Spain and South Africa have selected 5 and 3 glyphosate-resistant weeds respectively in orchards as well.

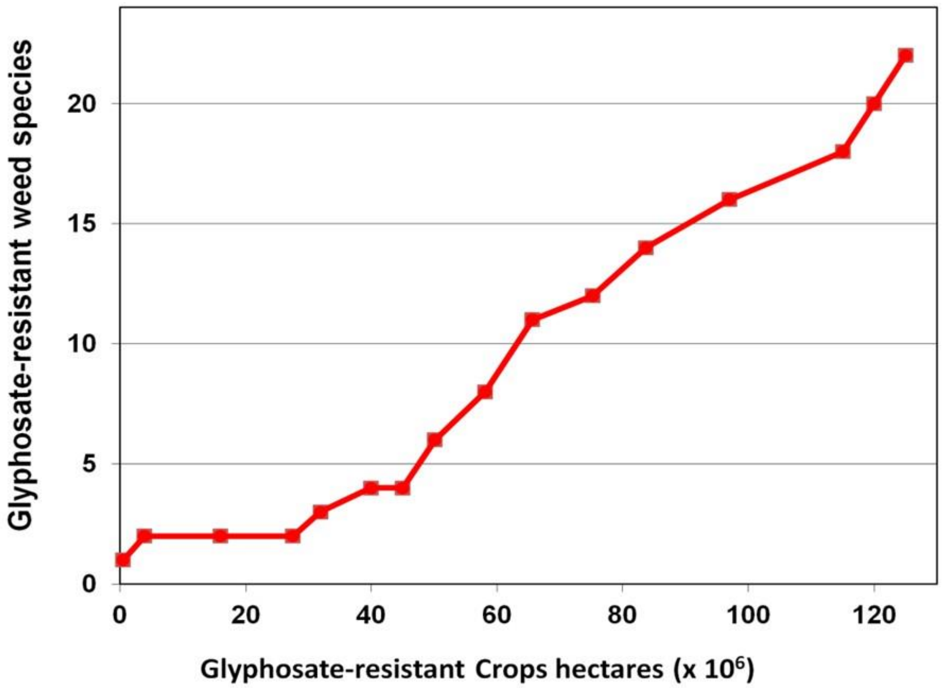
Table 1. Global list of glyphosate-resistant weeds.

#	Species	Year	Countries	Crops
1	*Lolium rigidum*	1996	Australia, France, Israel, Italy, South Africa, Spain, USA	11
2	*Eleusine indica*	1997	Colombia, Malaysia, USA	4
3	*Conyza Canadensis*	2000	Brazil, China, Czech Republic, Spain, USA	10
4	*Lolium multiflorum*	2001	Argentina, Brazil, Chile, Spain, USA	11
5	*Conyza bonariensis*	2003	Australia, Brazil, Colombia, Greece, Israel, Portugal, South Africa, Spain, USA	10
6	*Plantago lanceolata*	2003	South Africa	2
7	*Ambrosia artemisiifolia*	2004	USA	1
8	*Parthenium hysterophorus*	2004	Colombia	1
9	*Ambrosia trifida*	2004	Canada, USA	3
10	*Sorghum halepense*	2005	Argentina, USA	1
11	*Amaranthus palmeri*	2005	USA	5
12	*Amaranthus tuberculatus*	2005	USA	4
13	*Digitaria insularis*	2006	Brazil, Paraguay	6
14	*Echinochloa colona*	2007	Argentina, Australia, USA	5
15	*Kochia scoparia*	2007	Canada, USA	4
16	*Urochloa panicoides*	2008	Australia	2
17	*Lolium perenne*	2008	Argentina	4
18	*Conyza sumatrensis*	2009	Brazil, Spain	2
19	*Poa annua*	2010	USA	2
20	*Chloris truncate*	2010	Australia	1
21	*Leptochloa virgate*	2010	Mexico	1
22	*Bromus diandrus*	2011	Australia	1
23	*Cynodon hirsutus*	2012	USA	1
24	*Amaranthus spinosus*	2012	Argentina	1

Table 2. Number of Glyphosate-Resistant Weeds in Countries

Country	# GRW	Country	# GRW
USA	13	Malaysia	1
Australia	6	Chile	1
Brazil	5	France	1
Spain	5	China	1
Argentina	5	Paraguay	1
South Africa	3	Czech Republic	1
Colombia	3	Greece	1
Israel	2	Poland	1
Italy	2	Portugal	1
Canada	2	Mexico	1

Figure 1. The Relationship between the adoption of Roundup Ready Crops and the evolution of glyphosate-resistant weeds.



Three plant families (Poaceae, Asteraceae, and Amaranthaceae) account for 92% of the reported cases of glyphosate-resistant weeds even though they only account for about 60% of weeds in crops. Grass weeds account for 13 of the 24 glyphosate resistant weeds and three of these are in the genus *Lolium* (*L. rigidum*, *L. multiflorum*, and *L. perenne*). Similarly there are three cases of glyphosate resistant weeds in the genus *Amaranthus* (*A. tuberculatus*, *A. palmeri*, and *A. spinosus*) and *Conyza* (*C. canadensis*, *C. bonariensis*, and *C. sumatrensis*). In addition there are two *Ambrosia* sp. (*A. artemisiifolia* and *A. trifida*). The lesson to be learnt from this is that if a weed evolves resistance to glyphosate then it is highly likely that close relatives will evolve resistance to glyphosate and should be managed accordingly.

The occurrence of glyphosate resistance is often associated with farming systems that rely upon glyphosate alone for weed control, minimum tillage, and the use of low rates glyphosate.

Glyphosate is the most useful herbicide ever developed and it is important that its effectiveness is maintained for as long as possible. Rotation of herbicide modes of action, the use of tank mixes with different modes of action, and integrated weed management are the primary tools that growers have to preserve glyphosate.

Southeastern Experience with Herbicide Resistance

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Glyphosate-resistant Palmer amaranth has changed agriculture forever in the Southeast. To combat this pest, growers rely heavily on herbicides, tillage, and hand weeding. Herbicide use has increased sharply with 2.5 times more herbicide active ingredient applied in cotton today as compared to before resistance. Use of most herbicides, except glyphosate, have risen sharply, although the residual herbicides (acetochlor, diuron, flumioxazin, fomesafen, pendimethalin, *S*-metolachlor, trifluralin) and glufosinate have increased the most. Although growers spend $68/A on herbicides, control is not adequate. Thus, ninety-two percent of Georgia cotton growers are hand weeding 52% of the crop with an average cost of $11.40 per hand weeded acre. In addition to increased herbicide use and hand weeding, growers are relying on soil disturbance for the control of Palmer amaranth; presently, in-row cultivation, deep turning, and tillage for the incorporation of herbicides are each being used on 20 to 30% of the cotton acreage. Current management programs are diverse, complex, and expensive, but were more successful at controlling glyphosate-resistant Palmer amaranth in 2012 as compared to the strategies employed during the previous eight years. In fact, hand weeding costs were reduced by half in 2012 as compared to 2011, saving Georgia cotton growers nearly $7.7 million. Several factors were critical in obtaining better management during 2012, but growers being more aggressive and making wise decisions had the greatest influence.

Although these management programs are more effective, they are not economically sustainable and are still too dependent on herbicides. Therefore, an effort is underway to help growers integrate a heavy rye cover crop into their weed management program. Research results show that, if an adequate stand is achieved, rye itself, after being rolled, can reduce Palmer amaranth emergence 65 to 95%. Although the rye cover does not provide sufficient control when used alone, the rolled rye cover in conjunction with a sound herbicide program has proven extremely effective. In two large on-farm (4-8 A) dry land cotton studies conducted during 2012, the addition of a heavy rye cover crop reduced Palmer amaranth populations at harvest 70 to 95% and increased yields 16 to 23%, when all other variables, including herbicide program, were held constant. In addition to improving Palmer amaranth control and increasing yields, the rye cover crop system also has the potential to reduce herbicide input overtime, prevent or at least delay additional herbicide resistance, reduce labor needs compared to conventional tillage, mitigate wind and water erosion, improve moisture conservation, and likely reduce impact from other pests such as thrips, ryegrass, and horseweed. Although numerous benefits from this system exist, there are challenges that must be addressed including: finding time to get the rye cover established, increased nitrogen requirements, purchasing or building a roller, and obtaining a uniform cotton stand. Large-acreage on farm studies will be used to determine the overall economics of the heavy rye system and these results should be available by winter of 2013/2014.

Lessons Learned From Glyphosate-Resistant Palmer Amaranth

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The production and profitability of cotton has been greatly improved by the development and release of genetically-modified, herbicide-tolerant cultivars, particularly those resistant to glyphosate. The proposed benefits of glyphosate-resistant (GR) crop technology include: improved weed control (including difficult-to-control flora such as perennials and volunteer crop plants) and reduced crop injury. Improved crop safety and weed control efficacy can, in turn, result in higher crop productivity, a reduction in total herbicide input, and decreased weed management costs. The adoption of GR cultivars has also allowed US cotton growers to engage, more readily, in conservation tillage. This transition has been especially beneficial for farmers in the SE Coastal Plain, where the soils are sandy, compacted, nutrient-poor and have low moisture-holding capacities.

Unfortunately, the widespread use of glyphosate across space and time has resulted in the development of GR weeds. In 2004, the existence of GR Palmer amaranth was confirmed at a 250 ha field site in Macon County, Georgia; production at this site had been a monoculture of GR cotton where glyphosate, often applied at reduced rates, was used, singly, for at least seven years. Within three years of its discovery, GR Palmer amaranth became the single greatest threat to the economic sustainability of cotton production. As of 2012, GR Palmer amaranth populations have been confirmed in at least 16 US states (http://www.weedscience.org/In.asp). Biotypes that are resistant to other herbicide classes (ALS-inhibitors, DNAs, 4-HPPD-Inhibitors and PSII-inhibitors have been documented throughout the US; Palmer amaranth biotypes with multiple-resistances have been identified in GA (glyphosate and ALS-inhibitors), MS (glyphosate and ALS-inhibitors) and KS (ALS-inhibitors, PSII-inhibitors and 4-HPPD-inhibitors) (http://www.weedscience.org/In.asp).

When acceptable weed control is not realized and Palmer amaranth is allowed to set seed, population densities can become quite high in infested fields. Research conducted at the University of Georgia indicated that Palmer amaranth seed densities exceeded 35,000 seeds per m^2 in a field where the GR biotype was ineffectively managed. Palmer amaranth seed are very small (approximately 1 mm in size) and possess limited nutrient reserves. Therefore, Palmer amaranth plants that become established in the field are likely germinating and emerging from relatively shallow depths within the soil profile. Results from a recent study in GA showed that the majority of Palmer amaranth seedlings emerged from depths up to 2.5 cm; less than 2% emergence was observed for Palmer amaranth seeds buried at depths greater than 10 cm.

Weed management has historically focused on the prevention of seedling establishment and growth (e.g. PRE and POST herbicides, cultivation, etc.); little attention has been provided to strategies that maximize seed depletion from the soil seedbank. A reduction in the number of seed reduces the number of individuals that will be subjected to chemical weed management, as well as the potential number of weed management survivors that can then replenish the seed bank. Recent research initiatives at the University of Georgia have evaluated the efficacy of a single deep tillage event to bury surface/near surface Palmer amaranth seeds to depths below their optimal emergence zone, thereby removing these individuals from the germinable seedbank. Results suggest that GR Palmer amaranth seed bank densities and emerged seedling densities can be reduced by 40 to 60%, as compared to undisturbed soil. However, the ultimate success of this proposed strategy for reducing weed populations is dependent, in part, by the dormancy and longevity of seeds in the soil.

In 2007 and 2008, a study was initiated to evaluate Palmer amaranth seed longevity in the soil seedbank. Glyphosate-resistant and -susceptible seed were hand-harvested and -cleaned and divided into replicate seed-lots of 100 seed each. Each seed-lot was mixed with sand, placed in nylon bags, and buried in a Tifton sandy loam at depths of 1 cm to 40 cm for up to three years. By 36 months, seed viability ranged from 9% (1 cm depth) to 22% (40 cm depth). Results suggest that seeds near the soil surface will not be as persistent as those that are more deeply buried. Results also suggest that deep burial of Palmer amaranth seeds may reduce in-field population densities, but only if the seeds that are present at the lowest depths have been buried for a sufficient period of time before the next soil inversion event.

In addition to seedbank depletion, research efforts in GA have also focused on reducing seed inputs within farming systems. Growers are advised to remove Palmer amaranth plants that have escaped weed control measures (but prior to them achieving reproductive maturity) in order to prevent seed set and return. Subsequently, GA cotton growers have engaged in significant hand-weeding efforts (92% of growers hand-weeded, on average, 52% of their cotton acreage) in order to maintain their fields as weed-free as possible. Unfortunately, growers, extension agents, and university research personnel have observed instances where: 1) previously pulled Palmer amaranth plants have re-rooted and become reestablished in a field and 2) plants that have been cut back (using hoes or machetes) have re-sprouted from dormant buds and resumed normal growth. Therefore, studies were developed to evaluate the potential of Palmer amaranth to grow and develop following defoliation occurring during a simulated hand-weeding failure.

Experimental plots were established in fields planted to glufosinate-tolerant cotton in 2010 and 2011. At flowering (June to August), Palmer amaranth plants were assigned to one of four defoliation treatments: no defoliation, removal of all stem and leaf tissue to the soil line (2011 only), removal of all stem and leaf tissue to a height of 2.5 cm above the soil line and removal of all stem and leaf tissue to a height of 15 cm above the soil line. Floral tissues from all plants in the trials were harvested when seeds were 50 to 75% mature and total seed mass and number were determined. Results from these experiments showed that Palmer amaranth plants cut back (all stem and leaf tissue removed) between 2.5 and 15 cm above the soil line were able to successfully regrow and achieve reproductive maturity. Although none of the defoliated plants achieved the same size as their intact counterparts, they were still able to produce significant amounts seed. Palmer amaranths that were allowed to grow and develop normally produced an average of 435,000 seeds per plant (in 2011); plants cut back to 2.5 and 15 cm above the soil line produced an average of 28,000 and 116,000 seeds per plant, respectively (in 2011). As a consequence, growers need to be aware that ineffectual salvage attempts could negate efforts designed to manage the size of Palmer amaranth populations in the field.

Results from studies conducted in Georgia suggest that practices aimed at altering the weed seedbank (either by enhancing removal or reducing inflow) may be useful for reducing in-field population densities. An analogous strategy is currently being evaluated in CA to determine if seed production by GR weeds can be similarly altered. Each year, orchard growers in California devote a considerable amount of their physical and financial resources towards herbicide applications. Unfortunately, complete (100%) weed control is not assured, even when the most effective chemical programs are employed. Weed escapes can occur for numerous reasons including: improper herbicide selection or inappropriate timing of chemical applications, unfavorable weather conditions, and the development of herbicide resistance in the target weed population, among others. As was stated previously, weeds that survive control operations are a significant concern for growers; seed produced by rogue plants can be returned to the soil may become management problems in subsequent seasons.

Herbicide efficacy is often diminished when products are applied to mature plants; however, there is evidence to suggest that weed seed production can be significantly reduced by late-season, pre-harvest chemical applications. A project was initiated in 2012 to evaluate the effects of POST (glyphosate, glufosinate, paraquat and saflufenacil) herbicides on the growth and seed production of GR weeds common in California orchards. Specifically, we evaluated the effects of sub-lethal and labeled application rates on the seed production and regrowth potential of hairy fleabane in a series of greenhouse and shade-house experiments. As anticipated, small plants (pre-bolting) were injured more than larger plants, regardless of herbicide used. Even when substantial regrowth occurred, weed seed production was reduced by the late season treatments. Interestingly, even glyphosate reduced seed head production in GR hairy fleabane by nearly two-thirds and caused malformations of the flowers and heads that were produced. In the coming year, the fleabane work will be validated in orchard studies, the effects of herbicides on fleabane seed viability will be evaluated, and the effects of late-season herbicides on junglerice seed production will be determined.

Integrating Weed Management in California

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RR cotton was the first genetically engineered herbicide tolerant crop used in California. The acreage of herbicide tolerant cotton has increased dramatically in the United States. They account for approximately 95 percent of the cotton in other cotton-producing states; whereas, in California RR cotton is grown on approximately 50 percent of the upland and 85 percent of California Pima cotton. The acreage of herbicide tolerant cotton will likely continue to increase as higher yielding varieties are developed with these traits and as genetically engineered crops with resistance to more than one herbicide are developed.

RR technology has provided growers with an excellent tool for managing most annual and perennial weeds, including weeds such as nightshades, annual morningglory, and nutsedge. Before the adoption of RR cotton, purple and yellow nutsedge were widespread problems in California cotton fields and existing control measures were only marginally effective at best. Using a combination of glyphosate and cultivation, now nutsedge is seldom a serious problem. Additional advantages of this system include the following: Glyphosate can be applied post emergence so growers can delay application to observe the weeds present and their density. There are no plant-back restrictions. This technology has allowed growers to reduce tillage operations and experiment with ultra-narrow row systems. Cost savings from RR technology typically range from $25 to $200/acre.

Concerns have already surfaced in California regarding reduced control of barnyardgrass, sprangletop, pigweed, and lambsquarter with continual use of RR systems. Amaranth species (pigweed) is becoming more difficult to control. Volunteer RR corn in RR cotton is now a major problem. Resistance management will become a greater part of our production systems. Sprangletop, palmer amaranth, horseweed, and hairy fleabane have now infested most canals, roadsides, and field edges throughout the San Joaquin Valley. In some cases these weeds are beginning to encroach into cotton fields. Liberty Link systems that use Rely 280 (glufosinate) are being used on a limited basis on upland seed fields.

Even if growers use an herbicide tolerant system, it is still advisable to use a preplant incorporated herbicide in cotton. The cost is low ($6-$8/A) and these herbicides control most annual grasses and many broadleaves. Rotating glyphosate or tank mixing with ET, Chateau, Diuron, Shark, or Rely is an effective way to control annual morningglory at layby. Ultimately the decision of which herbicide tool(s) to use and how to integrate different herbicides into the weed management system will depend on their cost and effectiveness. The solution is to avoid using a single approach.

When RR cotton was the only glyphosate tolerant crop in California, crop rotation in itself was usually enough to avoid problems with weed shifts or resistant weeds. However, now with the commercialization of other glyphosate-tolerant crops like RR corn, cotton, and alfalfa the potential for the evolution of herbicide resistant weeds is greater. The more crops relying on glyphosate for weed control the greater is the selection pressure. A major concern for an increase in GR weeds is that cotton is often rotated with RR corn and often RR volunteer corn becomes a problem in RR cotton or vice versa. In addition, there has been considerable interest in reduced tillage corn, a system that relies on glyphosate for weed control. A crucial component of no-till corn production should be effective weed management.

Corn growers have access to a variety of different herbicide programs due to the sheer number and effectiveness of herbicides registered for use in corn. Despite the abundance of available herbicides for conventional corn, the RR system continues to gain popularity because it is the easiest to use in terms of weed management, especially when tillage is completely eliminated or reduced. Most no-till corn growers who use the RR system do not use a pre-emergence herbicide, preferring instead to rely on over-the-top applications of glyphosate, often alone but sometimes in tank mixes with 2,4-D, dicamba, halsulfuron (Sempra) or in conjunction with separate treatments of these herbicides. As a result in RR corn where glyphosate-alone is used GR jungle rice, pigweeds, and RR alfalfa is becoming a common problem. Corn growers using dairy manure to fertilize fields need to be particularly diligent to stay on top of weed control. Some tillage once in a while, combined with use of herbicides with a different mechanism of action, may be necessary for effective weed control especially where dairy manure is applied to fields.

Effective Farmstead Weed Management

Sound stewardship practices to avoid weed shifts and the evolution of herbicide-resistant weeds is not restricted to weed control practices within the actual crop fields. As mentioned earlier, many of the GR weeds did not evolve in agronomic crop fields themselves. Instead many evolved in non-crop areas or orchards and vineyards and subsequently invaded crop fields. Many of these annual weed species are dispersed by wind and/or water and can therefore easily move from field borders and fence-lines into cropland. For example, sprangletop, horseweed, and hairy fleabane have now infested most canals, roadsides, and field edges throughout the San Joaquin Valley and in many cases these weeds are now encroaching into crop fields. Growers should be more diligent in their weed control practices and be sure to control weeds along field edges and border areas using mechanical practices or other effective control measures. It is imperative for growers to have a lower tolerance threshold and control weeds around fields so that these herbicide-resistant biotypes don't get a foothold in crop fields.

Summary

A sound approach to resistance management must incorporate crop and herbicide rotation and control of weed escapes through tillage or hand weeding. An integrated weed management system supplements an existing transgenic or conventional weed control program and uses a variety of the available pre-plant, selective over-the-top and layby herbicides along with tillage. Although herbicide tolerant crops provide an easy-to-use and effective tool, it will continue to be necessary to use a range of weed management strategies in the future to economically and effectively control weeds and prevent to the greatest degree possible weeds from building up in the seed bank to infest future crops.

New Weed Management Handbook for Natural Areas

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While there are several publications that provide information on the management of weeds in agricultural systems, there is currently no comprehensive book that provides control options for invasive and weedy species in natural areas. However, in January of 2013, the first such book will be published by the Weed Research and Information Center at the University of California. The book, entitled *Weed Control in Natural Areas in the Western United States*, will cover about 340 species of weeds that invade or cause problems in wildland and natural areas, rangelands, grasslands, pastures, riparian and aquatic areas. The scope of the book is the 13 western states that include Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. The species chosen were those that were on the state noxious weed lists of the western states, as well as other non-crop weeds that are frequently problematic in natural areas of the western United States. Within the book there are control options, both non-chemical and chemical, provided in full write-ups for nearly 242 species, with a little under 100 additional species included in a susceptibility table only, again both non-chemical and chemical options. Although the vast majority of species are non-native, some native species are included, as they occasionally are problems in certain human use areas, both terrestrial and aquatic.

While the bulk of the text is dedicated to providing control options, it also includes additional information on the variety of control techniques and equipment used in natural areas, as well as safety and environmental considerations, herbicide characteristics, rainfast periods and grazing and haying restrictions for terrestrial herbicides, a list of species with biological control agents either available or under development, and helpful conversion tables. The chemical control options include the recommended rate, timing and any helpful remarks or cautions. There are some instances when the data for control was lacking on the particular species, but through inference with a very closely related species, it includes options the authors feel should be effective.

The authors of the book comprise many individuals within California and other western states that conduct research on the control of invasive plants and other non-crop weeds. Though the project was led by Dr. Joe DiTomaso and Guy Kyser at UC Davis, it also includes Drs. Lars Anderson, Tim Prather from the University of Idaho, Tim Miller from Washington State University, George Beck from Colorado State University, Corey Ransom from Utah State University, Celestine Duncan in Montana, and several other UC Cooperative Extension experts, including Scott Oneto, Steve Orloff, John Roncoroni, Rob Wilson, Steve Wright, Katie Wilson, and Jeremiah Mann. The information in the book comes from a number of sources, including personal experience of the authors, peer-reviewed literature, and non-peer reviewed literature, herbicide labels, and reviews in books. In addition, the authors conducted extensive internet searches for credible websites that contained information on weed and invasive plant control and management. All forms of control, including chemical and non-chemical were included. With this information, the authors summarized what they considered to be the most relevant and practical control options for each weed.

It is the intention of the authors to provide as many options as possible, with the hope that at least a few can achieve the desired objection and be implemented without restrictions. The choice of any option should be weighed against its desirable or undesirable impact on the ecosystem and the desired function of that system. Finally, because weedy and invasive plants are dynamic with new species appearing each year and new control techniques being developed by researchers and field practitioners around the west, the objective is to update and reprint the handbook about every three years so the information stays current.

Aminocyclopyrachlor: A New Active Ingredient for Non-Crop Weed Control

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Aminocyclopyrachlor (hereafter referred to as MAT28) is a new generation synthetic auxin herbicide in the pyrimidine carboxylic acid class of chemistry. It has activity on a wide spectrum of broadleaf weeds and brush with quick uptake and translocation. MAT28 is taken up both through foliage and roots and is active post and pre-emergence. MAT28 is used at low use rates (approximately 0.5 to 4 oz ai/A) and has favorable environmental and toxicity profiles. Products have been and are being developed which combine MAT28 with complementary active ingredients such as chlorsulfuron, metsulfuron, 2,4-D, imazapyr and triclopyr to offer weed control tailored to non-crop and rangeland weed control needs. At the time of this presentation, MAT28 is available in formulated products (Perspective®, Streamline® and Viewpoint®) for non-crop weed control only outside of California and is not yet available in California.

Research conducted recently in California and Oregon on brush and tree species has demonstrated the excellent spectrum and efficacy that MAT28 possesses for uses in the utility right-of-way market. This research was done primarily by Mr. Ed Fredrickson (Thunder Road Resources, Redding CA) and included a wide spectrum of brush and tree species and application methods (broadcast, individual plant spray, basal spray, cut stem and hack-and-squirt

A broadcast spray of MAT28 at 4 oz ai/A was effective for control of several brushy species such as bear clover (*Chamaebatia foliolosa*), deerbrush (*Ceanothus integerrimus*), poison oak (*Toxicodendron diversilobum*), whitethorn (*Ceanothus leucodermis*), chamise (*Adenostoma fasciculatum*), buckbrush (*Ceanothus cuneatus*) and French broom (*Genista monspessulana*), but was not effective for control of greenleaf manzanita (*Arctostaphylos patula*) or whiteleaf manzanita (*Arctostaphylos manzanita*).

Individual plant treatment (directed spray) with MAT28 at 16 oz ai/100 gallons of water plus 5% MSO adjuvant increased activity on greenleaf manzanita to 60% control after one year and also provided excellent control of deerbrush, black oak (*Quercus kelloggii*), California hazel (*Corylus cornuta*), bitter cherry (*Prunus emarginata*), whitethorn, snowberry (*Symphoricarpos albus*), gooseberry, madrone (*Arbutus menziesii*), bear clover, poison oak and buckbrush.

Hack and squirt testing was conducted by injecting 0.5 or 1 ml of undiluted 2 lb ai/gallon liquid MAT28 formulation into hacks at one hack per 2, 3 or 4 inch diameter at breast height on big leaf maple (*Acer macrophyllum*) and live oak (*Quercus chrysolepis*). Big leaf maple was very sensitive to MAT28 and rapidly defoliated with complete control at one year after treatment with all hack spacings with the 1 ml per hack rate. Big leaf maple was also completely controlled at 0.5 ml per hack at the 2 and 3 inch hack spacings but control declined at the 4 inch hack spacing. Live oak was less susceptible and the greatest control achieved was approximately

80% with the 1 ml per hack and 3 inch diameter spacing and with both rates at the 2 inch diameter spacing.

Basal trunk application with 10% MAT28 360SL in basal oil resulted in 100% control of live oak and coyote brush (*Baccharis pilularis*).

In conclusion, MAT28 has excellent activity on several brush and tree species commonly encountered in utility right-of-ways including difficult to control species such as live oak and has excellent application method flexibility.

The Search For New Melon Herbicides

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Weed control in melons is difficult due to the limited availability of registered herbicides. Field trials over the past five years have examined a range of herbicides for potential melon tolerance and weed control. The herbicides evaluated included Lorox, Dual Magnum, Château, Prowl H_2O, Zeus (also called Spartan), Reflex, Matrix, Sandea, and Command (granular form is Cerano). Two cantaloupe varieties (Esteem and Oro Rico), a honeydew melon (Saturno) and a watermelon variety (Paradise 2008-2011, Charleston Grey 2012) were tested for tolerance and weed control with these herbicides. Herbicide applications were made after planting, but prior to crop emergence and incorporated with sprinkler irrigation (0.5 to 0.75 inches) in some years or with a shallow mechanical incorporation in other years.

Melon stand was measured for each variety during the establishment period, followed by melon vigor ratings made later in the season. Melon vigor was visually assessed (0 to 10 scale, with 0 = no melons, and 10 = good melon stand and growth), in each plot, noting chlorosis, leaf abnormalities, and any reduction in stand, growth or vigor. Weed control by species was visually assessed (0 to 100 scale, with 0 = no control). Mature marketable melons were harvested (1 to 7 times), counted and weighed for each plot.

Mechanical incorporation appeared to be safer than sprinkler incorporation for most of the herbicides tested. Sprinkler incorporation often resulted in greater reductions in melon stand, and loss of early season vigor. Sprinkler irrigation likely allowed the herbicides to move deeper into the soil profile than mechanical incorporation, and thus the loss of stand and the reduction of growth. Weed control with Chateau and Reflex was also compromised by mechanical incorporation, as these herbicides are similar to Goal, in that mechanical incorporation dilutes the herbicide concentration at the soil surface and reduces weed control. Mechanical incorporation also seemed to lower weed density. This may have been due to the mechanical incorporation, killing any weeds that had emerged or were near the soil surface and about to emerge. Additionally, watermelon is far more tolerant of herbicides than honeydew melon. Cantaloupe is the least tolerant of herbicides among the melon types tested.

Overall weed control was good in most years with Zeus, Dual Magnum, Matrix or Sandea treatments. Sandea is currently labeled for melons and in numerous trials, has provided excellent, broad-spectrum weed control when applied preemergence, but only seems to control nutsedge when applied postemergence. Prowl H_2O was highly effective against the grass weeds in this trial, but weaker on pigweed or purslane in some years. Zeus was generally among the best of the experimental herbicides in terms of broadleaf weed control and duration of weed control, but weak on grasses. However, Zeus often caused some stand loss and reduction in early season vigor. Mechanical incorporation of Zeus appeared to reduce injury to melons with no loss of weed control.

Dual Magnum appeared to be safe on melons, regardless of the method of incorporation. Weed control was good in all years but best in the years where sprinkler incorporation was used. Among the treatments, Dual Magnum was easily the best in terms of yellow nutsedge control. Command is registered in all states other than California for weed control in cucurbits. In preliminary trials, rates were very low and weed control was poor. In the past two years, rates have been increased and weed control has been very good to excellent, with the exception of pigweed, which has been only moderately controlled by Command. Matrix appeared safe on melons and weed control was very good, however, DuPont was not willing to support this registration in California, and thus was only included in one of the past five years of study.

FMC, makers of both Zeus and Command, is currently moving forward to register these products in melons in California.

Melon yields have been closely related to melon tolerance and weed control, with higher yields where little or no injury occurred, and where most weeds have been controlled. Cantaloupe yields were highest with Zeus in most years, in spite of some early season injury, indicating that weed control was more important than early season melon tolerance in terms of yield.

Weed Management Options in Transplanted Bell Peppers in California

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Weed control in pepper production fields in California can be challenging:

- peppers are slow growing and do not effectively compete with weeds for the first 40-60 days in the crop production cycle;
- peppers have a long growing season (e.g. April-May planting to September-November harvest) that subjects them to infestation with cool as well as warm season weeds;
- weed removal operations must be continued throughout the long growing season to maintain the yield and quality of the crop, so weed control costs can easily be $500/Acre.

Common weeds in peppers include several species of nightshades and pigweeds, but also lambsquarters, purslane, sowthistle, and grasses, especially barnyardgrass and junglerice. Depending on the location in the state, specific weeds can make weed control in peppers more difficult. In particular, yellow nutsedge and field bindweed are problematic in nearly all production districts. Puncturevine is troublesome in the Central Valley, and on the Central Coast little mallow (*Malva parviflora*) is difficult to control, particularly late in the growing season. The difficulty of late-season weeds is that growers have already spent a large portion of their weed control budget to control weeds earlier in the season. Additionally growers are reticent to send crews into pepper fields with significant weed pressure late in the season because the crop plant becomes brittle and damages easily. The good news is that there are a number of cultural practices as well as registered herbicides that are now available to help manage weeds profitably. Peppers are produced in two ways: with the use of plastic mulch on the beds and on bare soil (without the use of plastic mulch). Weed control in these two systems varies considerably.

Plastic mulch culture: Opaque plastic mulches are used in pepper production and do not allow light through to the soil that can stimulate weed germination. As a result, the mulch provides a barrier to weed growth over a large portion of the bed. However, weeds can emerge through the planting holes and in the furrows. Preplant fumigants such as metam sodium (Vapam, K-Pam) are commonly used to control both weeds and soilborne pathogens. In addition, oxyfluorfen (Goal Tender) is registered for use under the plastic and provides additional control of weeds such as little mallow, which is not controlled by fumigants. Weeds can be problematic in the furrows if moisture becomes available from late-season rains or irrigation water. Flumioxazin (Chateau) was registered under an indemnified 24c label in 2011 for use as a spray directed to the furrow and can provide control of a wide spectrum of broadleaf weeds. Weed control in plastic culture can be very good, but hand weeding is used to control escaped weeds.

Bare soil culture: Transplanting is the most common method of establishing peppers in bare soil culture on beds. Beds are treated a number of ways prior to transplanting depending on the growers schedule, but significant weed control and reductions in weed control expense can be achieved with preplant cultural practices such as preirrigation and selection of sites with low populations of problematic weeds such as yellow nutsedge and field bindweed. Preplant fumigation can be carried out with materials such as metam sodium applied through the drip system and can help reduce weed pressure as well as soilborne diseases. The full range of preplant and preemergence materials listed in Table 1 is available for use on transplanted peppers. They can be selected based on the weed spectrum present at the site (Table 2). Early season weeds can generally be successfully controlled with the combination of preplant cultural practices, herbicides and mechanical cultivation; as a result, hand weeding costs can be minimized at this point in the growth cycle. Approximately 30-40 days after transplanting, before the crop canopy begins to close, the layby herbicide treatments are generally made. The available materials provide good control of a wide spectrum of broadleaf and grass weeds.

Table 1. Registered herbicides for use on peppers

Preplant	Preemergence	Layby	Post Emergence
glyphosate	oxyfluorfen [1,2]	DCPA	halosulfuron
paraquat	bensulide	pendimethalin	clethodim
oxyfluorfen [1,2]	napropamide	s-metolachlor	sethoxydim
carfentrazone	trifluralin		carfentrazone [3]
pelargonic acid	s-metolachlor		pelargonic acid [3]
metam sodium	pendimethalin		flumioxazin [4]

1 – applied to beds up to 30 days prior to planting, beds must be thoroughly tilled before planting; 2 – applied to shaped beds under plastic mulch; 3 – applied as hooded application between rows to burn down weeds; 4 – applied to row middles to provide preemergence weed control.

Table 2. Susceptibility of weeds to pepper herbicides

Weed Species	bensulide	DCPA	S-metolachlor	napropamide	pendimethalin	trifluralin
Chickweed	P	C	C	C	C	C
Nettleleaf goosefoot	P	C	P	C	C	C
Groundsel	N	N	N	C	N	N
Henbit	N	P	-	N	C	C
Lambsquarters	C	C	P	C	C	C
Little Mallow	N	P	P	P	P	N
Burning nettle	P	P	C	P	N	N
Black nightshade	N	P	C	N	N	N
Hairy nightshade	N	P	C	N	N	N
Yellow nutsedge	N	N	P	N	N	N
Pigweed	C	C	C	C	C	C
Purslane	C	C	C	C	C	C
Shepherd's purse	N	N	P	P	P	N
Sowthistle	N	P	P	C	N	N

N = no control; P = partial control; C = controlled

There are several postemergent herbicides registered for use on peppers that can control specific weed problems in established peppers: the grass materials, clethodim (Select) and sethoxydim (Poast) as well as the nutsedge and broadleaf material halosulfuron (Sandea).

Since 2004 tandem field studies have been conducted in two of the four major growing regions of California (Central Valley and Central Coast) looking for selective preemergence herbicides suitable for use in transplanted bell pepper production on unmulched beds. Application timings include at planting and at layby. At planting applications have looked at pre-transplant, post-transplant over the top, and post-transplant directed spray for some of the herbicides in order to achieve better crop safety. Crop phytotoxicity and weed control ratings, weed counts and bell pepper yields were collected. Pigweeds (prostrate, tumble and redroot), nightshades (black, hairy, and groundcherry), common lambsquarters, common purslane, common groundsel, puncturevine and junglerice were the main weeds tested. Trial results investigating weed control and crop safety of flumioxazin, oxyfluorfen, s-metolachlor, and pendimethalin compared to DCPA and napropamide have led to changes in label registrations for California.

One weed that escapes control is little mallow. Over the past several years we have experimented with flumioxazin (Chateau) as a layby material for use on the pepper beds to control this weed. It controls mallow better than the currently available materials (Table 3). One of the difficulties has been finding an effective way to get the material to the soil surface without damaging pepper foliage or fruit. We looked at a number of techniques (granular formulation, applying the herbicide to dry fertilizer, through the sprinklers, etc.), but we have not found a way to apply the herbicide without it causing too much damage to the pepper plant. As a result, flumioxazin is only registered for use in peppers in the furrow, but not on the bed.

Table 3. Comparison of layby weed treatments

Treatment	**Application**	**Material/A**	**Mallow per 6 ft^2**	**Total weeds per 6 ft^2**
Untreated	---	---	5.0	39.0
S-metolachlor + pendimethalin	Directed	1.5 pints 2.0 pints	5.3	12.0
flumioxazin[1]	Directed	3.0 oz	1.0	9.0

1 – not registered for this use

San Joaquin Valley Layby Experiments with Preemergence Herbicides: Field trials investigating six preemergence herbicides at 1x and 2x rates were compared to an untreated check and two standard herbicide treatments in transplanted bell peppers in 2011 and 2012. One herbicide (Outlook) was applied at a 4x rate. All applications were made at layby and the crop had no previous (at planting) herbicide applications. The herbicide trials were conducted at the UC West Side Research and Extension Center in Five Points in Fresno County. Soil type is a

Panoche Clay Loam. Bell peppers were transplanted in single rows into 40” beds using a commercial transplanter. Within row spacing was 10” between plants and stand establishment was very good. Weed pressure at planting was significant as there was no preemergence herbicide applied at planting.

At layby the entire field was mechanically cultivated and hand weeded so that preemergence herbicides could be applied as layby treatments to weed free plots. The treatments were replicated 4 times in a randomized complete block design in the field. Plot size was either one or two 40-inch bed(s) wide by 70-feet of row length. The sprayer was a CO^2 backpack sprayer at 30 psi with a two nozzle wand outfitted with 2 XR Teejet nozzles 8003 evs and a water volume of 30 GPA. The herbicide application was aimed at the base of the plants (not over the top), but drop nozzles were not used for a directed spray. The herbicides were set with sprinklers, but the trial was grown under furrow irrigation. The herbicides tested at layby included:

Trade name	**Common name**
Dual II Magnum	s-metolachlor
Outlook	dimethenamid-p
Prowl H2O	pendimethalin
Sandea	halosulfuron
Sonalan (2011)	ethalfluralin
Nortron (2012)	ethofumesate
Dacthal (2011)	DCPA
Devrinol (2011)	Napropamide

Weed control results are shown in Tables 4 and 5. Nortron, Outlook, Sonalan, and Zeus are not currently registered for use in transplanted bell peppers. These trials show that layby applications of Outlook provide excellent weed control and crop safety. Where Nortron and Zeus contacted the foliage they caused initial phytotoxicity on the leaves, however these symptoms were greatly reduced with time. A 4x application of Outlook resulted in less phytotoxicity to pepper leaves than a 2x rate of Nortron or a 1x rate of Zeus. An application of a 2x rate of Outlook showed the same pepper phytotoxicity as a 1x application of Prowl H_2O, both of which diminished as the peppers grew. In all trials Dual Magnum, Prowl H_2O and Outlook provided excellent results in broadleaf and grass weed control. Sandea is weak on nightshades and Sonalan is a weaker dintiroaniline than Prowl and less effective on weeds in general. Zeus was weak on purslane and grasses. Populations of nutsedge and puncturevine were too erratic to include in these results.

Summary: As with all vegetable crops, there are very few new herbicides in development for use on peppers, so research strives to find new uses for older herbicides. In general the array of weed control tools available for use on peppers is varied and effective. A key challenge for the pepper industry moving forward is to keep the current herbicide registrations. Through careful selection and use of these herbicides, hopefully they will be available for use by the pepper industry for many years to come.

Table 4. 2011 Layby Application: Phytotoxicity, Weed Control, and Weed Counts in San Joaquin Valley Trial

				June 22	July 8		August 9								
	Preemergence Herbicide			Pepper	Ratings (1-10)*		---- Weed Counts (~100 ft^2) ----							Total	
Code	Treatment	Layby	Rate/Acre	Stand #	Phyto	Weed	PIGs	Night	Grndcherry		Purslane		Lambs	Brdlvs	
1	Untreated	-		67.3	0.1	10	0.3	7.5	7.8	a	5.5	b	0.5	**21.5**	**a**
2	Dual Magnum 7.63	**1x**	1.5 pts	72.3	0.1	10	0.3	6.3	0.0	c	0.8	bc	0.3	**7.5**	**bcd**
3	Outlook 6.0	**1x**	10.7 ozs	68.8	0.1	10	0.3	4.3	0.3	c	1.5	bc	1.0	**7.3**	**bcd**
4	Prowl H_2O 3.8EC	**1x**	3 pts	68.5	0.9	10	0.0	4.5	0.0	c	1.0	bc	0.5	**6.0**	**cd**
5	Sandea 75%	**1x**	1.0 oz	73.8	0.8	10	0.0	12.5	0.3	c	3.0	bc	0.0	**15.8**	**abc**
6	Sonalan HFX	**1x**	3.7 pts	65.5	0.5	10	0.0	10.0	3.5	b	2.5	bc	0.3	**16.3**	**ab**
7	Zeus 4F	**1x**	3.2 ozs	68.5	2.0	10	0.0	7.8	3.0	bc	11.5	a	0.8	**23.0**	**a**
8	Dual Magnum 7.63	**2x**	3.0 pts	75.0	0.2	10	0.0	5.8	0.0	c	0.5	bc	0.5	**6.8**	**bcd**
9	Outlook 6.0	**2x**	21.4 ozs	71.3	0.1	10	0.3	4.8	0.3	c	1.8	bc	0.5	**7.5**	**bcd**
10	Prowl H_2O 3.8EC	**2x**	6 pts	70.5	1.6	10	0.3	0.5	0.0	c	0.0	c	0.3	**1.0**	**d**
11	Sandea 75%	**2x**	2 ozs	71.8	0.7	10	0.3	6.8	0.5	bc	1.3	bc	1.3	**10.0**	**bcd**
12	Sonalan HFX	**2x**	7.4 pts	72.8	2.0	10	0.5	4.8	0.8	bc	1.3	bc	0.8	**8.0**	**bcd**
13	Zeus 4F	**2x**	6.4 ozs	73.5	2.0	10	0.0	4.3	3.0	bc	5.0	bc	0.8	**13.0**	**abc**
14	Dacthal 75WP	**1x**	9.3 lbs	67.3	0.5	10	0.8	5.3	1.5	bc	1.0	bc	0.3	**8.8**	**bcd**
15	Devrinol 50DF	**1x**	4 lb	73.8	0.1	10	0.0	4.3	2.5	bc	3.0	bc	0.3	**10.0**	**bcd**
16	Outlook 6.0	**4x**	42.8 ozs	63.3	0.5	10	0.0	6.3	0.3	c	0.5	bc	0.5	**7.5**	**bcd**
			Average	**70.2**	**0.7**	**10.0**	**0.2**	**6.0**	**1.5**		**2.5**		**0.5**	**10.6**	
			LSD (.05)	**NS**	**0.4**	**NS**	**NS**	**NS**	**3.1**		**5.3**		**NS**	**10.1**	
			CV%	11.6	37.6		230.8	98.8	146.3		150.1		178.1	67.1	

* One mechanical cultivation & hand in-row weeding on June 15-16, 2011. No herbicides applied until layby on June 17, 2011. Counts=70' row x 18" wide

Phytotoxicity (1-10): 0=No crop damage; 10=dead. Weed ratings (1-10): 1=No weed control; 10=100% weed control.

Not registered for use in peppers: Outlook, Sonalan, Zeus. Always follow the label.

Table 5. 2012 Layby Application: Pepper Stand, Crop Phytotoxicity, Weed Control Ratings in San Joaquin Valley Trial

Code	Preemergence Herbicide LaybyTreatments		Lbs a.i./A	Material/A	June 7, 2012		June 29	August 16, 2012		
					Pepper Stand		Phyto	Phyto	Broadleaf	Grass
					W bed	E bed	Rating	Rating	Control	Control
1	Dual Magnum 7.63	**1x**	1.43	1.5 pts	36.0	33.5	0.50	0	8.8	8.8
2	Dual Magnum 7.63	**2x**	2.86	3 pts	37.3	35.3	0.25	0.25	9.1	9.1
3	Nortron 4SC	**1x**	1.75	3.5 pts	35.0	33.0	2.00	0	7.0	7.0
4	Nortron 4SC	**2x**	3.50	7.0 pts	37.3	35.3	4.75	0	7.0	7.0
5	Outlook 6.0	**1x**	0.05	10.7 ozs	33.0	35.0	0.50	0.25	7.3	7.3
6	Outlook 6.0	**2x**	1.0	21.4 ozs	38.5	34.0	1.25	0.50	8.3	8.3
7	Prowl H_2O 3.8EC	**1x**	1.5	3 pts	31.8	32.8	1.25	0	9.0	9.0
8	Prowl H_2O 3.8EC	**2x**	3.0	6 pts	36.8	34.3	1.75	0	9.6	9.6
9	Zeus 4F	**1x**	0.094	3 ozs	36.0	31.8	3.50	0.50	4.3	4.3
10	Zeus 4F	**2x**	0.188	6 ozs	37.3	32.3	8.25	3.25	4.3	4.3
11	Outlook	**4x**	2.0	42.8 ozs	35.3	31.3	3.00	2.25	8.1	8.1
12	Untreated	**-**			34.5	34.8	0.75	0.0	3.5	3.5
				Average	**35.7**	**33.6**	**2.3**	**0.7**	**8.7**	**7.2**
				LSD (0.05)	**8.1**	**7.2**	**1.2**	**1.3**	**0.7**	**1.5**
				CV%	15.75	15.02	36.89	154.6	5.7	14.2
					NS	**NS**	**	**	**	**

* Weed Control Rating: 10 = perfect weed control; 1= no weed control
Phytotoxicity Rating: 10 = crop totally dead; 0 = no crop injury

Concerns of Transplanting Tomatoes into DNA-Treated Soil in Buried Drip Fields

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For decades, dinitroaniline (DNA) herbicides have been used in California in tomatoes and crops rotated with tomatoes with few negative issues reported, but reports of damage to tomatoes caused by DNA herbicides have greatly increased in Fresno County. We conducted a small-plot field trial in 2012 to look at possible cause(s) of why we were seeing this tomato injury where labeled rates of DNA herbicides were used.

Over the last two decades, processing tomato production in Fresno County has shifted from using sprinkler and furrow irrigation with annual deep tillage to buried drip irrigation with shallow tillage. Today, 100,000 acres of processing tomatoes in the county are transplanted and over 95% is farmed using buried drip irrigation and shallow tillage. High costs of surface water ($100-$300/ac ft) and expense of moving sprinkler pipe ($100/acre) have been the driving forces in this shift toward using buried drip in processing tomatoes. Growers save water, costs, and achieve yields of 60 tons per acre or more when buried drip irrigation is used. An added benefit of using buried drip is that the bed surface remains fairly dry during the growing season, so weed emergence is generally reduced, saving in hand-weeding costs.

To help reduce the cost of having to replace drip tape every time a new crop is planted and save in land preparation operations, the tape is buried about 10" deep and left in-place in "semi-permanent" beds for the life of the tape, which is usually three to five years. Once tomatoes are harvested, the beds are tilled shallow to destroy crop residues and prepare beds for the next crop planting. Under this type of production system, rotational crop options are limited, including tomatoes, cotton, dry beans, and melons, all of which DNA herbicides are routinely used in to help control weeds.

In 2009, we began observing commercial processing tomato fields in western Fresno County that showed stunted tomato plants with substantial root reduction. Field patterns of crop damage and plant symptoms expressed was consistent with injury caused by DNA herbicides. We determined that there were four factors common to nearly all of the fields we visited where crop injury occurred: 1) pendimethalin was used in the tomato crop and/or the previous crop(s), 2) tomatoes were produced using semi-permanent beds with buried drip irrigation and shallow cultivation, 3) deep tillage was not performed for bed preparation before tomato planting, and 4) tomato root plugs were planted shallow (<3" deep), although some fields showed damage even when tomatoes were planted at a depth of four to five inches. Furthermore, the number of fields showing tomato damage was greater during years when the region received below-normal winter rainfall amounts, particularly in 2009/10 and 2011/12.

We conducted a field trial in 2012 to determine whether or not planting tomatoes too shallow was the likely cause of crop injury observed in commercial fields treated with labeled preplant DNA herbicides. The trial was conducted at the UC West Side Research and Extension Center in Five Points, California in a clay loam soil. The trial was set up as a split-plot experimental design with four replications. Six preplant herbicides (trifluralin, pendimethalin, s-metolachlor, pendimethalin + s-metolachlor, sulfentrazone, and no herbicide) used at labeled rates were the main plot treatments and two planting depths (<2" and 4-5") were the sub-plot treatments.

Sixty-inch tomato beds were prepared in May and drip tape was placed 10" deep in the center of the beds with one drip line per bed. Herbicides were applied with a pressurized CO_2 backpack sprayer, and then incorporated 3" deep with a three-row bed shaper. Tomato transplants were planted with a hand trowel into treated beds in a single line, with plant root plugs placed either directly into the herbicide-treated zone (<2" deep) or below the herbicide zone (4-5" deep). Sprinkler irrigation was used to apply 1.5" of water immediately after planting, and then all plots were irrigated with buried drip the rest of the season. Effects on tomato growth were measured by visually rating above-ground growth and determining shoot and root dry weights (DW) at 7, 14, 21, and 35 days after treatment (DAT). To determine shoot and root DW, two plants per plot were removed with a shovel, the soil washed from the roots with water, and plants clipped at the top of each root plug. Shoot and root portions were oven-dried at 110 °F for seven days then weighed. Plots were not taken to yield.

Results from the study showed that plots not treated with a preplant herbicide had the best overall above-ground plant growth and produced the highest shoot and root DW (table 1). Although plots treated with DNA herbicides (trifluralin and pendimethalin) alone had significantly lower root DW than no herbicide plots at 35 DAT, top shoot DW were not different than the no herbicide plots. All other herbicide treatments produced significantly lower shoot and root DW and above-ground growth.

Planting depth had a significant impact on tomato growth and shoot and root DW at 35 DAT (table 2). Planting shallow resulted in a 12%, 37%, and 24% reduction in visual plant growth, shoot DW, and root DW, respectively. Results were similar when comparisons were made without including the no herbicide treatment in the evaluation (data not shown).

When we took into consideration both herbicide and planting depth effects, data at 35 DAT showed that all of the herbicides used resulted in a reduction in root DW, regardless of planting depth (table 3). However, shoot DW of trifluralin- and pendimethalin-treated plots were similar to that of no herbicide plots, except where tomatoes were planted shallow in pendimethalin-treated plots, in which case shoot DW was reduced. Similarly, plots treated with s-metolachlor, pendimethalin + s-metolachlor, and sulfentrazone had a lower shoot DW when tomatoes were planted shallow.

Table 1. Tomato growth and dry weights sorted by herbicide treatment

Herbicide	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
trifluralin	8.8 ab	9.4 a	11.80 a	113.86 a	2.32 b	5.93 b
pendimethalin	8.3 b	8.6 b	10.60 a	92.06 ab	2.28 b	4.29 cd
s-metolachlor	6.8 c	8.0 bc	6.98 b	73.63 bc	1.20 c	5.17 bc
pendimethalin+ s-metolachlor	5.5 c	7.5 c	4.88 c	77.78 b	0.76 d	3.44 de
sulfentrazone	5.7 c	6.8 d	5.24 c	49.83 c	1.14 c	2.60 e
no herbicide	9.8 a	9.9 a	12.15 a	113.08 a	2.67 a	8.39 a
P=0.05 *CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*
LSD	*1.35*	*0.68*	*1.70*	*24.74*	*0.34*	*1.82*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Table 2. Tomato growth and dry weights sorted by planting depth

Planting Depth	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
Normal (4 to 5" deep)	8.2 a	8.9 a	10.06 a	106.17 a	2.05 a	5.64 a
Shallow (<2" deep)	6.8 b	7.8 b	7.16 b	67.24 b	1.41 b	4.30 b
P=0.05 *CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Table 3. Tomato growth and dry weights sorted by herbicide treatment and planting depth

Herbicide	Planting depth	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
trifluralin	4 to 5"	9.8 a	9.8 ab	14.02 a	134.97 a	2.59 ab	7.01 bc
trifluralin	<2"	7.7 b	8.9 abc	9.57 bc	92.75 a-d	2.05 bc	4.85 de
pendimethalin	4 to 5"	9.7 a	9.5 ab	11.83 ab	111.18 ab	2.83 a	4.92 de
pendimethalin	<2"	7.0 bc	7.7 cd	9.37 bcd	72.95 b-e	1.72 c	3.67 efg
s-metolachlor	4 to 5"	8.0 b	8.2 bcd	8.91 cde	94.48 a-d	1.43 cd	5.77 cd
s-metolachlor	<2"	5.7 de	7.8 cd	5.04 fg	52.78 de	0.97 de	4.58 def
pendimethalin + s-metolachlor	4 to 5"	5.7 de	8.3 bcd	6.57 def	101.13 a-c	1.00 de	4.40 def
pendimethalin + s-metolachlor	<2"	5.3 de	6.7 de	3.19 g	54.43 de	0.52 e	2.48 g
sulfentrazone	4 to 5"	6.3 cd	7.5 cde	6.20 ef	60.16 c-e	1.57 cd	2.91 fg
sulfentrazone	<2"	5.0 e	6.0 e	4.27 fg	39.50 e	0.70 e	2.29 g
no herbicide	4 to 5"	9.8 a	10.0 a	12.80 a	135.12 a	2.86 a	8.85 a
no herbicide	<2"	9.8 a	9.8 ab	11.50 abc	91.04 a-d	2.47 ab	7.98 ab
P=0.05	*CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*
	LSD	*1.12*	*1.66*	*2.90*	*44.15*	*0.64*	*1.82*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Transplanting tomatoes shallow into soil previously treated with DNA herbicides can cause reduced shoot and root growth, although the amount of root growth reduction may not necessarily reflect an equal reduction in shoot growth. Not surprisingly, this confirms the fact that growers need to make sure tomato transplants are place below the herbicide-treated soil or shoot and root DW and above-ground growth will likely be reduced. This helps explain what we had observed in commercial tomato fields.

Surprisingly, it appears from this study that pendimethalin negatively affected shoot and root growth more so than trifluralin. Pendimethalin (Prowl H2O) was registered in California in 2008 as a preplant incorporated herbicide option for tomato growers. While DNA herbicides are not thought to be mobile in the soil, our data and observations suggest that downward movement of pendimethalin through the soil profile may have occurred, since water from the buried drip tape was not a limiting factor, and tomato roots in pendimethalin-treated plots was clearly reduced. A similar argument could be made where s-metolachlor and sulfentrazone were used. It's not clear if the initial sprinkler irrigation contributed to any downward movement of herbicides. Although the soil was not tested for the presence of DNA herbicides before or after treatment, no DNA herbicides were applied to this field location for at least 12 months before the project was started.

Additional work needs to be done where tomatoes are grown on semi-permanent beds with buried drip irrigation and shallow tillage to determine the extent to which this production technique (conditions of low soil surface moisture and reduced soil mixing) may have on DNA herbicide carryover and potential impacts on tomato growth and fruit yield.

Weed Control Strategies for Processing Onions

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From 2009-2011, we evaluated preemergence and postemergence herbicides applied at several rates and application times in small-plot weed control studies at the Intermountain Research and Extension Center (IREC). In 2012, Tulelake onion growers requested a larger-scale University study to evaluate promising herbicide treatments using commercial chemigation equipment at IREC and in Tulelake grower fields. Weed control data for kochia (the predominant weed at IREC), redroot pigweed, common lambsquarter, hairy nightshade, and clover was collected at IREC over the 4-year period. At grower sites, weed control data was collected for kochia, lambsquarter, redstem filaree, tumble mustard, hairy nightshade, and volunteer horseradish. DCPA (Dacthal), ethofumesate (multiple trade names), pendimethalin (Prowl H_20), and sulfentrazone (Zeus) were evaluated preemergence. Oxyflurofen (Goal), bromoxynil (Buctril), dimethenamid-p (Outlook), and fluroxypyr (Starane) were evaluated postemergence. Experiment results are summarized in IREC progress reports. Reports can be viewed and downloaded at:
http://ucanr.edu/sites/Intermountain_REC/Research_Progress_Reports978/

Preemergence Weed Control Summary

DCPA and ethofumesate applied post-plant and pendimethalin applied at the loop stage reduced kochia density compared to the untreated control in multiple trials. Unfortunately, these preemergence treatments did not reduce kochia density enough for control to be considered effective without a follow-up postemergence treatment. Pendimethalin applied at the loop stage was a versatile herbicide treatment. By itself, pendimethalin controlled or suppressed several grass and broadleaf weeds. When pendimethalin applied at loop stage was combined with ethofumesate or DCPA applied post-plant, pendimethalin had an additive effect on weed control compared to ethofumesate or DCPA used alone. Ethofumesate control of common lambsquarter was especially enhanced when used in combination with pendimethalin. When DCPA was used in combination with pendimethalin, the DCPA rate could be reduced (from 5 pt/A to 2.5 pt/A) without decreasing kochia, lambsquarter, and pigweed control.

Postemergence Weed Control Summary

Oxyflurofen (GoalTender) applied alone at the 1.5 leaf stage followed by oxyflurofen + bromoxynil at the 2.5 leaf stage was a top-performing postemergence herbicide program in multiple trials. The 1.5 leaf-stage timing of the oxyflurofen application improved control of most weed species compared to delaying the first application of oxyflurofen until the 2.5 leaf stage. At the 2.5 leaf stage, oxyflurofen + bromoxynil provided better kochia control compared to oxyflurofen + dimethenamid-p or oxyflurofen alone. Fluroxypyr applied between the 3-5 leaf stages gave greater than 90% kochia control in cases where kochia escaped oxyflurofen +

bromoxynil treatment. Fluroxypyr is currently not labeled for use on onions in CA. In trials with high weed pressure, applying DCPA or ethofumesate post-plant and pendimethalin at loop stage greatly improved postemergence herbicide weed control. The pre-emergence herbicides provided a dual benefit in that they controlled several weeds before onions reached the 1.5 leaf stage, and they stunted growth of weed escapes making them more susceptible to postemergence herbicides.

Influence of Herbicides on Onion Yield

Weed competition decreased onion yield in trials with moderate to heavy weed pressure. Thus, herbicide treatments with the best weed control typically had the highest onion yield regardless of herbicide injury. In trials with low weed pressure, some herbicides caused injury that resulted in onion yield reduction. In one of two trials on sandy loam soil, ethofumesate applied post-plant or at the loop stage reduced onion yield; ethofumesate applied post-plant did not reduce onion yield in trials located on silty clay loam soil. DCPA applied post-plant and pendimethalin applied at the loop stage did not reduce onion yield on any soil type studied. Almost all postemergence herbicides injured onions (stunting, leaf curling, or chlorosis), but the injury was usually temporary and did not influence onion yield. One exception was oxyflurofen + bromoxynil + dimethenamid-p applied as a three-way tank-mix at the 2.5 leaf stage. This treatment reduced onion yield in two of four trials at IREC.

Field Bindweed Management for Processing Tomatoes

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Field studies were conducted at UC Davis and West Side Research and Education Center (WSREC) near Five Points in Fresno County to evaluate the potential of registered herbicides to control field bindweed (*Convolvulsus arvensis*) in processing tomatoes under furrow and drip irrigation[1]. Field bindweed is a significant and growing problem for tomato growers in many areas of California. The large root system typical of field bindweed makes control very difficult, and the rapid adoption of drip irrigation in processing tomatoes, and the resulting minimal tillage practices required for this irrigation system, seems to have exasperated the problem.

At each location, a split-plot, randomized block design with 4 replications was used, with main plots as pre-plant and pre-emergent applications of Prowl H_2O (pendimethalin), Treflan (trifluralin), Zeus (sulfentrazone), Matrix (rimsulfuron), and untreated. Split plot treatments were post emergence applications of Matrix or Shark (carfentrazone). Adjacent to this trial, other herbicide treatment combinations were tested with a randomized block design, and included sequential POST applications of Matrix or Shark, Matrix + Sandea (halosulfuron), Treflan applied two times, a Treflan + Dual (metalochlor) combination that is commonly used in tomatoes, and untreated controls. The trials included a hand-weeded check plot. Total number of unique treatment combinations = (5 x 3) + 6 = 21. Tomatoes were transplanted using standard equipment and plant spacing, and were managed using standard production practices. The UC Davis site was furrow irrigated; WSREC employed drip irrigation. Weed control was evaluated 2 and 4 weeks after herbicide application, and at harvest. A listing of these treatments is shown in Table 1 and Figure 2.

At both locations, the herbicide combinations suppressed field bindweed growth, but none of the herbicides provided complete control. Main and split plot treatment affects for the WSREC location are shown in Figure 1, and show weed and crop phytotoxicity ratings based on a 0 – 10 scale, where 10 indicates all weeds/crop phytotoxicity. Thus, high ratings indicate high weed pressure. Best control of field bindweed was observed with pre-plant incorporated (PPI) Treflan at 2 pints/A. This treatment had significantly lower field bindweed on the May 30 and June 14 evaluation dates, but this effect was marginal on Aug 9. At that time, the untreated plots had a bindweed score of 7.3 compared to 4.3 for the Treflan treated area. Thus, the best PPI treatment provided only about 50% control of the bindweed by the end of the season. Results were similar with furrow irrigation at the UC Davis location.

Application of Matrix or Shark as a post treatment provided significant suppression of bindweed as compared to the untreated plots on all evaluation dates. Matrix performed better than Shark, but again by the end of the season average control was marginal – only about 50%. Best overall bindweed control occurred with the Treflan PPI + Matrix POST or Treflan PPI + Shark POST

[1] Both field sites funded by a grant from the California Tomato Research Institute.

treatment (Figure 1). All of the PPI treatments significantly reduced other broadleaf weeds (mainly puncture vine, pigweed, lambsquarters, purslane, and nightshades) as compared to the untreated control at all evaluation dates, though pigweed control at UC Davis was marginal in the Prowl treatments. Unlike with bindweed, the addition of post emergence herbicides did not improve control of other broadleaf weeds.

The main effect of the additional herbicide treatments are shown in Table 1. The application of Treflan both as a pre-plant and at layby gave best overall bindweed and other broadleaf control of all the treatment combinations tested in this trial. End of the season bindweed rating was 3.8, compared to the untreated at 7.3.

Crop injury was noted only at WSREC in the PPI Prowl, Treflan, and Zeus treatments and in any treatment where Shark was applied. Visible crop injury was gone by the end of the season, however, some areas where Shark and Treflan were applied resulted in the complete loss of plants because of overspray (Shark) or shallow transplant depth (Treflan).

Overall, the Treflan treatment has remained near the top among treatments for the past three years at studies conducted with furrow irrigation at UC Davis; these results were very similar when tested at WSREC under drip irrigation in 2012. Postemergence applications of Shark or Matrix also reduced field bindweed levels, but bindweed in the crop row could not be treated with the shielded application used with Shark. The combination of a preemergence herbicide and either Matrix or Shark applied postemergence, or applying Treflan both pre and at layby, were the best treatments for field bindweed in these trials. Future work will continue to examine treatment and timing combinations that optimize field bindweed management in processing tomatoes.

Table 1. Field bindweed, other weeds, and crop phytotoxicity ratings* as affected by additional herbicide treatments in processing tomatoes (harvest ratings not shown). WSREC, 2012.

				May 30			crop	June 14			crop
Herbicide Treatment and Use Rate:		Incorporation	Application date	Bindweed	BL (1)	Grass (2)	phyto	Bindweed	BL	Grass	phyto
1	Matrix (2 oz) post and again at 20 days	water	May 11 & 30	5.0	2.0	0.0	0.0	4.8	0.5	0.0	0.3
2	Shark (2 fl oz) post + 20 days	none	May 11 & 30	5.0	4.8	0.0	2.0	4.3	2.8	0.5	0.8
3	Matrix (2 oz) + Sandea (1 oz/A), post	water	May 11 & 30	4.5	0.0	0.0	0.0	4.5	0.5	0.0	0.0
4	Treflan (1 lb) pre + Treflan (1 lb) at layby	mechanical	Apr 24 & May 30	3.8	0.5	0.0	0.3	2.3	0.0	0.0	0.8
5	Treflan (1 lb) + Dual Magnum (1.5 pints/A) PPI	mechanical	24-Apr	4.3	0.3	0.0	0.8	7.8	0.5	0.0	1.8
6	Untreated, hand weeded control**	---	---	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
			Average	4.5	1.5	0.0	0.6	4.7	0.9	0.1	0.7
			LSD 0.05	**ns**	**1.25**	**---**	**1.28**	**2.2**	**1.5**	**---**	**ns**
			CV, %	24.6	54.1	---	139	29.7	117	---	135

* Ratings are based on a 0 - 10 scale, where 0 = no weeds/phyto and 10 = complete weed cover/crop death.

1) BL = broadleaf weeds other than field bindweed. Main species included puncture vine, pigweed, lambsquarters, purslane, and nightshades.

2) Grass = grassy weeds, dominated by Jungle Rice and Barnyard Grass.

** Hand weeded plots used for comparison and not included in the statistical analysis.

LSD 0.05 = Least significant difference at the 95% confidence level. Means within a column separated by less than this amount are not significantly different.

ns, --- Not significant, or insufficient data for statistical analysis.

CV = coeffecient of variation.

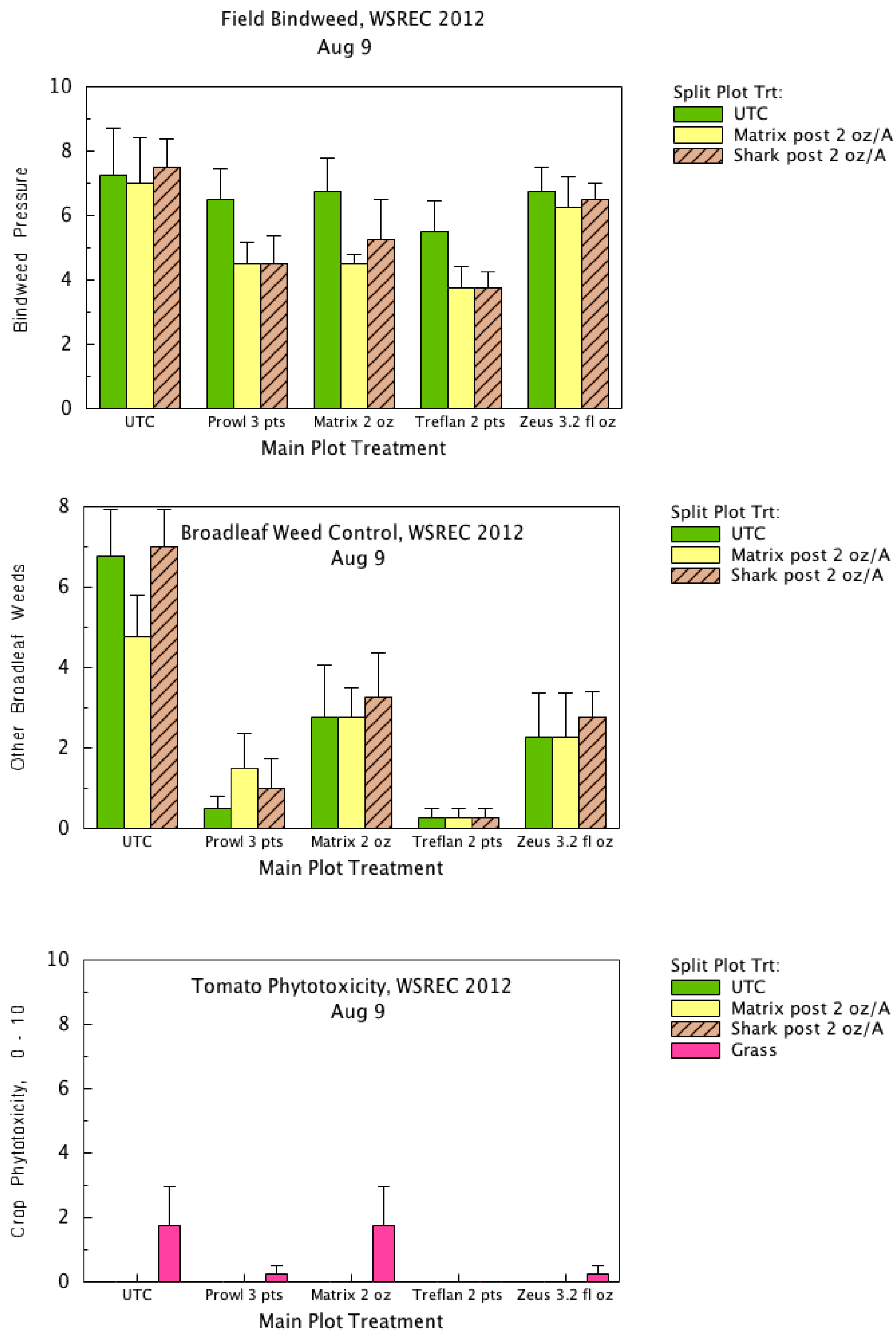

Figure 1. Field bindweed, other broadleaf weeds, and crop phytotoxicity ratings for all treatment combinations at WSREC on August 9, 2012.

Regulatory Update on Volatile Organic Compound Emissions from Pesticides

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Under the Clean Air Act, California must meet national standards for air pollutants and must specify how it plans to achieve these standards in a State Implementation Plan (SIP). SIPs require the control of emissions of nitrogen oxides and volatile organic compounds (VOCs) because they are precursors to ozone. Under California's SIP, the Department of Pesticide Regulation (DPR) must track and control VOC emissions from pesticide products used in agriculture and by structural applicators in five ozone nonattainment areas (NAAs): the Sacramento Metro area, the San Joaquin Valley, the Southeast Desert region, Ventura County and the South Coast area. Under the SIP, DPR is required to reduce pesticide VOCs during May-October (peak ozone season) by 12 percent in the San Joaquin Valley and 20 percent in the other four NAAs, compared to 1990 levels. The SIP goals have been met in all five NAAs since 2007.

The SIP reduction goals have been met primarily due to DPR's 2008 regulations that reduce VOC emissions from fumigant pesticides. These regulations require "low-emission" fumigation methods in the San Joaquin Valley, the Southeast Desert, and Ventura County NAAs during May-October. Additionally, Ventura County has a fumigant emission limit. The county agricultural commissioner enforces the limit through allowances issued to growers, or tracking and stopping fumigations once the limit is reached.

The fumigant regulations provide sufficient controls to meet the SIP goals in at least four of the NAAs, even for the highest pesticide use years. The San Joaquin Valley NAA may not meet the goal for the highest use years because most of its pesticide VOCs come from nonfumigant products. For this reason, the SIP requires DPR to implement restrictions on nonfumigant products for the San Joaquin Valley. DPR's proposed regulations would: 1) designate certain abamectin, chlorpyrifos, gibberellins, and oxyfluorfen products as "high-VOC" based on a product's VOC content; 2) require pesticide dealers selling high-VOC products for use in San Joaquin Valley to provide VOC information to purchasers; 3) require growers using high-VOC products in the San Joaquin Valley during May-October to obtain a pest control adviser recommendation prior to application to any of seven crops: alfalfa, almond, citrus, cotton, grape, pistachio, or walnut; and 4) prohibit most applications of high-VOC products to the seven crops in the San Joaquin Valley during May-October, if pesticide VOC emissions exceed a trigger level. The regulations should go into effect in November 2013.

NPDES Program Overview
And
Pesticides Permitting

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The National Pollutant Discharge Elimination System (NPDES) Program is a Federal Regulating Program that began with the 1972 Amendments to the Clean Water Act (CWA). The main objective of the NPDES Program is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The United States Environmental Protection Agency (USEPA) is responsible for implementing the NPDES Regulations but it has delegated its authority to most states including California. In California, the State Water Resources Control Board is the agency responsible for implement the NPDES Program. CWA Section 101(a) has set several program goals including: 1) making the nation's waters fishable and swimmable by 1983, 2) eliminating the discharge of pollutants by 1985, and 3) prohibiting the discharge of toxic pollutants in toxic amounts. The NPDES Program has solved a lot of pollution problems by controlling the most obvious sources of water pollution such as industrial wastewater discharges and sewage discharges. However, we're still working towards achieving the anticipated National goals.

The NPDES regulations prohibit the discharge of any pollutant from a point source to US waters unless the discharge is allowed by an NPDES permit. The key to understanding the NPDES Program is to understand how the terms **pollutant, point source, and waters of the US** have been defined in Chapter 40 of the Code of Federal Regulations (CFR) section 122.2 and interpreted by the regulations.

- A pollutant is defined as any dredged spoil, solid waste, incinerator residue, filter back wash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and Agricultural waste **discharged into water**. It does not include sewage from vessels or water, gas or other material that is injected into a well to facilitate production of oil or gas. However because of recent court decisions, biological pesticides as well as residues of chemical pesticides are now considered pollutants.
- A Point source is defined as any discernible, confined, and discrete conveyance, including but not limited to: Any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft **from which pollutants are or may be**

discharged. However, it does not include return flows from irrigated agriculture or agricultural storm water runoff.

- Waters of the U.S includes all waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce including all waters which are subject to the ebb and flow of the tide. All interstate waters, including interstate wetlands. All other waters such as intrastate lakes, rivers, streams, lakes, mudflats, sandflats, ponds, wetlands, sloughs, prairie potholes, intermittent streams, territorial seas, etc. In addition, all tributaries to these mentioned waters are also considered waters of the U.S.

In drafting NPDES Permits, the State Water Board and Regional Boards use Federal and State Regulations, local Water Quality Control Basin Plans, and established policies. Some of the most important tools used when drafting NPDES Permits include:

- The California Toxics Rule which lists toxicity criteria for aquatic life and human health for 126 priority pollutants.
- The Thermal Plan which lists temperature criteria applicable to the different waters of the state.
- The State Implementation Policy which provides the procedures to follow in determining requirements for toxic priority pollutants.
- The applicable Regional Water Board Basin Plans which establish local water quality standards and objectives.
- In addition if a discharge is to the Ocean, then the Ocean Plan applies, which also contains water quality objectives for a number of pollutants and implementation procedures.

An NPDES Permit is an authorization to discharge and has a five-year lifecycle. There is no right to an NPDES Permit, so it can be revoked at any time. To get coverage under an NPDES Permit, an application is required. An NPDES Permit can be issued either as an individual permit or a General permit. An NPDES Permit will include Federal Standard Provisions, effluent limitations, receiving water limitations, monitoring requirements, and applicable pretreatment or sludge management requirements, and any needed special studies. Effluent limitations in an NPDES Permit can be of two types, technology based or water quality based. Technology based limits are established by USEPA depending on the type of industry and they can be found in 40 CFR sections 405 thru 409. Water Quality based limitations on the other hand are established to protect the receiving water beneficial uses and comply with water quality objectives under the California Toxics Rule, Ocean Plan, or the Regional Boards' Basin Plans. When writing an NPDES Permit one needs to consider the following aspects:

- The type of discharge, if it an industry or a Publicly Owned Treatment Works (POTW).
- The discharge flow, because it if is a POTW and is more than 5 million gallons per day (mgd), then the pretreatment regulations would also apply.

- The applicable beneficial uses of the receiving water. These can include Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Industrial Process Supply (PROC), Industrial Service Supply (IND), Cold Freshwater Habitat (COLD), Warm Freshwater Habitat (WARM), Water Contact Recreation (REC-1), Non-contact Water Recreation (REC-2), Marine Habitat (MAR), Estuarine Habitat (EST), Wetland Habitat (WET), Wildlife Habitat (WILD), Navigation (NAV), etc.
- The available dilution and assimilative capacity in the receiving water, both of which can have an effect on the stringency of the final effluent limitations. Dilution is available if flows in the receiving water are greater than the discharge flows, and assimilative capacity is available if the concentration of the pollutant in the receiving water is lower than the applicable water quality objective.

Effluent limitations are established where there is reasonable potential for a discharge to cause or contribute to an excursion above water quality standards protective of the applicable beneficial uses of the receiving water. Effluent limitations could be applied for individual pollutants or for whole effluent toxicity. Effluent limitations can result in increased monitoring and reporting costs, or the need for additional special studies for dilution or toxicity evaluation. Non-compliance with effluent limitations will signify penalties and liability as well as the need for additional controls or advanced treatment. There are the 3 triggers we evaluate when determining reasonable potential and the need of an effluent limitation for a specific pollutant:

- Trigger 1- If the maximum effluent concentration of a pollutant is greater than the applicable criteria, then an effluent limitation is needed.
- Trigger 2- If the maximum receiving water concentration of a pollutant is greater than the applicable criteria and the pollutant has also been detected in the effluent, then an effluent limitation is needed.
- Trigger 3- If there is any other information on the pollutant that warrants the need of an effluent limitation. Any other information that may be used includes : Facility type, discharge type, lack of dilution, history of compliance problems, potential toxic impact of discharge, fish tissue residue data, water quality and beneficial uses of the receiving water, CWA 303d listing of the pollutant, presence of endangered species or critical habitat.

With regards to pesticides, the understanding was that as long as pesticides were being used in conformance with USEPA's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) labeling directions, pesticides will not pose unreasonable risks to human health and the environment. Thus pesticides applications to waters of the U.S in the past did not require an NPDES Permit, however, because of recent court decisions (9th Circuit Headwaters v. Talent in 2001 and 6th Circuit National Cotton Council v. EPA in 2009), pesticides applications that discharge to waters of the U.S are now required to be covered under an NDPES Permit. In addition to the court decisions, the State Water Board also regulates pesticides because pesticides cause impairment in many surface water bodies in California, the public expects it, and the regulated community wants to be permitted. Here is a chronology of the permitting events in the last few years:

- It all started with the 9th Circuit court's decision on the Headwaters vs Talent Irrigation District case in March 2001. In Talent, the court ruled that the direct application of an aquatic pesticide into a surface water body or its tributaries is a discharge of a pollutant to waters of the U.S, thus, requiring coverage under an NPDES permit.
- Because of the court's decision, the State Water Board adopted an Emergency Pesticide Permit in July 2001.
- Later in May 2004, the State Water Board adopted the Vector and Weed Control General Permits to replace the Emergency Pesticide Permit.
- In September 2005, the 9th Circuit court ruled in Fairhurst v. Hagener that residual chemical pesticides are pollutants.
- In spite of the 9th Circuit court rulings, in November 2006, USEPA adopted the Aquatic Pesticide Rule. The rule stated that a pesticide applied directly into, over, or near water per FIFRA is not a pollutant, thus, an NDPES permit is not needed.
- However, in January 2009, the 6th Circuit court issued its initial ruling vacating USEPA's Aquatic Pesticide Rule.
- Six months later, in June 2009, the 6th Circuit court granted USEPA's request for a 2-year stay on the 6th Circuit court's January 2009 ruling to allow USEPA time to issue a national General NPDES permit on Aquatic Pesticides. The stay meant that the Rule will remain in place until April 9, 2011.
- In March 2011, the State Water Board adopted three pesticides permits, the Vector Control General Permit, the Aquatic Animal Invasive Species Control General Permit, and the Spray Applications General Permit, and that same month, the 6th Circuit court extended the stay for another 6 months ending on 10/31/2011.
- State Board is scheduled to adopt the Algae and Aquatic Weed Control Applications General Permit on February 19, 2013.

Therefore, since the court rulings and as of February 2013, the State Water Board will have the following General NPDES Permits adopted:

- A Vector Control Pesticide General Permit for control of mosquitoes and mosquito larvae.
- A Spray Applications Pesticide General Permit for pest management and eradication programs for invasive insects and terrestrial weeds, and applicable only to the California Department of Food and Agriculture and the United States Department of Agriculture Forest Service.
- An Aquatic Animal Invasive Species Control Pesticide General Permit for the control of invasive species such as the quagga and zebra mussels, New Zealand mudsnails, Chinese Mitten Crabs, etc.
- Aquatic Weed Control Pesticide for the control of algae and aquatic weed.

Court-Ordered Injunctions on Pesticide Use and the Protection of Endangered Species

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Over the last 9 years, three separate pesticide use injunctions have resulted from litigation between U.S. EPA and environmental advocacy groups such as Californians Against Toxic Substances (CATS), Washington Toxics Coalition, and the Center for Biological Diversity

The first injunction was put into place in February of 2004, and is known as the "Salmonid Injunction". It resulted from a lawsuit by environmental and fishery groups charging U.S. EPA with failure to solicit National Marine Fisheries Service (NMFS) formal consultation on the risks from 38 pesticides to 26 distinct populations of Chinook salmon, Coho Salmon and Steelhead. This injunction imposes prohibitions for use of 38 active ingredients 100 yards by air, and 20 yards by ground from "Salmon Supporting Waters". It also requires EPA to consult with NMFS on the potential hazards posed by the 38 active ingredients to Salmon populations.

The first round of consultations in 2008 resulted in a Biological Opinion for Chlorpyrifos, Diazinon, and Malathion. DPR expressed disagreement with the Biological Opinion and posted comments to the Public Docket. The Biological Opinion proposed buffers of 500 feet for ground applications and 1000 feet for aerial applications. Additionally, it imposes requirements for fish kill reporting, runoff prevention measures, and environmental monitoring. Consultations between U.S. EPA and National Marine Fisheries Service have continued and their completion expected in the Summer of 2013:

http://www.epa.gov/oppfead1/endanger/litstatus/effects/biop-revised-3-2012.pdf

In response, U.S. EPA decided to impose variable buffers depending on application rate + droplet size + size of adjacent body of water. Nevertheless, for aerial applications the resulting buffers are still almost 1000 feet. For ground applications, the resulting buffers can be a minimum of 100 feet.

In November of 2009, U.S EPA submitted 40 draft California Bulletins for Chlorpyrifos, Diazinon and Malathion. They were reviewed by DPR's Endangered Species Program staff and comments sent to U.S. EPA. In January of 2010 U.S. EPA submitted the revised bulletins, including a test version of an application intended to help pesticide applicators calculate the corresponding buffer for their intended application rate, droplet size and body of water adjacent to the application site. U.S. EPA is asking registrants of Chlorpyrifos, Diazinon and Malathion to voluntarily modify labels for pesticides containing these active ingredients and refer users to the Bulletins Live Web site at: http://137.227.242.131/espp_front/view.jsp in order to find out which buffer size applies to the product they intend to apply. Registrants will be granted 18 months to generate new labels or update existing product. If the registrants don't agree to modify product labels, they could face cancellation proceedings. The use limitations imposed by the bulletins will be voluntary until product labels are modified.

The second injunction in place is known as the "Stipulated Injunction and Order for Protection of California red-legged frog". It became effective on 10/20/2006. The lawsuit by the Center for Biological Diversity alleged that U.S. EPA failed to solicit U.S. Fish & Wildlife Service (FWS) formal consultation on the risks from 66 pesticides to California red-legged frog (CRLF). It imposes prohibitions for use of 66 active ingredients 200 feet by air, and 60 feet by ground from California red-legged frog's aquatic and upland habitats occurring in 33 counties.

As with the Salmonid injunction, the Ninth District Court in Seattle ordered U.S. EPA to initiate Formal Consultations with the FWS, and schedule it in such a way it can be completed in approximately 5 years. Since 2007, U.S. EPA has been working on effects determinations for all 109 active ingredients included in this and other injunctions. This information has been made available at: http://www.epa.gov/oppfead1/endanger/litstatus/effects/

The third and latest injunction is referred to as the "Bay Area Stipulated Injunction and Order". This lawsuit by the Center for Biological Diversity charges U.S. EPA with failure to consult U.S. Fish & Wildlife Service (FWS) on the risks from 75 active ingredients to 11 listed species in the San Francisco Bay Area. Eight counties are affected: Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano and Sonoma. The injunction imposes different "no-use" buffers for some of the 75 active ingredients, depending on the type of species. The species included are: Alameda whipsnake, Bay checkerspot butterfly, California clapper rail, California freshwater shrimp, California tiger salamander, Delta smelt, salt marsh harvest mouse, San Francisco garter snake, San Joaquin kit fox, tidewater goby and Valley elderberry longhorn beetle. The buffers imposed by this injunction range from 100 to 700 feet for ground applications, and from 200 to 700 feet for aerial applications.

During the public comment period, DPR recommended U.S. EPA replace the proposed interim buffer zones with use limitations specified in our WEB-based database PRESCRIBE.

U.S. EPA completed their review of public comments and posted the final injunction on May 17, 2010 in their Web site at: http://www.epa.gov/espp/litstatus/stipulated-injuc.html

All these injunctions share some common denominators:

1) They have resulted from the lack of consultation by U.S. EPA on the effects of "pesticide x" on "species y" with the U.S. Fish & Wildlife Service (FWS) or National Marine Fisheries Service (NMFS).

2) They impose a consultation schedule between EPA and The Services (FWS or NMFS) typically 4 to 6 years minimum.

3) Public vector control and invasive weed control programs are exempt. However, in the case of the Salmonid Injunction, the use limitations resulting from consultation don't provide exemptions for vector control or invasive weed control programs.

4) They can only be enforced through citizen lawsuits. Federal, State, County and other local authorities are "vacated' from enforcing them.

5) As products go through consultation, if deemed "not likely to adversely affect" a species they will be taken off the injunction list.

6) If deemed "likely to adversely affect" a species, EPA may impose restrictions to be enforced through labeling.

This process is very contentious, generating a great deal of mistrust between the regulated community and regulatory agencies – in this case U.S. EPA. It also affects DPR, since each injunction comes with its own set of buffers and species; DPR's comprehensive, programmatic approach to protection of endangered species is being impacted by the multitude of injunctions and their litigation-derived buffers. The imposition of court-ordered absolute buffers further discourages good land stewardship efforts, since growers who in previous years might have managed their fields to include field-edge vegetation cover, hedgerows, etc., see their habitat enhancement efforts as a potential liability if listed species move in. Under these injunctions - even with exemptions- some invasive weed programs are still facing no-use zones that become refuges for noxious weeds.

Protecting Urban Water Quality: New Surface Water Regulations of 2012

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The California Department of Pesticide Regulation adopted new surface water regulations on June 19, 2012. The regulations restrict outdoor urban applications of pyrethroid insecticides made by professional applicators. Pyrethroids are highly active insecticides that control crawling, chewing, and flying insects as cockroaches, ants, beetles, caterpillars, termites, mosquitos, and wasps; in addition they are highly active on arachnids as spiders, ticks, and mites. Pyrethroids are highly hydrophobic and sorb to soils and sediment; half-lives of pyrethroids range from weeks to more than a year. Pyrethroids are being regulated in urban (non-agricultural) areas because of the following characteristics:

1) high use in urban areas;
2) prone to runoff in urban areas due to the engineering design of urban areas, especially during rainstorms;
3) more frequently detected in urban areas than in agricultural areas;
4) highly toxic to aquatic invertebrates and fish;
5) cause aquatic invertebrate toxicity when detected in surface waters.

The new surface water regulations will reduce the amount of pyrethroids applied by limiting applications to spot applications, crack and crevice applications, pin stream applications, and by limiting applications to impervious surfaces. Because more pyrethroids runoff during rainstorm events, applications are prohibited during rainfall (except under eaves), in standing water, to stormdrains and curbside gutters, and unprotected termiticide applications. More specific information can be found at the CDPR website (http://cdpr.ca.gov/docs/legbills/calcode/040501.htm). Although the new surface water regulations will reduce pyrethroid use, they will also prolong the life of these insecticides.

References

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California Weed Science Society
Custom Summary Report
July 1, 2012 through May 24, 2013

	Jul 1, '12 - May 24, 13
Ordinary Income/Expense	
Income	
4000 · Registration Income	107,503.00
4001 · Membership Income	490.00
4010 · Proceedings Income	1,361.92
4015 · Field Tour Income	1,900.00
4020 · Exhibit Income	17,750.00
4030 · Sponsor Income	10,500.00
4040 · CWSS Textbook Income	10,000.00
4065 · Orchid Fundraiser	400.00
4290 · Refunds	-2,108.00
Total Income	147,796.92
Expense	
4300 · Conference Accreditation	190.00
4310 · Conference Facility Fees	550.00
4315 · Conference Bus Tour	656.40
4320 · Conference Catering Expense	44,992.25
4330 · Conference Equipment Expense	3,818.20
4360 · Student Awards/Poster Expense	2,000.00
4361 · Awards-Board/Special Recog.	145.77
4370 · Scholarship Expense	11,500.00
4380 · Conference Supplies	1,824.02
6090 · Advertising	1,500.00
6110 · Chase Paymentech charge	886.30
6111 · Moolah Bankcard Online Charge	1,911.66
6112 · Gateway Online Service Charge	233.40
6115 · American Express service charge	501.48
6120 · Bank Service Charges	214.09
6130 · Board Meeting Expenses	988.54
6240 · Insurance - General	3,103.00
6270 · Legal & Accounting	3,323.50
6280 · Mail Box Rental Expense	76.00
6300 · Office Expense	306.43
6307 · Outside Services - PAPA	37,386.90
6340 · Postage/Shipping Expense	3,210.23
6345 · Printing Expense - Newsletter	2,900.17
6355 · Website Expense	1,200.00
6360 · Storage Rental Expense	264.00
6390 · CWSS Textbook	5,000.00

California Weed Science Society
Custom Summary Report
July 1, 2012 through May 24, 2013

	Jul 1, '12 - May 24, 13
6520 · Telephone/Internet Expense	749.21
6530 · Travel - Transport/Lodging	2,303.74
6540 · Travel - Meals/Entertainment	450.87
6545 · Student Travel - Transport/Lodg	2,326.30
6550 · Student Travel - Meals	124.43
6555 · Speaker Lodging/Travel Expense	2,265.25
Total Expense	136,902.14
Net Ordinary Income	10,894.78
Net Income	**10,894.78**

RBC Wealth Management Account

Balance as of 4/30/13

$273,140.74

24% Cash and money market

28% US equities

47% Taxable fixed income

1% Other assets

CWSS HONORARY MEMBERS LISTING

Harry Agamalian (1983)
Norman Akesson (1998)
Floyd Ashton (1990)
Alvin Baber (1995)
Walter Ball *
Dave Bayer (1986)
Carl E. Bell (2010)
Lester Berry
Tim Butler (2008)
Mick Canevari (2008)
Don Colbert (2002)
Floyd Colbert (1987)
Stephen Colbert (2012)
Alden Crafts *
Marcus Cravens *
Dave Cudney (1998)
Richard Dana
Boysie Day *
Nate Dechoretz (2003)
Jim Dewlen (1979)*
Paul Dresher *
Ken Dunster (1993)*
Matt Elhardt (2005)
Clyde Elmore (1994)
Bill Fischer *
Dick Fosse *
Tad Gantenbein (2004)
Rick Geddes (2006)
George Gowgani
Bill Harvey *
David Haskell (2009)
F. Dan Hess (2001)*
Floyd Holmes (1979)
Nelroy Jackson (1997)
Scott A. Johnson (2013)
Warren Johnson (1977)*
Bruce Kidd (2009)
Jim Koehler
Harold Kempen (1988)
Don Koehler (2003)
Butch Kreps (1987)
Edward Kurtz (1992)
Art Lange (1986)
Wayne T. Lanini (2011)
J. Robert C. Leavitt (2010)
Oliver Leonard *
Jim McHenry
Bob Meeks
Bob Mullen (1996)
Robert Norris (2002)
Ralph Offutt
Jack Orr (1999)
Ruben Pahl (1990)
Martin Pruett
Murray Pryor *
Richard Raynor
Howard Rhoads *
Jesse Richardson (2000)
Ed Rose (1991)
Conrad Schilling *
Jack Schlesselman (1999)
Vince Schweers (2003)
Deb Shatley (2009)
Conrad Skimina (2003)
Leslie Sonder *
Stan Strew
Huey Sykes (1989)
Tom Thomson (1999)
Robert Underhill
Lee VanDeren (1983) *
Ron Vargas (2001)
Stan Walton (1988) *
Bryant Washburn (1988)
Steve Wright (2007)

*Deceased

CWSS AWARD OF EXCELLENCE MEMBERS LISTING

1985	June McCaskell, Jack Schlesselman & Tom Yutani
1986	Harry Agamalian, Floyd Colbert & Ed Rose
1987	Bruce Ames, Pam Jones, & Steve Orloff
1988	Bill Clark & Linda Romander
1989	Earl Suber
1990	Ron Hanson & Phil Larson
1991	John Arvik & Elin Miller
1992	Don Colbert & Ron Kelley
1993	Ron Vargas
1994	Jim Cook & Robert Norris
1995	Mick Canevari & Rich Waegner
1996	Galen Hiett & Bill Tidwell
1997	David Haskell & Louis Hearn
1998	Jim Helmer & Jim Hill
1999	Joe DiTomaso
2000	Kurt Hembree
2001	Steven Fennimore, Wanda Graves & Scott Steinmaus
2002	Carl Bell & Harry Kline
2003	Dave Cudney & Clyde Elmore*
2004	Michelle LeStrange & Mark Mahady
2005	Scott Johnson & Richard Smith
2006	Bruce. Kidd, Judy Letterman & Celeste Elliott
2007	Barry Tickes & Cheryl Wilen
2008	Dan Bryant & Will Crites
2008	Ken Dunster* & Ron Vargas*
2009	Ellen Dean & Wayne T. Lanini
2010	Lars W.J. Anderson & Stephen F. Colbert
2011	Jennifer Malcolm & Hugo Ramirez
2012	Rob Wilson
2013	Rick Miller

*President's Award for Lifetime Achievement in Weed Science

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Perennial Plants: The Tricks and Turns of Their Perennating and Overwintering Structures

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Perennial plants live more than two seasons. This can be contrasted with annual plants which complete their life cycle in one season, or biennials, which complete their life cycle in two seasons. Perennial plants can be woody shrubs and trees, or they can be perennial herbs. Many perennial herbs produce new fresh growth each year when the weather is optimal and then die back during their dormant season to storage stems or roots. In California, we have perennial herbs in the mountains that persist through the winter snow as storage stems or roots. In other parts of the state, the dormant season is the drought months of June through October; many of perennial herbs in the Central Valley specialize in producing above-ground growth between November and May, dying back to storage stems and roots once drought starts. Our California weed flora includes many perennial herbs with a variety of storage stems and roots, and an understanding of these structures can be key to their control.

It is useful to review the basic landmarks of stems and roots. When a seed germinates, it produces a shoot and a root. The shoot becomes the shoot system, which includes the stem and the leaves. The stem is divided into nodes, where the leaves emerge, and internodes (the areas between the nodes). At each node, just above where the leaf meets the node, there is usually a small bud called an axillary bud. Finding these landmarks on a plant part means it is a stem.

In many plants, the seedling root develops into a tap root system, best illustrated by carrot or dandelion. However, in grasses, lilies, and other monocotyledons, the initial seedling root does not continue to develop, and roots develop instead from the stem system. This type of root system is called a fibrous root system. Another term used for roots that develop from stems (or sometimes leaves) is “adventitious roots.” Adventitious roots often develop from stem nodes, and they can be present in plants that also have a tap root system. Regardless of how they develop, roots do not have nodes, internodes or axillary buds.

After the initial seedling stage, as plants age, growth patterns can be complex and it can be difficult to distinguish roots from stems. Some roots are able to produce stems (root-borne shoots), and as discussed above, some stems can produce roots (shoot-borne roots). Stems and roots differ anatomically when examined in cross-section. Roots have their vascular tissue in one large cylinder in the middle of the root, while stems have their vascular tissue distributed in a number of vascular bundle cylinders that are arranged either in a ring (non-monocotyledons) or scattered throughout the stem (monocotyledons).

In perennial herbs, there are many different types of storage stems that are used to persist during the dormant season. Short upright storage stems that form at the very base of the seedling (below the first seedling leaves), such as those found in crocuses, are called corms. Stems with very short internodes and thickened storage leaves (onion) or storage axillary buds (garlic) are called bulbs. In both corms and bulbs, offset cormlets and bulblets can be produced that allow the plant to reproduce asexually through cloning.

Other perennial herbs produce below-ground horizontal storage stems called rhizomes which when examined have clear nodes and internodes. In some cases, rhizomes only produce above-ground leaves at their nodes, often at their slowly-growing tip. This is the case in irises. In other types of rhizomes, above-ground stems grow from axillary buds produced at the rhizome nodes. This is the case in many grasses and sedges, which produce a line of erect stems (with leaves) from a below-ground rhizome. Sometimes, rhizomes produce engorged storage areas that are called tubers, best illustrated by the potato (which can produce stems from the axillary buds in its eyes, which are nodes). Related to rhizomes, are above-ground horizontal stems called stolons, best seen in strawberries or Bermuda grass. Stolons typically have long internodes called runners and then produce an upright stem with adventitious roots at each node. It is sometimes difficult to know if one is dealing with a rhizome or stolon, since the distinction has to do with whether or not the stem is above or below ground. Just as with corms and bulbs, rhizomes, tubers, and stolons can fragment, allowing the plant to reproduce asexually through cloning.

In some perennial herbs, it is storage roots that are used to get through a dormant season. As mentioned above, some roots can produce a shoot system, and storage roots are a good example of this. Some storage roots, such as carrot, are storage tap roots, which develop from a tap root system. Other storage roots develop from adventitious roots and are sometimes called tuberous roots.

Plants can be complex and have a number of different strategies for persisting through drought or cold as well as for cloning. They may combine the structures discussed in this paper, producing an initial shoot above ground and an initial tap root system, then producing a rhizome with adventitious roots and small tubers, which then can produce more upright stems. In some plants, bulbs or tubers may be produced in unexpected places, such as the inflorescence bulbs of bulbous blue grass or the aerial stem tubers of air potato. In other plants, such as Bermuda buttercup, copious storage roots, rhizomes, and bulbs may be produced underground, making the plant very difficult to eradicate. An understanding of the basic morphology of perennial herb dormancy structures, as well as the timing of when these structures are produced, can be key to the control of perennial herbs.

Evaluation of Saflufenacil on Glyphosate and Paraquat-resistant Hairy Fleabane (*Conyza bonariensis*)

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Hairy fleabane is a problematic weed in California. This problem has been further aggravated by the discovery of glyphosate-resistant (GR), paraquat-resistant, and glyphosate + paraquat resistant (GPR) hairy fleabane biotypes in the Central Valley. New herbicides are being sought to control these resistant biotypes. The objective of this experiment was to evaluate the effect of temperature on the efficacy of a fairly new herbicide, saflufenacil (Treevix ®), on glyphosate-susceptible (GS), GR, and GPR biotypes of hairy fleabane at different temperature regimes. Potted hairy fleabane plants were treated at the 5-8 leaf stage with either saflufenacil (1 oz/ac), glyphosate (28 fl. oz/ac), or a mixture of saflufenacil (1 oz/ac) + glyphosate (28 fl. oz/ac). The experimental design was a split-split-plot. Prior to treatment, the plants were kept for 3 days in growth chambers programmed at 15/10° C (sub-optimum), 25/20° C (optimum), and 35/30°C (supra-optimum) day/night temperatures. Immediately after treatment, plants were returned to the respective growth chambers and kept there for 7 additional days before being returned to the greenhouse set at 25°C with ambient lighting for additional 23 days (30 DAT). Results showed that saflufenacil alone and saflufenacil + glyphosate were equally effective at controlling all three biotypes at 15/10˚C and 25/20˚C. However, at 35/30˚C, the saflufenacil + glyphosate treatment controlled 100% of the plants, but saflufenacil alone provided only 20%-25% control of GS and GPR biotypes and 0% control of the GR biotype. Glyphosate-alone provided 100%, 60%, and up to 50% control of the GS, GPR and GR biotypes respectively at 15/10˚C and 25/20°C. At 35/30°C, glyphosate-alone provided no control of the GPR and GR biotypes and only 60% control of the GS biotype. In conclusion, during warmer periods, using a tank mix of saflufenacil and glyphosate may provide better control of hairy fleabane.

Effect of Postemergence Herbicides and Application Time on Small Grain Injury and Yield

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Abstract

Often times both broadleaf and grassy weeds are problematic in cereal production requiring the use of two different herbicides with different application timing. To cut costs, growers are interested in combining applications. However, crop safety with herbicide combinations is a concern, and the appropriate application timing for different herbicides and herbicide combinations was not well tested. Research was conducted in the San Joaquin Valley area of central California to evaluate weed control and crop safety with selected new and standard herbicides applied alone and in combination at two different growth stages (3-5 and 6-8 leaf stage). In general, herbicide treatments with Puma (*Fenoxaprop*), Axial (*Pinoxaden*), or Axial + MCPA had little to no crop injury at any site. The differences in crop injury between tank mixes were minor at one site with the exception that when Axial was used the injury increased. The wheat (*Triticum aestivum*) injury that did occur with some of the tank mixtures typically disappeared after four to five weeks and there was no significant difference in bushel weight, protein, or yield between any of the treatments.

All of the treatments gave excellent control of wild oats (*Avena fatua*) at both timings, except for treatments with only ET (*Pyraflufen*) or Shark (*Carfentrazone*). Simplicity (*Pyroxsulam*) gave fair to good control of wild oats and some broadleaves. All treatments controlled Shepherd's-purse (*Capsella bursa-pastoris*) at both timings, except for treatments with only Puma or Axial. All treatments gave good to excellent control of common chickweed (*Stellaria media*) at both timings, except for treatments with Puma or Axial alone. All of the treatments with Shark, Osprey (*Mesosulfuron*), or Simplicity gave excellent control of coast fiddleneck (*Amsinkia menziesii*). All of the treatments except Puma or Axial alone gave excellent control of burning nettle (*Urtica urens*). The results of this research supported 2012 label change to allow tank mixing of Axial + MCPA.

Horseweed (*Conyza canadensis*) Control in Almond Orchards with Pre- and Postemergence Herbicides in the Southern San Joaquin Valley

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In recent years, populations of horseweed (*Conyza canadensis*) have been observed more frequently in orchards in the Southern San Joaquin Valley. Since glyphosate-resistant (GR) biotypes of this species were confirmed in 2007, alternative integrated techniques are needed to manage GR and glyphosate-susceptible horseweed populations and to prevent further development of herbicide resistance. A field experiment was conducted in January, 2012 in Tulare County to control horseweed with various pre- and post-emergence herbicides labeled for use in almond orchards. Herbicides included glufosinate (82 fl oz/ac), flumioxazin (8 oz/ac), rimsulfuron (4 oz/ac), oxyflurazon (3 pts/ac), isoxaben (1.33 lbs/ac), penoxsulam (3 pts/ac), indaziflam (5 fl oz/ac), saflufenacil (1 oz/ac), and pendimethalin (2 qts/ac). These herbicides were applied either pre- or post-emergence with a CO_2 backpack sprayer at rates labeled for almonds. The experiment was designed as a randomized complete block with four replications. Evaluations on survival or control of the horseweed plants were taken at 7, 14, and 50 days after treatment (DAT). Results indicated that at the 7 and 14 DAT saflufenacil at 1oz/ac provided significantly better control of horseweed than the other treatments. However, at 50 DAT, all treatments were similar and provided excellent control of horseweed. Therefore, this study showed that any of the herbicides tested could be used to control horseweed effectively but rapid early control could be obtained with saflufenacil.

Weed Population Dynamics In Overhead And Subsurface Irrigated No-Till Cotton Cropping Systems

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Water is a limiting factor for agriculture in California's San Joaquin Valley, and therefore irrigation efficiency is highly important. Drip irrigation systems have become increasingly popular, and overhead (OH) systems (such as linear and center pivot) are being experimented with to increase irrigation efficiency. These OH irrigation systems are much more common in mid-western U.S. than in California, but in recent years their mechanization, ease of use, as well as compatibility with minimum tillage systems, is drawing attention of researchers and growers. A field study was conducted at the University of California West Side Research and Extension in 2011 and 2012. The experimental design was a randomized complete block and treatment comparisons included sub-surface drip (SSDI) and OH irrigation in no-till Roundup Ready 'Acala' cotton. An application of glyphosate was made one month after cotton planting. The crop was irrigated with the same volume of water, and was monitored throughout the growing season for several parameters. In this report, only information on weed populations is being presented. In both years, weed densities were similar early in the season but in July the densities were higher in the OH than in the SSDI treatment. Weed biomass at crop harvest was greater in the OH than in the SSDI plots. Seedbank samples showed that, although weed densities were lower mid-season in the SSDI plots, more viable seeds were present in this treatment indicating that the seeds failed to germinate because of lack of moisture at the soil surface. The growth, development, and yield of the crop were similar in both systems. Though crop growth and yield was not affected, plots with OH irrigation may require two weed control operations during the growing season to prevent weed seed return whereas one weed control application may be sufficient in SSDI systems.

Can The Activity Of Rimsulfuron Be Enhanced With Aquatrols® (Soil Surfactant) In Transplanted Fresh Market Deficit Irrigated Tomatoes?

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Shortages of water have led to research on regulated deficit irrigation (RDI) and use of soil surfactants such as Aquatrols IrrigAid Gold® that potentially improves water infiltration. We hypothesized that this soil surfactant may also improve the distribution and thus the efficacy of a soil-applied pre-emergence herbicide such as rimsulfuron (Matrix). A field study was conducted in 2012 at the California State University, Fresno farm to evaluate the efficacy of rimsulfuron when applied with Aquatrols IrrigAid Gold® on weed control and to see if reduction in irrigation increased weed competition. The fresh market tomato variety 'Quali T 47' was transplanted on 60 inch beds in late-May. The experimental design was a split-split plot with 3 irrigation regimes (100%, 80%, and 60% of the daily ET) as the main plot. Soil surfactant applied at the rate of 4 oz/ac or no-surfactant were the sub-plots. Rimsulfuron applied at 0, 1, 2, and 4 oz/ac were the sub-sub-plots. Irrigation and fertilizer was applied through a sub-surface drip irrigation system buried 6 inches deep. The soil surfactant and rimsulfuron were applied immediately after transplanting tomatoes and the herbicide was water-incorporated. Data were taken on weed densities, weed biomass, and crop growth, yield, and quality. Irrigation levels did not affect weed density or crop yield but weed biomass was lowered and fruit maturity was delayed as irrigation was reduced. The soil surfactant had no effect on any of the weed or crop parameters. Presence of herbicide affected both weed and crop parameters but the herbicide rate did not. Weed density, biomass, and crop yield was lower when no herbicide was applied. In conclusion, under RDI better weed control may be required as presence of weeds delayed fruit maturity and lowered the yield more so in the 60% ET plots than in the other plots.

Screening for Natural Product Herbicides

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Natural products have long been used to manage pests, particularly as insecticides and fungicides. However, their usefulness as herbicides has been limited. Only one commercial herbicide is a natural product and a handful of others are natural product-like. However, the continuing emergence of herbicide resistant weeds has renewed the interest for new herbicide chemical classes with new potential molecular target sites. There are a number of advantages in utilizing natural products for the discovery of new herbicides, but there are also a number of problems or limitations associated with using such compounds (Table 1).

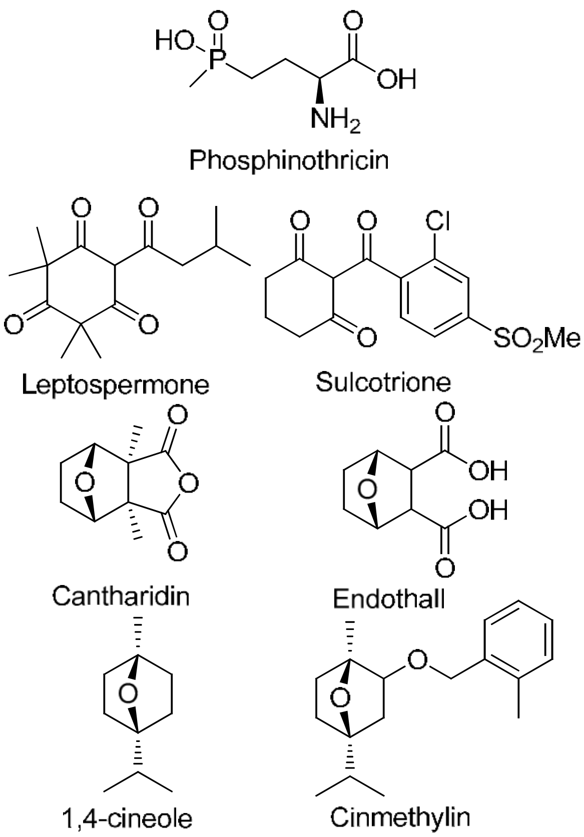
Table 1. Advantages and limitations of using natural products as a source of new herbicides or new modes of action.

Advantages	**Limitations**
New structural backbones extending to unexplored chemical spaces	Complicated structures that may be too expensive to synthesize
New molecular target sites	May have high general toxicity problems
Evolved biological activity increase the likelihood of discovering relevant structures	Structure may already be optimized for activity but have inadequate physicochemical properties
Improved instrumentation makes identification easier and requires smaller amounts	Rediscovery of known compounds is costly and sourcing may be limiting
Generally environmentally friendly	Too short environmental half-life
Better public acceptance	Public expects low rate use
May be cheaper to register	Patent protection may be limited

Investigating natural products as herbicides is advantageous because many secondary metabolites have been selected over time to address specific biological stresses. Therefore, it is likely to lead to the discovery of biologically active compounds that often have new target sites. Additionally, natural products tend to have unique scaffolds that are rich in oxygen and nitrogen molecules, and possess more chiral centers than synthetic pesticides. Such structures explore chemical spaces not exploited by their synthetic counterparts. These features, however, can sometimes be a problem because many natural product target sites may be unsuitable for a herbicidal mode of action due to general toxicity.

Determination of the mode of action of phytotoxins is a challenging endeavor due to the multitude of potential molecular targets. This short review will describe commercial herbicides that are either natural products or natural products-derived, and approaches to screening natural products for herbicides.

Bialaphos, a tripeptide analog of phosphinothricin (Figure 1), is the only natural broad-spectrum post-emergence herbicide (Figure 1). This fermentation product from *Streptomyces hygroscopis* cultures is marketed as a herbicide in eastern Asia. Bialaphos is a proherbicide that is bioactivated into phosphinothricin by plants before exerting its herbicidal action as a glutamine synthetase inhibitor. There are no other commercial herbicide with this mode of action. The commercial version of phosphinothricin is commercialized as glufosinate.



The triketone herbicides were derived from leptospermone (Figure 1), a herbicidal natural triketone component produced by bottlebrush (*Calistemon* spp.). Triketone herbicides inhibit *p*-hydroxyphenylpyruvate dioxygenase (HPPD), disrupting biosynthesis of carotenoids and causing bleaching (loss of chlorophyll).

Endothall (Figure 1) is a natural product-like herbicide that resembles cantharidin, a toxin produced by the blister beetle (*Epicauta* spp.). Endothall and cantharidin are strong inhibitors of plant serine/threonine protein phosphatases. This herbicidal mechanism of action is unique to endothall.

Figure 1. Phosphinothricin (the only natural product herbicide) and the similarity between some natural products (left) and their structurally related commercial herbicides (right).

Cinmethylin (Figure 1) is a structural analog of 1,4-cineole, a monoterpene present in the essential oils of many aromatic plants. The benzyl ether moiety was added to the monoterpene to lower the volatility of the natural product. A physionomics investigation of the mode of action of cinmethylin discovered a novel mechanism of action for herbicides, namely inhibition of plant tyrosine aminotransferase.

Screening for Natural Product for Herbicide Discovery

The successful examples mentioned above provide a good rationale for screening natural products to discover new herbicides. Investigating compounds from exotic organisms is a fairly common strategy. Phytotoxins from microbial origin are particularly interesting because large scale fermentation enables the production of sufficient amounts of toxins for agricultural use. Rediscovery of compounds is fairly common but the process is much faster with newer dereplication processes integrating analytical instrumentation and informatics. New interfaces between HPLC, mass spectrometry (MS) and nuclear magnetic resonance simplify the isolation and identification of natural products. Commercial, public and private databases of natural products as also available to identify previously known compounds.

The outcome of the isolation process is dependent on the sorts of bioassays used. These can range from enzymatic assays to whole organism assays. In general, target site-specific assays can be automated and miniaturized for high-throughput screenings but are likely to miss a large number of potential herbicidal compounds. We prefer miniaturized whole organism bioassays. These are slower but may be more suitable for natural product-based discovery processes. Indeed, bioassay-guided fractionation protocol based on *in vivo* responses minimizes the risk of missing active compounds (that would be overlooked in site-specific assays), and maximizes the possibility of discovering new molecular sites of action.

Carefully planned dose-response experiments that use whole organisms can yield important qualitative and quantitative information in evaluating the effect of the inhibitor, and also may offer some hints as to the possible sites targeted by the compound. We currently use the free statistical software R with the DRC module developed by Streibig and Ritz in Denmark. This program easily calculates the concentration necessary for any level of inhibition as well as calculating the selectivity index.

A great number of natural products with interesting phytotoxic profiles have been discovered but very few have been studied to the extent necessary to be considered as candidate compounds. Table 2 summarizes some of the better natural products to have been considered as herbicides.

Table 2. Relevant information on the natural products mentioned in the text.

Compound	Mode of action	Unique	Patent for herbicide use
Microbial source			
Thaxtomin A	Cellulose synthesis	New	Yes
Cyperin	Enoyl-ACP Reductase	New	No
Actinonin	Peptide deformylase	New	Yes
Phaseolotoxin	Ornithine carbamoyl transferase	New	No
Hydantocidin	Adenylosuccinate synthetase	New	Yes
Albucidin	Adenylosuccinate synthetase	New	No
Tentoxin	CF1 ATPase	New	No
Pyridazocidin	Photosystem I electron acceptors	No	No
Cinnacidin	Jasmonic acid-mimic	New	No
Ascaulitoxin	Unknown	New	No
Plant source			
Pelargonic acid	Removal of cuticles	New	Yes
Sarmentine	Removal of cuticles	New	Yes
Citral	Microtubule polymerization	New	Yes

Thaxtomin A (Table 2) is a phytotoxic cyclic dipeptide analog produced by *Streptomyces scabies* and other *Streptomyces* species, the causative agents of common scab disease in potato and other taproot crops. Thaxtomin inhibits cellulose synthesis by affecting the formation of the cellulose synthase complexes on the outside of the plasma membrane. This mode of action is different from that of known cellulose biosynthesis inhibiting herbicides such as dichlobenil and isoxaben, though the symptoms of the plants are similar.

Cyperin (Table 2) is produced by several fungal plant pathogens. This phytotoxic natural diphenyl ether that causes light-independent membrane degradation. We recently discovered that cyperin inhibits enoyl (acyl carrier protein) reductase (ENR). ENR is the molecular target site of the diphenyl ether triclosan which is commonly used as a component of antimicrobial soaps, but this enzyme has not been targeted by any commercial herbicide to date.

Actinonin (Table 2) is a naturally occurring hydroxamic acid pseudopeptide produced by a soil actinomycetes. It inhibits metallopeptidase peptide deformylase involved in initiating protein translation in prokaryotes by removing the *N*-formyl group from *N*-formyl methionine. Actinonin effectively controls a wide range of plants, including many agriculturally important and difficult-to-control weed species. This compound has been patented for herbicide use but no commercial product has been developed to date.

Phaseolotoxin (Table 2) is a sulfodiaminophosphinyl peptide produced by *Pseudomonas syringae* pathovars, the causal agent of halo blight on legumes. It is a competitive inhibitor of ornithine carbamoyl transferase.[51] Ornithine carbamoyl transferase is a key enzyme in the urea cycle which converts ornithine and carbamoyl phosphate to citrulline. No commercial herbicides have been developed to target this enzyme.

Hydantocidin (Table 2) is produced by different *Streptomyces* strains and has been the subject of intense research. It was at one time seriously considered as a natural herbicide,[52,53] but the cost of synthesis appeared prohibitive. Hydantocidin is a proherbicide that must convey bioactivity via phosphorylation in order to inhibit adenylosuccinate synthetase, and enzyme involved in purine biosynthesis.[54] The toxicological implications of this molecular target site may also have deterred development of a herbicide with this target site.

Albucidin (Table 2) was isolated from *Streptomyces albus*. The compound is a very potent nucleoside toxin that induces chlorosis and bleaching. Albucidin has moderate levels of pre-emergence activity, with broadleaf weeds being more sensitive than grasses. Pre-emergence herbicidal activity implied that the mechanism of action may involve metabolic perturbation not limited to bleaching, as the development of the majority of affected plants was halted at the cotyledonary stage. Post-emergence activity was broad spectrum. .

Tentoxin (Table 2) is a cyclic tetrapeptide produced by *Alternaria alternata* that causes extreme chlorosis of the foliage of sensitive species by inhibiting chloroplast development. Tentoxin inhibits the energy transfer of the chloroplast-localized CF1 ATPase. Tentoxin also interferes with the transport of the nuclear-coded enzyme polyphenol oxidase into the plastid of sensitive plants, but does not affect the transport insensitive species. The linked relationship between the effect of tentoxin on the β subunit of proton ATPase and polyphenol oxidase processing is not understood.

Pyridazocidin (Table 2) was purified from cultures of *Streptomyces*. Post-emergence application of pyridazocidin produced necrosis at high concentration and chlorosis at lower application rates. Pyridazocidin is positively charged and appears to act like bipyridinium herbicides (e.g. diquat) but disrupting photosystem I electron transport, resulting in rapid membrane lipid peroxidation.

Cinnacidin (Table 2) was isolated from a fungal fermentation extract of *Nectria* sp., a plant pathogen that causes cankers on many tree species. Cinnacidin causes stunting and chlorosis that spread throughout the foliar tissues. Its mode of action may be similar to that of coronatine and acts as a hormone-like herbicide by mimicking the role of jasmonic acid.

Ascaulitoxin has been isolated from the plant pathogen *Ascochyta caulina*. This natural product is already patented as a mycoherbicide. Its activity is associated with the production of the phytotoxin ascaulitoxin and its non-protein amino acid aglycone (2,4,7-triamino-5-hydroxyoctanoic acid) (Table 2). The mode of action is unknown but appears to be novel, possibly involving amino acid amino acid transporters.

Sarmentine (Table 2) is an example of the ethnobotanical approach to herbicide discovery from natural products. The fruits of long pepper (*Piper longum* L.) have been used in traditional medicine for the treatment of several diseases and ailments. Therefore, it is likely that this plant possesses a number of bioactive compounds. The bioassay-guided purification of the crude extract of long pepper led to isolation of the broad-spectrum contact natural herbicide sarmentine. The phytotoxicity of sarmentine matched that of herbicidal fatty acids such as pelargonic acid (Table 2). These molecules are broad-spectrum, foliar-applied, post-emergent herbicides that lead to plant desiccation and burndown.

Citral (Table 2) is a diterpene component of many plant essential oils that can account for up to 80% of the steam distillate, as in lemongrass (*Cymbopogon citratus* Stapf.). Citral is patented as a herbicide and is the active ingredient of a number of lemongrass oil-based natural herbicides. Citral disrupts plant microtubule polymerization rapidly. The phenomology of citral action on microtubule is distinct from that of well known mitotic inhibitors used as herbicides, such as oryzalin, suggesting that it may have a novel target site in disrupting mitosis.

Suggested Literature

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Career Opportunities for Weed Scientist

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There has probably never been a more important time to consider a career in the agricultural sciences, especially Weed Science! As we face the future, we'll have little choice but to face the age-old problems of hunger and resource limitations, but now on a global scale. To begin to meet this need, we must recognize that the solutions of the past just won't bring us any further than they already have. We are rapidly approaching a point where we, as a people, will no longer be insulated by the apparent abundance of food and as we approach the future, there are going to be greater and greater demands for agricultural output; this can't happen without an embrace of all forms of agriculture and a deep commitment to technology and innovation. We need to be producing more food, not less, to meet the needs of an expanding population. While the scale of this challenge is a bit intimidating, these difficult circumstances also bring us enormous opportunities to do things in new ways and this will require dedicated scientist, technicians and agricultural practitioners with new ways of seeing the world.

Here are several facts that should make you uncomfortable (and this is just a small subset of what's really going on!)!

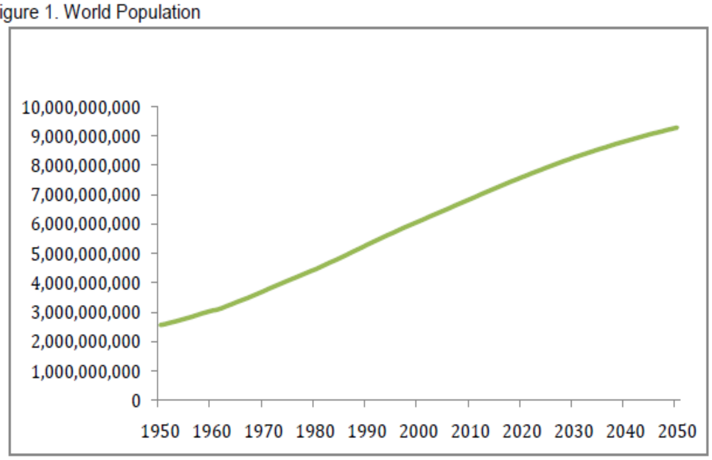
- In late 2007, several factors pushed up the price of grains consumed by humans as well as used to feed poultry and dairy cows and other cattle, causing higher prices of wheat (up 58%), soybean (up 32%), and maize (up 11%) over the year.
- Food riots took place in several countries across the world (Morocco, Yemen, Mexico, Guinea, Mauritania, Senegal, Uzbekistan and Pakistan). Contributing factors included drought in Australia and elsewhere, increasing demand for grain-fed animal products from the growing middle classes of countries such as China and India, diversion of food grain to biofuel production and trade restrictions imposed by several countries.
- An epidemic of stem rust on wheat caused by race Ug99 is currently spreading across Africa and into Asia and is causing major concern.
- Approximately 40% of the world's agricultural land is seriously degraded. According to UNU's Ghana-based Institute for Natural Resources in Africa, if current trends of soil degradation continue, the continent might be able to feed just 25% of its population by 2025,
- Water deficits, which are already spurring heavy grain imports in numerous middle-sized countries, including Algeria, Iran, Egypt, and Mexico, may soon do the same in larger countries, such as China or India.

<u>The Moral Imperative for a Career in Agriculture:</u>

The world is getting smaller and crowded! By 2050, the world's population is expected to grow to nearly nine billion (figure 1) – the equivalent of two more Chinas – and all the while, the ratio of agricultural land to population continues to decrease. The UN FAO predicts that global food production must double by 2050, and 70 percent of the world's additional food needs can be produced only with new or adapted agricultural technologies.

We've all seen charts like figure 1 below which depicts the projected rate of global population growth. And we know that this increase in population also means an increased demand for food, water, land, and other resources. Simply put: we will need to produce more food to feed more people.

Figure 1. World Population

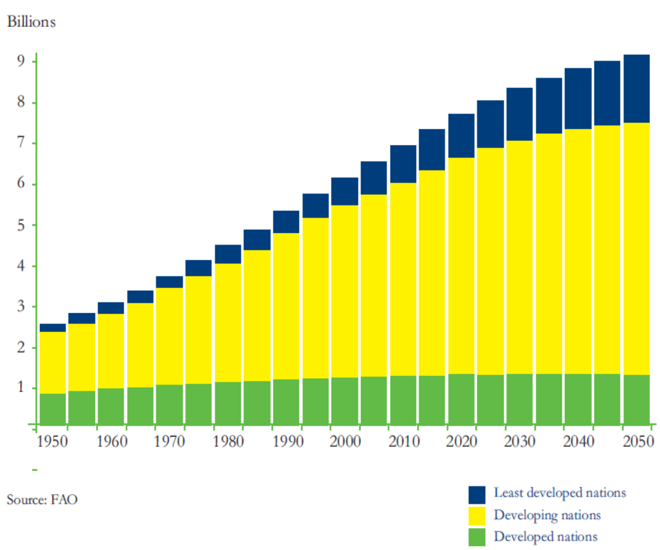


Source: U.S. Census Bureau. International Database. (Retrieved September 16, 2010). Available from: www.census.gov/ipc/www/idb/region.php

But this is a simple view. Let's add just one layer of complexity to this graph (figure 2).

Figure 2

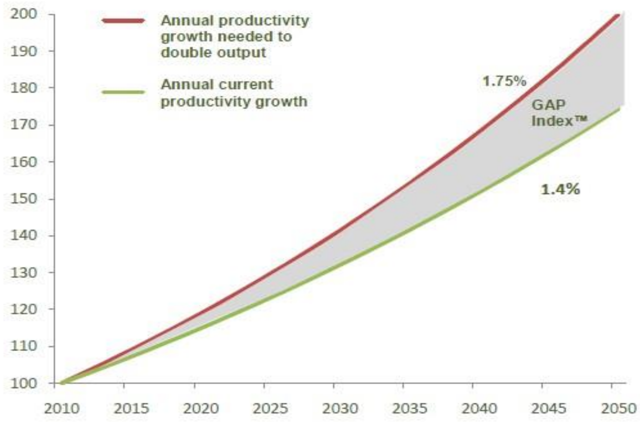
Figure 1
Global Population Growth



Source: FAO

This view breaks down the same projections by economic standing. At the bottom of the chart are the developed countries – such as the United States and much of Western Europe – which will show little growth and will, in fact, dip slightly over the next 40 years. At the top of the chart are the least developed countries – countries like Ethiopia, Liberia, and Tanzania in Africa, as well as Bangladesh, Cambodia, and Yemen in Asia, Samoa in the Pacific, and Haiti in the Caribbean. They will grow significantly within their category, but it's the middle of the chart where there's a cause for concern: developing nations, such as China, India, Egypt, and much of Eastern Europe, will continue to be the largest population and will also see dramatic growth over the next 40 years.

Figure 3. The Global Agricultural Productivity Index™



Source: Farm Foundation, NFP calculations (2010) based on USDA ERS data.

Figure 3 shows the gap between the current annual productivity growth rate (the bottom line) and the rate of growth needed to double production (the top line) without additional land resources.

What it boils down to is that we must increase the rate of productivity growth an average of 25% every year over the next 40 years just to meet the needs of the global population growth.

From even this simplest of viewpoints, there's already a projected gap of 1/3%, that's as of this morning.

There are many opportunities to contribute to the growth in productivity we need and Weed Science is just one, but it's a critical one! Weeds cause severe yield losses in arable and horticultural crops, which may be more than 34% worldwide. Weeds compete with crops for water, nutrients, light and space reducing crop yields. Weeds also contaminate seeds, foul milk, slow tillage, and interfere with harvesting practices as well as harboring diseases, insects and nematode pests. Additionally, weeds poison livestock, interfere with transportation, create fire hazards, block waterways, obstruct power lines and reduce land values. When the costs of weeds are combined with the cost of their control, the economic impact was calculated to be over $34 Billion[i].

Weed Scientist are called upon by growers, homeowners, and private or public agencies to provide information on Weed Biology and Management. Though the goals for industry academia do differ, there is substantial overlap, the objectives of each group are:

- Industry Scientist:
    - ❑ Generate new knowledge on herbicide Mode-of-Action and in chemistry, biochemistry and formulations science
    - ❑ Create, develop and make available new technology and vegetation management solutions
    - ❑ At the practitioner level, we apply these solutions to increase productivity.
- University Scientist (all roles) are expected to:
    - ❑ Train students in the art and science,
    - ❑ Generate and make public new knowledge on the biology, ecology, spread, and control of weed species in agriculture, aquatics, urban environments, parks and other recreation areas
    - ❑ Generate new knowledge on the interactions of taxa involved in natural and managed ecosystems.
    - ❑ Transfer that knowledge and technology to the practitioner

Weed Scientist have "new" and critical global issues trends that must be addressed, these will drive the future of the discipline and the define job opportunities in the twenty first century:

1. Serious problems with herbicide resistance require a re-thinking of weed management strategies in all crops
2. Impressive growth in the Agricultural Science Companies driven primarily by the development of transgenic crops with input and output traits require highly trained scientists and technicians
    a. Weed scientists, plant physiologists, molecular biologists, plant breeders, entomologists, plant pathologists, etc.
3. And the Organic Growers are desperate for solutions.

There are demographic trends in Weed Science that must be addressed if we are going to be able to populate the discipline:

- Will there be enough highly qualified Weed Scientists to satisfy demand in the public and private sector in the next 5 to10 years?
- Many Weed Scientist in academia and industry are expected to retire in the next 5-10 years (median age ≥ 55-58 years)
- In 2009, there were almost 5-times as many graduate students in entomology (1032) and 3-times as many in plant pathology (624) compared to Weed Science (220)[ii].

Qualifications!

- To work as a Weed Scientist in the greenhouse or field, you should:

- ❑ *Be fascinated by weed science* (including taxonomy and plant ecology), soil science, and agriculture.
- ❑ Have a minimum of a Bachelor's degree in a field such as agronomy, plant science, horticulture, range science, soil science, chemistry, biochemistry, genetics, or Ag engineering.
- ❑ For a laboratory research career you'll need a degree in chemistry, biochemistry, plant science, genetics or plant physiology.
  - *For research positions past technician, you'll need a Graduate degree.*
- ❑ To work in business, you should have an interest in sales, marketing, and economics plus a BA degree in business with emphasis on agribusiness or agricultural economics.
  - An MBA is helpful, but best with some on-the-job experience.

The jobs categories for Weed Scientists are only limited by your creativity, but here are a few!

- University Weed Scientist
- Farm Advisor, Extension Agent or Specialist
- Government Researcher (USDA ARS)
- Crop Protection Industry (at many levels)
- Pest Control Advisor or Certified Crop Advisor
- Professional Applicator
- Federal Regulatory (EPA) or State (DPR)

More-or-less typical University Weed Scientist job description:

- Responsibilities may include 55% research, 40% teaching, plus 5% advising and university service.
- Expected to develop an externally funded program in some area of plant production or agroecological research including specialty crops and teach classes in the same subject area.
- Develop research publications in peer-reviewed journals, teach and direct undergraduate and graduate students
- Create timely technical publications, training materials and programs for county extension staff, producers, agribusiness firms and other agencies
- Work independently and as a member of an interdisciplinary team to provide leadership for planning and implementing a statewide education programs.
- May also need to develop a strong extension and applied research program to evaluate new cultivars and agricultural technologies.

More-or-less typical Extension Weed Science Specialist job description:

- Leads in planning, implementing, and evaluating educational programs to *transfer weed control technologies.*
  - ❑ Knowledgeable in a broad range of weed control methods, chemical to cultural or mechanical.
  - ❑ Ability to explain the economic and environmental aspects of each option.

- Work with Farm Advisors, other Extension Specialists, faculty, land managers and the industry to conduct research on unmet State and local weed management needs.
- Develop a nationally competitive research program and obtain extramural grant funds.
- Minimum qualifications include:
  - Evidence of ability to communicate orally and in writing,
  - Ability to work effectively in a team environment with Extension and agribusiness personnel
  - Ability to effectively instruct undergraduate and graduate students
  - Skills regarding the effective use of electronic media in education and communication of technical information.

Weed Science Careers in USDA Agricultural Research Service:

- ARS is the principal research agency of the USDA charged with extending scientific knowledge and solving agricultural problems.
- Weed Scientist career options exist in two programmatic areas:
  - Natural Resources and Sustainable Agricultural Systems and
  - Crop Production and Protection.
- Program goals include research to improve strategies for cost-effective management of native and invasive weed pests, while minimizing impacts on the environment and human health.
- Careers span a variety of disciplines - chemistry, plant physiology, plant pathology, genetics, microbiology, engineering, soil science, and agronomy.
- Grade levels for research scientist positions in ARS are set using the Research Position Evaluation System (RPES).
  - The RPES is a peer review system based on the "person-in-the-job" concept and scientists have open-ended promotion potential based on their personal research and leadership accomplishments, this can change the complexity and responsibilities of their positions.

Careers as a California Pest Control Advisor

- A**ny person who offers a recommendation** on any agricultural use of a pest control product or technique and presents himself/herself as an authority on any agricultural use, or solicits services or sales for any agricultural pest control tool is a **Pest Control Adviser (PCA)**.
- **PCAs are tested to insure they're knowledgeable and proficient in all aspects of crop production and management.**
  - Exams are given (approximately) each month.
- **To become a PCA,** you must meet specific educational requirements, pass the laws, regulations, and basic principles exam, and pass an exam in a pest control area.
  - **Educational requirements:** At least 45 college-level semester units (67.5 quarter units) of required courses in the biological, agricultural, and pest management sciences.
- **California requires continuing education (CE)** for PCAs and pesticide applicators prior to license renewal.

There are many Weed Science roles in Industry, here's just a few:

- Field research scientist
- Discovery scientist (biologist, chemist, biochemist, molecular biologist)
- Characterization leader for discovery technology
- Technical expert to support commercial products
- Technology transfer

Opportunities in Industry don't preclude academic involvement and industry Weed Scientists have the opportunity to:

- Publish with academic scientists
- Accept Adjunct professorships
    - Stay involved with professional societies and participate and Associate Editors for scientific journals and act as Scientific Society Officers

Industry Field Research Scientist job description:

- Thrives in a fast-paced working environment as a part of a research and development team.
- Collaborates with other R & D team members to shape and meet product development goals
- Plans and conduct field, greenhouse and laboratory based experiments to evaluate plant health and herbicide efficacy.
- Generates, collect and prepare experimental data for presentation both internally and at regional and National scientific meetings.
- Coordinate with field and greenhouse staff to properly prepare fields and obtain permits and supplies necessary for research.

OK, I'm a field scientist… what's next???

- The opportunities moving forward are diverse and plentiful!
    - People leadership?
    - Regulatory?
    - Discovery?
    - Project leader?
    - Commercial?
    - Career field scientist?

Opportunities in Industry progress through a Variety of Roles and Work Experiences…

- Within a job, will likely work on a variety of projects over time and train in other disciplines
- Job change can be good to maintain enthusiasm and stimulate learning
- Job change does not necessarily require a geographical move

Non-technical competencies are important in any and every role! Non-technical competencies are:

- The basis for personal and professional effectiveness
- Transferable from one project, job/role to another
- Provide evidence of sustainable ability and flexibility
- For recruiting and hiring purposes, serve as strong discriminating factors when evaluating a large pool of available technical talent
    - Note: Non-technical skills are seldom formally taught in graduate school

Examples of Non-technical skills (Also called Key competencies)

- Leadership
- Teamwork
- Embraces Change
- Initiative/Accountability
- Interpersonal effectiveness
- Innovation & Value creation

These skills form basis of an employee performance review in almost any position!

In summary, Weed Science Careers are:

- Interesting, rewarding, important and diverse careers
- Can be found within Academia, Government, Multi-national crop protection companies and at the local level
- Continuous learning and improvement combined with flexibility are essential for personal growth
- Non-technical "soft skills" are critical for success and interpersonal effectiveness

There's never been a better time to be in the Agriculture Sciences!

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[i] Pimentel D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52 (2005) 273– 288

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The Three Fs: Filaree, Fluvellin, Fleabane (Actually The Two Fs and a W: Filaree, Fluvellin and Willowherb)

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I will begin with an explanation of the title. While 'Filaree, Fluvellin, Fleabane' are all problem weeds and it makes an intriguing title, hairy fleabane [*Conyza bonariensis* (L.) Cornq.] is not yet established as a serious weed of vineyards in California's North Coast vineyards where I conduct my research. Conversely, Panicle willowherb [*Epilobium brachycarpum* C. Presl] is well established in this area.

Several weeds have become established in vineyards due to the changing management practices adopted by a majority of growers in the North Coast (mainly Napa and Sonoma, but also Lake, Mendocino, Solano and Yolo). The change from heavy cultivation (French plow or disk) under the vines every year, to much lighter cultivation, or in many cases to 'no-till' and a dependence on glyphosate, or 'Roundup only' has changed the species that make up the major weed problems in vineyards.

I will summarize three experiments that effect the population of these weeds. The first experiment conducted in the winter of 2008 shows the effect of accumulated grapes on herbicide efficacy and resulting reduction in control of filaree [a combination of two species: Whitestem filaree (*Erodium moschatum*) and redstem filaree (*Erodium cicutarium*)] and panicle willowherb. The experiment was conducted in a mature Merlot grape vineyard in Rutherford, Napa County, California. Initially eight sets of paired treatments were established (One paired plot was eliminated because the vines in the plot were recently replanted allowing more sunlight to reach the ground, unlike the other plots). Each plot was 4 vines (24 feet) long. The pair treatments were: 1. Leaves in vine row removed; or 2. Leaves in vine row left in place. The grape leaves in the leaves removed plots were raked by hand within 1 hour before herbicide application. All plots were then treated with 10 oz of Chateau(flumioxazin) +24 oz Roundup(glyphosate) (product on a per acre basis)using a OC02 Off -center nozzles sprayed from both sides of row.

Table 1.	March 1		June 12	
% Leaf Cover	% Filaree Cover		% Willowherb control	
	Raked	Not	Raked	Not
60	5	50	100	70
50	7	30	100	50
50	15	40	90	40
40	3	20	90	50
40	5	10	100	70
33	1	15	90	70
25	5	20	100	70
AVE	8.30%	28%	96%	60%

The left column denotes the percentage of area under the vine covered by grape leaves. This area was determined visually in a .5 by 1 meter area. The amount of weed cover or control (filaree and willowherb) was also determined by visual evaluation. Due to the time of year, biology of filaree, and postemergence nature of the Roundup plus Chateau application, filaree was evaluated by percent coverage. Willowherb was evaluated 180 days after application and was evaluated on percent control.

Weed control in all raked treatments was improved in each paired plot. The differences were greater in the plots where raking was compared with the highest percent leaf cover. Because this operation, done commercially with sweeper or blower, would increased equipment costs, and possibly an additional pass through the field and may not be warranted at leaf cover percentages at 30 % and below.

In a second trial conducted in 2011 at the UC Davis Oakville Research Station to test several herbicides for their ability to control fluvellin (*Kickxia elatine*).

Treated 12/8/11		3/8/12		5/22/12			7/9/12			8/7/12	
Treatment[1]	Rate[2]	FLU		OA[3]	FLU[4]		OA	FLU		OA	FLU
1.UTC		9.75		1.0	9.25		6.75	8.88		4.75	7.25
2.Rely 280 (glufosinate)	2 qt	8.0		5.0	7.0		4.50	5.75		6.75	7.5
3.Roundup WM (glyphosate)	2 qt	7.25		6.25	6.75		4.25	4.75		7.0	9.88
4.Trellis (isoxaben)	1 lb	9.75		7.50	9.63		8.25	9.25		7.0	8.75
5.Chateau(flumioxazen)	12 oz	10.0		8.75	9.25		8.50	8.50		6.25	7.0
6.Goal 2X (oxyflourfen)	3 qt	9.37		6.50	6.25		5.63	5.88		3.75	4.75
7.Shark (carfentrazone)	2 oz	7.25		6.0	6.5		5.0	5.0		8.25	9.5
8.Venue (pyraflufen ethyl)	4 oz	7.25		5.5	6.25		5.0	5.75		7.75	9.5
9.Zeus (sulfentrazone)	12 oz	7.87		6.5	7.25		5.0	5.25		3.5	3.75
10.Matrix (rimsulfuron)	2 oz	8.25		7.5	7.25		4.50	4.75		2.75	2.75
11.Alion (indaziflam)	5 oz	9.87		8.25	8.75		7.38	7.50		6.50	6.75

[1] All treatments, except Rely 280 were applied with added 2 qt/acre Roundup Weather Max.
[2] Rate is in amount of product per acre.
[3] OA = Overall weed control rating on a 1-10 scale (1 no control; 10- complete control)
[4] Flu = Fluvellin weed control on a 1-10 scale (1 no control; 10- complete control)

This trial was conducted in an area of the Oakville research station not planted to grapes. Applications were made to plots 10ftx 10ft with a 3 nozzle boom using 8002 XR nozzles delivering 30 GPA. The area was heavily infested with fluvellin. Fluvellin was present but not actively growing at the time of application. All treatments except Rely 280(glufosinate) contained 2 qts/acre of Roundup WeatherMax (glyphosate) for postemergence activity. Treatments 2, 3, 7, and 8 (all postemergence only treatments) were reapplied on July 10, 2012)

Because fluvellin is capable of germinating very late in the growing season it is important that preemergence treatment last long enough to control germination. The purpose of this trial is to determine which of the preemergence herbicides can control fluvellin throughout the season and which postemergence treatments are the most effective.

Fluvellin appears to germinate best in clean (no weed growth), warm soil. Practically this means that if a grower uses a preemergence herbicide to provide weed control the herbicide must last throughout the season, or make a second postemergent application, to insure that the fluvellin is controlled.

Analyzing the results show that Trellis (isoxaben), Alion (indaziflam) and Chateau (flumioxazin) were the best preemergence herbicides in this trial, providing nearly season-long control. It is interesting that the untreated control plot had almost no fluvellin which equates to control equal to, or better than, both the Alion and Chateau treatments. This is true because of the abundance of other weeds, especially annual fescue that was established in this area. Fluvellin does not grow well in areas where there are other competitive plants growing. I feel this is due first to competition, and to the fact that the soil will be cooler longer into the season when compared to 'clean' soil.

The third study is a preliminary evaluation of a long-term study comparing three weed control methods: 1. Cultivation; 2. Postemergent weed control only; 3. Post+premeregence herbicide treatment. Future evaluation may include measuring water penetration and other differences between the three treatments. This study is being conducted at the UC Davis Oakville Research station in a vineyard that has been treated with a tank mix of post+ preemergence herbicide for the last five years. This is important because of the demonstrative differences in weed composition in the three treatments within one year.

Percent 'hits' in transect[1]							
Treatment	Willowherb	Blando Brome	Bristly Oxtongue	Zorro Fescue	Fluvellin	Field Bindweed	Bur Clover
Cultivate	2.2	23.0	0.7	51.8	0.4	1.7	3.3
Glyphosate	29.3	1.9	6.5	0.8	7.8	0.3	0.2
Glyphosate + Chateau	0.7	0	0	0	0	4.0	0

[1] Ratings are based on average of 4 replications of the percent of transect hits recorded every 6 inches for 128 feet directly under the vinerow of the middle row of each 3 row plot

Treatments were applied by a commercial management company using a Clemens (cultivator) and ATV applicator using a single OC02 nozzle for herbicide application.
Cultivation was done on December 5, 2011 and May 2, 2012. The herbicide applications were made December 14, 2011. The postemergence only treatment was Roundup (glyphosate) 2

quarts/acre of product and the post + preemergence treatment was Roundup at 2 quarts + Chateau (flumioxazin) 10 oz/acre of product.

Readings taken with a transect in the middle row of the three row plots (126 ft- read every 6 inches) show that the composition of weeds has quickly changed. Willowherb is by far the most prevalent weed in the glyphosate only treatment, with fluvellin being the second most abundant. The grasses Blando Brome and Zorro fescue were predominate in the cultivated plot with willowherb and fluvellin found in only 2.2 and 0.4% of the points respectively. In this trial there were almost no weeds in the post + preemergence treatment. These preliminary results show that there is a major difference in weed composition after only one year after changing weed management practices and that acceptable weed control for multiple years with preemergence herbicides does not necessarily mean that a grower can switch to a postemergence herbicide and expect any residual control.

Post-emergence Weed Control Options in Tree Nut Orchards

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Herbicides are the primary means of vegetation management in tree nut orchards in California. Among registered herbicides, post-emergence (POST) materials, like glyphosate, are the most widely used in tree crops because of low cost and broad weed control spectrum. However, herbicide resistance has compromised the efficacy of POST only herbicide programs in many parts of the state. Most cases of resistance in orchards are glyphosate-resistant hairy fleabane, horseweed, ryegrass, and junglerice. To manage resistant weed species, pre-emergence (PRE) herbicides can be applied during winter before weeds emerge; however, PRE herbicide use can be limited by cost and the need for rainfall to incorporate them. Even when PRE herbicides are used, most orchards will need a POST treatment to control weed escapes and to prepare the orchard for harvest operations.

One approach to optimize control of late emerging or glyphosate-resistant weeds is to use alternate herbicides, mixtures, rates, or more appropriate application timing. The objective of this project was to evaluate POST control of hairy fleabane and yellow nutsedge with different herbicides combinations.

Methods

Field experiments were conducted in a three year-old almond orchard infested with hairy fleabane and yellow nutsedge. The orchard was located in a sandy soil area in Merced County, and irrigated with solid set sprinklers. The area is known to be infested with glyphosate-resistant hairy fleabane. Hairy fleabane had been mowed for 3 to 4 times during season and allowed to regrow to six inches in height (bolting) before the treatments were applied. Nutsedge was still at vegetative stage with 8 to 12 leaves. Other species also found sparsely distributed at the site were three-spike goosegrass, large crabgrass, spotted spurge, and cut-leaf evening primrose.

Hairy fleabane treatments were applied to 20 by 7.5 ft plots between the tree rows on July 23 and August 21, 2012 for the first and second hairy fleabane trials, respectively (table 1). Spray equipment was a CO2-pressurized back pack sprayer using TT11002 (Teejet) nozzles and calibrated to deliver 25 gallons per acre. Percent visual control (%), weed density (plants per square meter), and plant biomass (g m^{-2}) were recorded 28 days after treatment (DAT). ANOVA analysis indicated no differences between experimental runs therefore data were combined.

The yellow nutsedge trial was conducted within the tree rows, and percent visual control (%) was recorded 35 DAT. Treatments were applied on August 21, 2012 using the previously described equipment. Treatments included herbicides known to have activity on nutsedge as standard comparison; however, not all tested treatments are registered for use in almonds (table 2).

Results – hairy fleabane trials

Hairy fleabane was not controlled with glyphosate (trt-2), carfentrazone (trt-3), or the tank mix of both herbicides (trt-4) 28 DAT. These treatments were not significantly different than untreated control in percent control or biomass (table 1, figure 1). Glyphosate and glyphosate + carfentrazone treatment reduced biomass of other species present at the site, but not biomass of hairy fleabane supporting the reports of glyphosate resistance in this population.
Good (>85%) to excellent (>95%) control of hairy fleabane was provided by treatments that included glufosinate (trt 5, 6 & 9), saflufenacil (trt 7, 8, 9 & 17), 2,4-D (10, 11, & 12), or paraquat (13, 14, & 19). The majority of these treatments completely eliminated hairy fleabane plants by 28 DAT (figure 1). These treatments could be used during pre-harvest weed control, when bare ground is desired, provided that their use follows label recommendations for pre-harvest interval.

Effective treatments for hairy fleabane control are also needed for other weed species, but not all tested treatments succeeded in both duties. Saflufenacil (trt 7) and 2,4-D (trt 10) treatments provided no control of other species, mainly grasses, present in the site. These herbicides are not active in grass species, and for this reason are recommended with burndown partners herbicides like glyphosate. Tank mixes of glyphosate + saflufenacil (trt 7) and glyphosate + 2,4-D (trt 11) provided excellent control of all species as indicated by biomass accumulation (figure 1). Mixtures of herbicides with different mode of actions, as the case of these treatments, are a good strategy to delay the onset of herbicide resistance and manage existing resistant species. Another approach for managing glyphosate-resistant weeds is the sequential herbicide application, as the case of glyphosate followed by paraquat (trt 14). In this treatment, the initial glyphosate application was followed 14 days later with a paraquat treatment. Excellent control of all species was provided by this treatment, but not statistically different than the paraquat treatment (trt 13). The sequential application has the disadvantage of additional application costs.

The residual herbicides penoxsulam/oxyfluorfen (trt 15), rimsulfuron (trt 16), and flumioxazin (trt 18) with glyphosate did not provide acceptable POST control of established hairy fleabane. These herbicides are effective for pre-emergence and early post-emergence control of hairy fleabane and many other weed species. When mature weeds are present, it is necessary to tank mix these herbicides with post-emergence herbicides such as glyphosate. However, the addition of glyphosate did not improve control of the glyphosate-resistant hairy fleabane in advanced stage of development. Tank mixes of glyphosate + rimsulfuron + saflufenacil (trt 17) or paraquat + flumioxazin (trt 19) provided excellent control of all species. These results indicate the importance of post-emergence herbicides to complement pre-emergence herbicide programs. Likewise it reiterates the importance of preserving the post-emergence herbicides for the long term to avoid onset of new resistance. Populations of hairy fleabane resistant to both glyphosate and paraquat are present in the state. The management of multiple-resistant populations would be greatly limited by the loss of paraquat susceptibility.

Yellow nutsedge trial

Best activity on nutsedge was provided by treatments including flumioxazin (trt 4), halosulfuron (trt 13), rimsulfuron (trt 12), and penoxsulam/oxyfluorfen (trt 9) (table 2, figure 2). Best POST activity (greater than 95% control) was observed up to three weeks after application (data not shown), and control started to decline at 35 DAT. Flumioxazin, rimsulfuron, and penoxsulam/oxyfluorfen are registered for almonds. These treatments did not provide acceptable post-emergence control of hairy fleabane, but did control yellow nutsedge up to 35 DAT thus may be a promising alternative for suppressing nutsedge.

Glyphosate, glyphosate + saflufenacil, glyphosate followed by paraquat, or glyphosate + glufosinate provided only initial suppression of nutsedge. The burndown activity of these treatments were only visible for the first three weeks (data not shown), and would require multiple application during the season in order to continue suppressing nutsedge growth.

Conclusion

There are herbicides to control hairy fleabane and yellow nutsedge. Mixtures of herbicides with different mode of action were, in some instances, superior to single herbicide application due to greater spectrum of weed control.

The success of post-emergence activity is dependent on the species present at the time. Some pre-emergence herbicides tested also provided good burndown activity in selected species, but the long-term activity was not evaluated in this trial. Additional research is required to evaluate timing of application for the pre-emergence material in order to explore its maximum potential of burndown and residual activity. However, because post-emergence herbicides will still be required to complement pre-emergence program, it is important to preserve post-emergence active ingredients for effective, season-long weed control in orchards.

Table 1. Hairy fleabane visual control (%) with herbicide combinations 28 days after treatment.

Trt #	Treatment	Rate per acre		Control %	(SE)
1	untreated control			0	(0.0)
2	Roundup Powermax (glyphosate) + NIS + AMS	27.6	fl oz	3	(1.6)
3	Shark EW (carfentrazone) + NIS + AMS	2	fl oz	1	(1.3)
4	Roundup Powermax (glyphosate) + NIS + AMS	27.6	fl oz	14	(5.3)
	Shark EW (carfentrazone)	2	fl oz		
5	Rely 280 (glufosinate) +AMS	69	fl oz	88	(4.1)
6	Roundup Powermax (glyphosate) + AMS	27.6	fl oz	82	(12.6)
	Rely 280 (glufosinate)	69	fl oz		
7	Treevix (saflufenacil) + AMS + MSO	1	oz	96	(2.6)
8	Roundup Powermax (glyphosate) + AMS + MSO	27.6	fl oz	92	(3.4)
	Treevix (saflufenacil)	1	oz		
9	Rely 280 (glufosinate) + AMS + MSO	69	fl oz	95	(2.5)
	Treevix	1	oz		
10	Dri-Clean (2,4-D)	27	oz	85	(9.6)
11	Roundup Powermax (glyphosate)	27.6	fl oz	99	(0.7)
	Dri-Clean (2,4-D)	27	oz		
12	Rely 280 (glufosinate) + AMS	69	fl oz	100	(0.3)
	Dri-Clean (2,4-D)	27	oz		
13	Gramoxone SL (paraquat) + NIS	4	pt	99	(0.6)
14	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	98	(1.2)
	[1]Gramoxone SL (paraquat) + NIS	2	pt		
15	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	54	(5.0)
	Pindar GT (penoxsulam/oxyfluorfen)	1.5	pt		
16	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	43	(5.0)
	Matrix (rimsulfuron)	2	oz		
17	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	94	(2.5)
	Matrix (rimsulfuron)	2	oz		
	Treevix (saflufenacil)	1	oz		
18	Roundup Powermax (glyphosate) + AMS + NIS	27.6	fl oz	11	(2.3)
	Chateau (flumioxazin)	6	oz		
19	Gramoxone SL (paraquat) + NIS	4	pt	100	(0.1)
	Chateau (flumioxazin)	6	oz		
		Tukey's critical value		30	

[1]paraquat applied 14 days after glyphosate treatment

abbreviations: NIS – non-ionic surfactant R-11 at 0.25% v/v; SE – standard error; AMS – ammonium sulfate Pro AMS plus at 10 lb/100 gal; MSO – methylated seed oil Monterey MSO at 1 % v/v

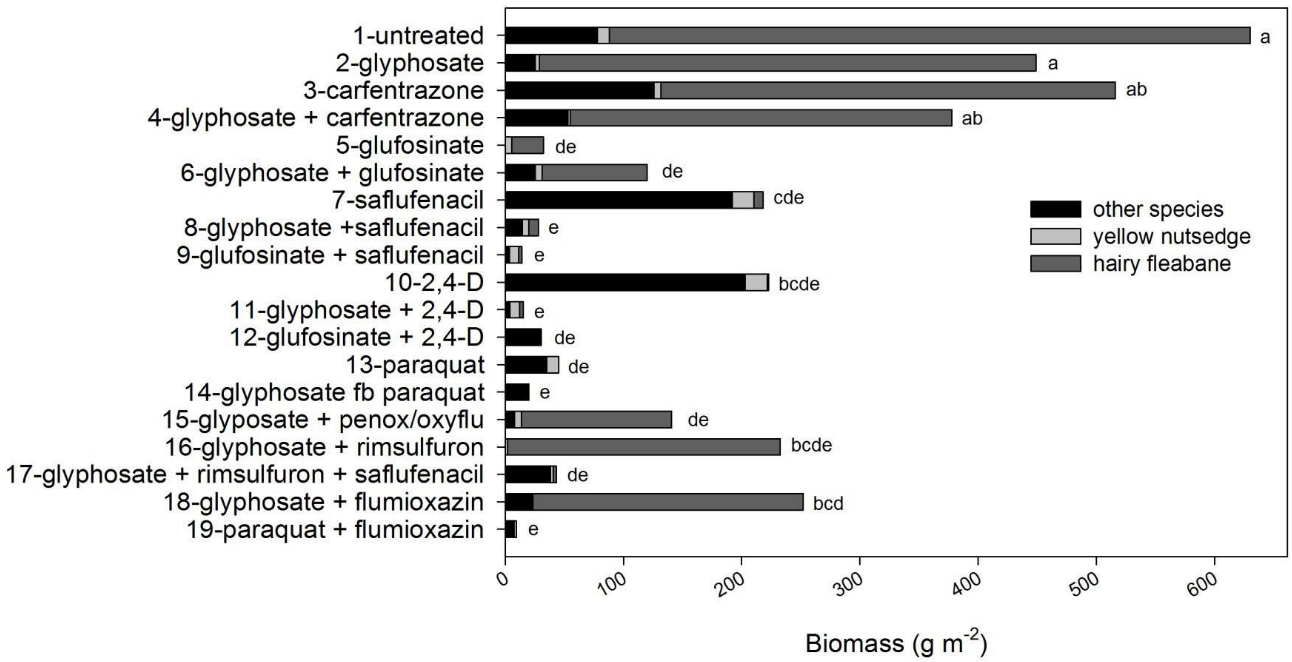

Figure 1. Weed dry biomass 28 day after herbicide treatment. Biomass of sparsely distributed species such as cut-leaf evening primrose, large crab-grass, three spiked goosegrass, and spotted spurge, were combined and are represented as black bars. Bars followed by the same letters are not statistically different according to Tukey's test (p<0.05).

Table 2. Yellow nutsedge visual control (%) with herbicide combinations 35 days after treatment.

Trt #	Treatment	Rate per acre		Control %	(SE)
1	Untreated			0	(0)
2	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(8.6)
3	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	20	(4)
	Treevix (saflufenacil)		oz		
4	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	89	(3.1)
	Chateau (flumioxazin)	12	oz		
5	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(8.6)
	Goal 2XL (oxyfluorfen)		oz		
6	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	50	(10.8)
	Goal 2XL (oxyfluorfen)		oz		
7	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	48	(7.5)
	Goal Tender (oxyfluorfen)		oz		
8	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	65	(8.6)
	Tangent (penoxsulam)	1.67	oz		
9	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	70	(7)
	Pindar GT (penoxsulam/oxyfluorfen)	2.5	pt		
10	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	55	(9.6)
	Zeus (sulfentrazone)	6	oz		
11	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	55	(8.7)
	Matrix (rimsulfuron)	2	oz		
12	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	70	(0)
	Matrix (rimsulfuron)	4	oz		
13	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	75	(6.5)
	Sandea (halosulfuron)	1	oz		
14	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	80	(0)
	Outrider (sulfosulfuron)	1.33	oz		
15	Roundup PowerMax (glyphosate) + AMS + NIS	28	fl oz	45	(9.5)
	Rely 280 (glufosinate)	48	fl oz		
16	Roundup PowerMax (glyphosate) + MSO + AMS	28	fl oz	43	(8.5)
	[2]Gramoxone SL (paraquat)	48	fl oz		
	Tukey's critical value			39	

[1]glyphosate rate is expressed as acid equivalent (ae); [2]paraquat applied 14 days after glyphosate treatment

abbreviations: NIS – non-ionic surfactant R-11 at 0.25 % v/v; SE – standard error; AMS – ammonium sulfate Pro AMS plus at 10 lb/100 gal; MSO – methylated seed oil Monterey MSO at 1 % v/v

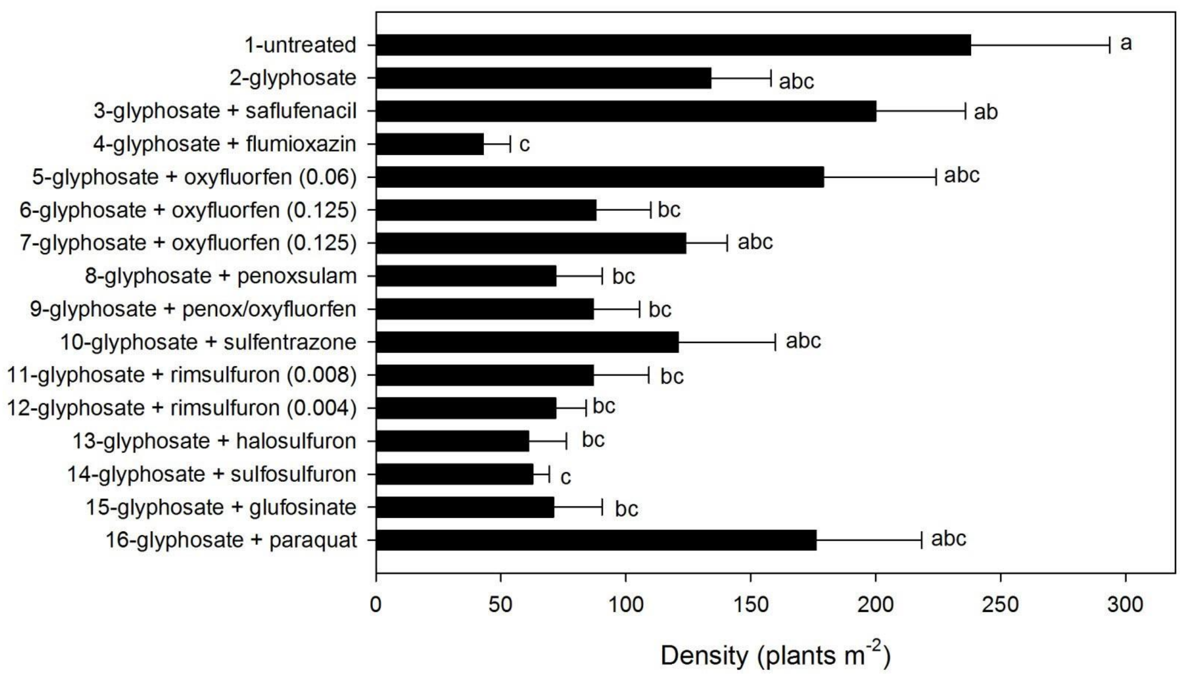

Figure 2. Yellow nutsedge plant density 35 days after herbicide treatment. Bars followed by the same letters are not significant different according to Tukey's test (p<0.05).

New Herbicide Uses for California Tree and Vine Crops

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For decades, herbicides have been used for weed management in perennial tree and vine crops in California. When used under the right conditions, herbicides provide effective control of a large variety of weeds and aid crop growth and productivity. While both pre- and postemergent herbicides are widely used, there has been a trend towards greater reliance on postemergent materials in recent years, particularly glyphosate (Figure 1). Between 2000 and 2005, growers relied mostly on five herbicide active ingredients (glyphosate, oxyfluorfen, paraquat, oryzalin, and simazine) for weed control in tree nuts, stone fruits, and grapes (Figure 2). In 2010, more than 80% of the acreage in the state was treated with three herbicide mode of actions (MOA), with over 40% attributed to a single MOA; the EPSP synthase inhibitor, glyphosate (Figure 3).

Widespread reliance on glyphosate in postemergent-only programs has contributed to glyphosate-resistant horseweed, hairy fleabane, rigid ryegrass, and junglerice in the state. Also, the implementation of regulated groundwater protection areas (GWPA) in 2004 contributed to this increase in glyphosate use as growers replaced using preemergent herbicides, like simazine, bromacil, and norflurazon (sensitive to runoff and leaching in GWPA), with safer alternatives, including glyphosate.

Figure 1. Herbicide use in trees and vines in CA
(by herbicide type in tree nuts, stone fruits, and grapes)

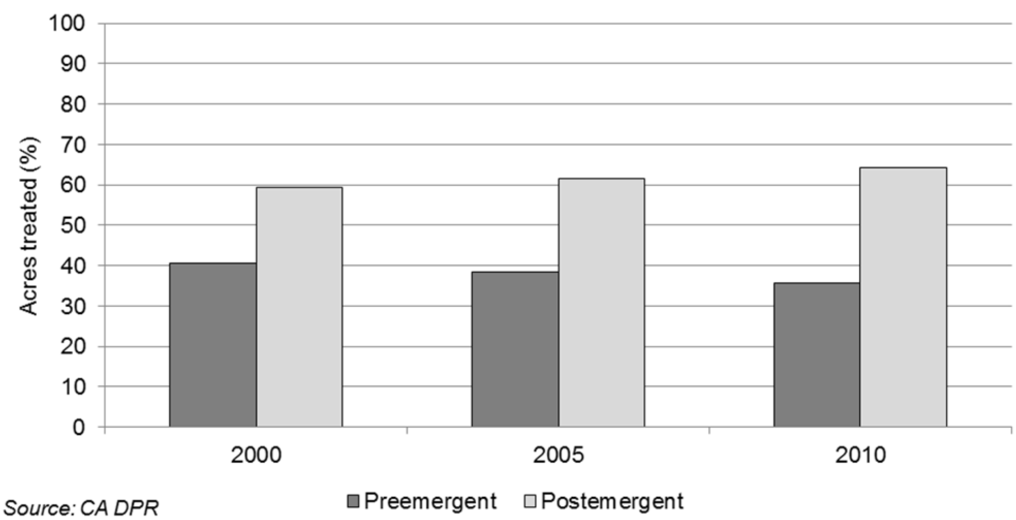


Figure 2. Herbicide use in trees and vines in CA
(by active ingredient in tree nuts, stone fruits, and grapes)

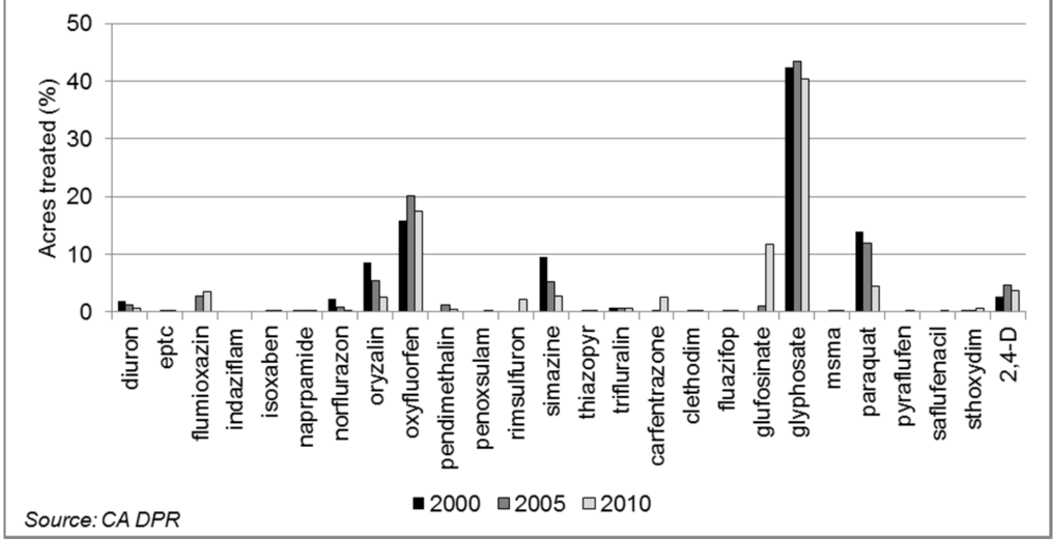
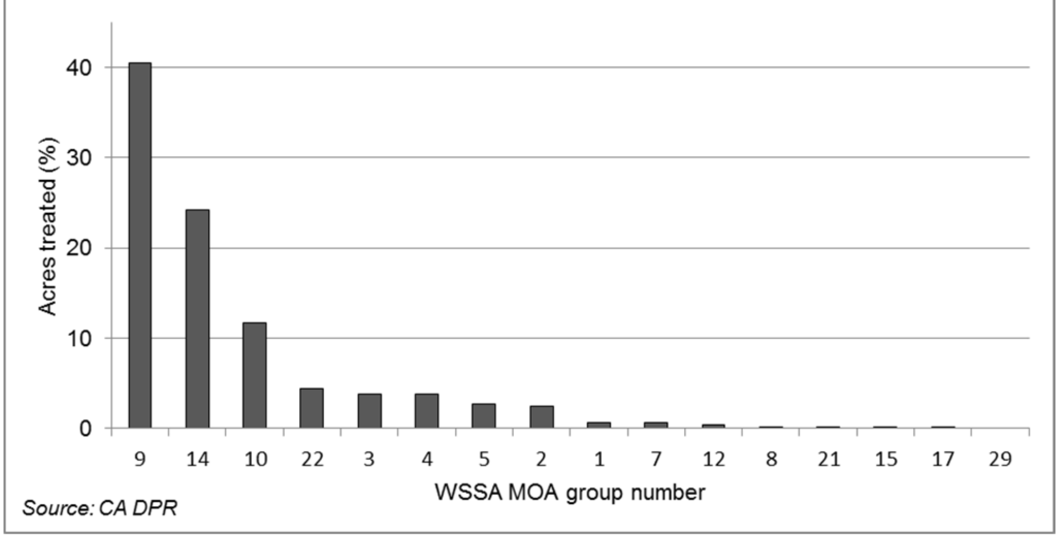


Figure 3. Herbicide use in trees and vines in CA in 2010
(by WSSA group number in tree nuts, stone fruits, and grapes)



Currently, there are about 30 herbicide active ingredients with 16 different MOAs (by WSSA group number) registered for use in the various perennial tree and vine crops in California (see table). Since 2004, eight new herbicide active ingredients with three new MOAs were registered for use. These materials were developed, in-part, in response to a need to find safer alternatives that could be used on farms located in GWPAs and offer control of a wide-array of weeds, including those resistant to glyphosate. While these newer herbicide have only been available a few years, they are already having a positive impact on the ability of growers to manage glyphosate-resistant weeds and others. These herbicides are not available for use in all tree and vine crops grown in the state, but each has its own fit in a particular set of crops. With the addition of these new herbicides, growers have been more diligent in rotating or tank-mixing herbicides with different MOAs to help maintain weed control and combat weed resistance.

Herbicides currently registered in perennial tree and vine crops in California

WSSA	HRAC	Herbicide mode of action	Herbicide active ingredient	Activity
1	A	Acetyl CoA carboxylase inhibitor	clethodim, fluazifop-p-butyl, sethoxydim	POST
2	B	Acetolactate synthase inhibitor	rimsulfuron*, penoxsulam*	PRE
3	K1	Microtubule assembly inhibitor	oryzalin, pendimethalin, thiazopyr, trifluralin	PRE
4	O	Synthetic auxin	2,4-D	POST
5	C1	Photosystem II inhibitor	bromacil, simazine	PRE
7	C2	Photosystem II inhibitor	diuron	PRE
8	N	Lipid synthesis inhibitor	EPTC	PRE
9	G	EPSP synthaseinhibitor	glyphosate	POST
10	H	Glutamine synthase inhibitor	glufosinate*	POST
12	F1	Carotenoid biosynthesis inhibitor	norflurazon	PRE
14	E	Protoporphyrinogen oxidase inhibitor	flumioxazin*, oxyfluorfen carfentrazone*, flumioxazin*, oxyfluorfen, pyraflufen*, saflufenacil*	PRE POST
15	K3	Cell division inhibitor	napropamide	PRE
17	Z	Unknown (Organoarsenicals)	MSMA	POST
21	L	Cellulose biosynthesis inhibitor	isoxaben	PRE
22	D	Photosystem-I-electron diversion	paraquat	POST
29	L	Cellulose biosynthesis inhibitor	indaziflam*	PRE
*Registered for use in California since 2004				

In California, preemergent materials are mainly applied during the winter dormant period to take advantage of winter rainfall for incorporation and activation and to improve crop safety. Here, newer materials like flumioxazin, rimsulfuron, penoxsulam, and indaziflam are providing good residual weed control. Postemergent herbicides, like glyphosate, glufosinate, and 2,4-D are added to the spray tank to control weeds that are emerged at time of treatment. Combinations of preemergent products (i.e. flumioxazin plus pendimethalin, indaziflam plus rimsulfuron, etc.) with different MOAs are often used to provide long-term control of a wide-array of weeds like hairy fleabane, horseweed, and ryegrass. In many cases, residual control with the newer materials last six months or more. Efficacy is usually improved where leaves and other trash are mechanically blown from the soil surface before the herbicides are applied. As the newer preemergents become more widely used, growers should see improved overall weed control and a need to rely less on postemergent materials for control.

Since about 2005, glufosinate has been an important herbicide for the control of established horseweed, hairy fleabane, grasses and other weeds not readily controlled with glyphosate. Glufosinate is often combined with glyphosate to control a large number of weeds, including nutsedge. To date, no weeds have shown resistance to glufosinate. However, lack of glufosinate availability in California since 2011 has caused growers to turn to other alternatives for burn-down control efforts, like using saflufenacil in tree nut crops. Since saflufenacil does not control grassy weeds, it too is usually combined with glyphosate to help control grassy species. A selective grass herbicide, like sethoxydim, is sometimes used to control glyphosate-resistant junglerice if glufosinate is unavailable. Paraquat continues to be an important player in postemergent weed control efforts. However, since it is a Restricted Use Pesticide, it requires a permit to purchase and use, a closed system for delivery, and special protective clothing during mixing, loading, and application, which sometimes discourages its use.

Tree and vine growers in California are fortunate to have a fairly large number of herbicide active ingredients and MOAs to select from to help manage weeds. Selecting and using these herbicides in a manner that considers weed species present, weed resistance, crop safety, and the environment is essential for their long-term viability. While no one herbicide can be expected to control all the weeds in any particular field, each one can play an important role when used appropriately.

Introduction to Adjuvants

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Introduction

Questions about adjuvant selection are common. Adjuvants are not regulated by the EPA or any other regulatory agency allowing an unlimited number of adjuvants. Adjuvants are composed of a wide range of ingredients which may or may not contribute to herbicide phytotoxicity. Results vary when comparing specific adjuvants, even within a class of adjuvants. POST herbicide effectiveness depends on spray droplet retention, deposition, and herbicide absorption by weed foliage. Adjuvants and spray water quality (Paragraph A6) influence POST herbicide efficacy. Adjuvants are not needed with PRE herbicides unless weeds have emerged and labels include POST application.

Spray adjuvants generally consist of surfactants, oils and fertilizers. The most effective adjuvant will vary with each herbicide, and the need for an adjuvant will vary with environment, weeds, and herbicide used. Adjuvant use should follow label directions and be used with caution as they may influence crop safety and weed control. An adjuvant may increase weed control from one herbicide but not from another. To compare adjuvants and determine adjuvant enhancement, herbicide rates should be used at marginal weed control levels. Effective adjuvants will enhance herbicides at reduced rates and provide consistent results under adverse conditions. However, use of below labeled rates exempts herbicide manufacturers from liability for nonperformance.

Surfactants (nonionic surfactants = NIS) are used at 0.25 to 0.5% v/v (1 to 4 pt/100 gal of spray solution) regardless of spray volume. NIS rate depends on the amount of active ingredient in the formulation, plant species and herbicides used. The main function of a NIS is to increase spray retention, but at a lesser degree, may function in herbicide absorption. When a range of surfactant rates is given, the high rate is for use with low herbicide rates, drought stress and tolerant weeds, or when the surfactant contains less than 90% active ingredient. Surfactants vary widely in chemical composition and in their effect on spray retention, deposition, and herbicide absorption.

Silicone surfactants reduce spray droplet surface tension, which allow the liquid to run into leaf stomata (“stomatal flooding”). This entry route into plants is different than adjuvants that aid in absorption through the leaf cuticle. Rapid entry of spray solution into leaf stomata from use of silicone surfactants often does not result in improved weed control. Silicone surfactants are weed and herbicide specific just like other adjuvants.

Oils generally are used at 1% v/v (1 gal/100 gal of spray solution) or at 2 pt/A depending on herbicide and oil. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum (PO) or methylated vegetable or seed oils (MSO) plus an emulsifier for dispersion in water. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of an oil adjuvant. Oil adjuvants enhance POST herbicides more than NIS and are effective with all POST herbicides, except Liberty and Cobra, and will antagonize Roundup. The term crop oil concentrate (COC) is used to designate a petroleum oil concentrate but is misleading because the oil type in COC is petroleum and not a crop vegetable oil.

MSO adjuvants greatly enhance POST herbicides much more than NIS and PO adjuvants. MSO adjuvants are more aggressive in dissolving leaf wax and cuticle resulting in faster and greater herbicide absorption. The greater herbicide enhancement from MSO adjuvants may occur more in low humidity/low rainfall environments where weeds develop a thicker cuticle. MSO adjuvants cost 2 to 3 times more than NIS and PO adjuvants. The added cost of MSO and increased risk of crop injury when used at high temperatures have deterred people from using this class of adjuvants. Using reduced herbicide rates with MSO adjuvants can enhance weed control while lowering risk of crop injury.

Some herbicide labels restrict use of oil adjuvants and recommend only NIS alone or combined with nitrogen based fertilizer solutions. Follow label directions for adjuvant selection. Where labels allow use of oil additives, PO or MSO adjuvants may be used.

NDSU research has shown wide difference in adjuvant enhancement of herbicides. However, in many studies, no or small differences occur depending on environmental conditions at application, growing conditions of weeds, rate of herbicide used, and size of weeds. For example, under warm, humid conditions with actively growing weeds, NIS + nitrogen fertilizer may enhance weed control to the same level as oil adjuvants. The following are conditions where MSO type additives may give greater weed control than other adjuvant types:

1. Low humidity, hot weather, lack of rain, and drought-stressed weeds or weeds not actively growing due to some stress condition.
2. Weeds larger than recommended on the label.
3. Herbicides used at reduced rates.
4. Target weeds that are somewhat tolerant to the herbicide. (buckwheat, lambsquarters, ragweed to Pursuit or Raptor, or yellow foxtail to Accent).
5. When university data supports reduced herbicide rates. Most herbicides, except Roundup, give greater weed control when used with MSO type adjuvants.

Oil adjuvant applied on a volume or area basis - Labels of many POST herbicides recommend oil adjuvants at 1% v/v. At water volume of 15 or 20 gallons per acre (GPA), 1% oil adjuvant will provide a minimum adjuvant concentration (1% v/v PO in 17 gpa = 1.4 pt/A). The optimum rate of a PO is 2 pt/A. State surveys show common spray volumes are 10 gpa or lower. PO at 1% v/v in 8.5 gpa = 0.68 pt/A and does not provide an sufficient amount of oil adjuvant. Further, in aerial applications at 5 GPA, PO at 1% v/v will not provide sufficient adjuvant. For example, Pursuit and Raptor labels require oil adjuvants to be added at 1.25% v/v or 1.25 gal/100 gal water for aerial application at 5 GPA.

Some herbicide labels contain information on adjuvant rates for different spray volumes. To insure sufficient adjuvant concentration, add oil adjuvant at 1% v/v but no less than 1.25 pt/A at all spray volumes. Surfactant at 0.25 to 1% v/v water is sufficient across all water volumes.

High surfactant oil concentrates (HSOC) were developed to enhance lipophilic herbicides without antagonizing glyphosate. HSOC adjuvants contain at least 50% w/w oil plus 25 to 50% w/w surfactant, are PO or MSO based, and are usually applied at ½ the oil adjuvant rate (area basis). Glyphosate must be applied with other herbicides to control glyphosate tolerant weeds and crops and to delay resistant weeds. Glyphosate is highly hydrophilic, is enhanced by NIS and nitrogen fertilizer surfactant type adjuvants, and is antagonized by oil adjuvants. Postemergence herbicides preferred by growers to mix with glyphosate to increase weed control are lipophilic (Select, Banvel, Laudis, others) and require oil adjuvants for optimum herbicide enhancement. Surfactants are less effective in enhancing lipophilic herbicides. Oil adjuvants, including PO and MSO adjuvants, may antagonize glyphosate. NDSU research has shown wide variability among PO based HSOC adjuvants with many performing no different than common PO adjuvants. However, MSO based HSOC adjuvants enhance both glyphosate and the lipophilic herbicide. MSO based HSOC adjuvants can enhance lipophilic herbicides more than PO based HSOC, MSO and PO adjuvants.

Some water pH modifiers are used to lower (acidify) spray solution pH because many insecticides and some fungicides degrade under high water pH. Most solutions are not high or low enough in pH for important herbicide breakdown in the spray tank. A theory has long been postulated that acidifying the spray solution results in greater absorption of weak-acid-type herbicides. pH-reducing adjuvants (water conditioners/AMS replacment) were developed under this belief. However, low pH is not essential to optimize herbicide absorption.

Many herbicides are formulated as various salts, which are absorbed as readily as the acid. Salts in the spray water may antagonize formulated salt herbicides. In theory, acid conditions would convert the herbicide to an acid and overcome salt antagonism. However, herbicides in the acid form are less water soluble than in salt form. An acid herbicide with pH modifiers may precipitate and plug nozzles when solubility is exceeded, such as with high herbicide rates in low water volumes. Antagonism of herbicide efficacy by spray solution salts can be overcome without lowering pH by adding AMS or, for some herbicides, 28% UAN.

Acidic AMS replacement (AAR) adjuvants (see page 130) contain adjuvants including monocarbamide dihydrogensulfate (urea and sulfuric acid) and some adjuvants in this class are similar to NIS + AMS in enhancing glyphosate and other weak-acid herbicides. The sulfuric acid forms sulfate when reacting with water and can prevent herbicide antagonism with salts in water. The conversion of urea to ammonium is slow but the ammonium formed can partially enhance herbicides. AAR adjuvants must be applied at 1% v/v or greater to achieve the same level of herbicide enhancement as AMS.

Basic pH blend adjuvants are blends of nonionic surfactant, fertilizer, and basic pH enhancer and are used at 1% v/v regardless of spray volume. Data indicate basic blend adjuvants at 1% v/v from 5 to 20 GPA will provide adequate adjuvant enhancement for similar weed control.

Basic pH blend adjuvants are surfactant based, increase spray solution pH, and contain nitrogen fertilizer to enhance herbicide activity. They contain a surfactant to aid in spray retention, spray deposition, and herbicide absorption, and a buffer to increase water pH. Basic pH blends adjuvants increase water pH to near pH 9 which increases water solubility of some herbicides and can increase herbicide phytotoxicity. Within the sulfonylurea chemistry the magnitude of solubility from high spray solution pH can increase from 40 fold (Harmony GT) to 3,670 fold (UpBeet). The solubility of herbicides in other chemical families increase with high pH: Achieve (1-Dim), florasulam (2-TPS), Everest (2-SACT), Sharpen (14), and diflufenzopyr (19), Callisto and Laudis (27-triketone), and pyrasulfatole and Impact (27-pyrazolone) (numbers represent herbicide mode of action).

Some herbicides degrade rapidly in high pH spray solution. Cobra (diphenylether), Resource and Valor (N_phenylphthalimide), and Sharpen (pH 9) degrade within a few minutes in high pH water but are stable for several days at low pH. Optimum use of pH adjusting adjuvants requires some knowledge of herbicide chemistry or experience. Research has shown that basic pH blend adjuvants may enhance weed control similar to MSO adjuvants and can be used in situations where oil adjuvants are restricted.

Commercial adjuvants differ in effectiveness with herbicides. Data from the table below are from experiments conducted at six NDSU R&E Centers in ND from 1992 through 1995 and repeated in 2005 and 2006 comparing commercial adjuvants with Roundup. In 1993-95, Roundup was applied at 1 to 1.5 oz ae/A to 16 grass and broadleaf weed species. In 2005-06 Roundup was applied at 1 to 4 oz ae/A to 26 grass and broadleaf weed species (272 averages). Higher rates were used in western ND because of low activity in low humidity.

Spray carrier water quality

Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Clay inactivates paraquat, diquat, and glyphosate. Organic matter inactivates herbicides. Hard water cations or micronutrients such calcium, magnesium, manganese, sodium, and iron reduce efficacy of all weak-acid herbicides. Cations antagonize glyphosate efficacy by complexing with glyphosate to form salts (e.g. Glyphosate-Ca) that are not readily absorbed by plants. Antagonistic minerals can inactivate the activity of most POST herbicides, including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Ignite. The antagonism is related to the salt concentration. At low salt levels, loss in weed control may not be noticeable under normal environmental conditions but will occur when weed control is marginal because of drought or partially susceptible weeds. The precise salt concentration in water that causes a visible loss in weed control is difficult to establish because weed control is influenced by other factors.

ND water often contains a combination of sodium, calcium, magnesium, and iron and these cations generally are additive in the antagonism of herbicides. Water in ND, SD, and MT is often high in sodium bicarbonate which does not normally occur in other areas of the U.S. Calcium levels above 150 ppm and sodium bicarbonate levels above 300 ppm in spray water can reduce weed control in all situations. Water with 1600 ppm sodium bicarbonate can occur in ND, but total hardness levels can exceed 2,500 ppm.

Ammonium nitrogen increases effectiveness of most weak-acid herbicides formulated as a salt. Fertilizers should always be used with herbicides unless prohibited by label. Ammonium ions greatly enhance herbicide absorption and phytotoxicity even in the absence of antagonistic salts in the spray carrier. However, enhancement of Roundup* and most other POST herbicides from ammonium is most pronounced when spray water contains large quantities of antagonistic cations. Herbicide enhancement by nitrogen compounds appears in most weed species but is most pronounced in species like volunteer corn and species that accumulate antagonistic salts on or in leaf tissue (lambsquarters, velvetleaf, and sunflower).

AMS enhances phytotoxicity and overcomes salt antagonism for weak-acid herbicides formulated as a salt including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Ignite. The antagonism may be overcome by increasing the glyphosate concentration relative to the cation content or by adding AMS and some water conditioners to the spray solution. Effective water conditioners include EDTA, citric acid, AMS, and some acidic AMS replacements. Of these, AMS has been the most widely adopted. When added to a spray solution, the ammonium (NH_4^+) ion complexes with the glyphosate molecule and reduces glyphosate interaction with the hard_water cations, and the sulfate (SO_4^{2-}) ion complexes with the hard_water cations (e.g. calcium sulfate), causing the salt to precipitate from solution. This combined effect increases absorption and efficacy. Natural sulfate in water can be disregarded but can reduce antagonism if the sulfate concentration is at least three times the calcium concentration.

Antagonism of Roundup by calcium in a spray solution was overcome by sulfuric but not nitric acid, indicating that the sulfate ion was important, but not the acid hydrogen ion. The importance of the sulfate ion explains the effectiveness of ammonium sulfate, and not 28% UAN, in overcoming calcium antagonism of glyphosate. Other herbicides that become acid at a higher pH than Roundup may realistically benefit from a reduced pH as has been shown for Poast. However, Poast does not require a low pH for efficacy. pH of 4 has overcome sodium antagonism of Poast, but nitrogen fertilizer or AMS also will overcome sodium antagonism of Poast without lowering the pH. The ammonium ion provided by these fertilizers is apparently the important ion.

AMS is recommended at 8.5 to 17 lb/100 gal spray volume (1 to 2%) on most Roundup* labels. However, AMS at 4 lb/100 gal (0.5%) is adequate to overcome most salt antagonism but more than 4 lb/100 gal may be required to fully optimize herbicides. AMS at 0.5% has adequately overcome antagonism of glyphosate from 300 ppm calcium. Use at least 1 lb/A of

AMS when spray volume is more than 12 gpa. The amount of AMS needed to overcome antagonistic ions can be determined as follows:

Lbs AMS/100 gal = (0.002 X ppm K) + (0.005 X ppm Na) + (0.009 X ppm Ca) + (0.014 X ppm Mg) + (0.042 X ppm Fe).

This does not account for antagonistic minerals on or in the leaf tissue in species like lambsquarters, sunflower, and velvetleaf which may require additional AMS.

AMS may contain contaminants that may not dissolve resulting in plugged nozzles. Use spray grade AMS to prevent nozzle plugging. Commercial liquid solutions of AMS are available and contain approximately 3.4 lbs of AMS/gallon. For 8.5 lbs of AMS/100 gallons of water add 2.5 gallons of liquid AMS solution.

28% UAN fertilizer is effective in enhancing weed control and overcoming mineral antagonism of most POST herbicides, but not calcium antagonism of Roundup. Sodium bicarbonate antagonism of Poast is overcome by 28% UAN and AMS. AMS or 28% UAN does not preclude the need for a oil adjuvant with lipophilic herbicides. Generally, 4 gal of 28% UAN/100 gal of spray has been adequate. AMS and 28% UAN enhance herbicide control of most weeds even in water without antagonistic salts. Nitrogen fertilizer/surfactant blends may enhance weed control of most herbicides formulated as a salt.

The Effects of Adjuvants on Herbicide Efficacy

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Abstract

Spray adjuvants generally consist of surfactants, oils and fertilizers. The main function of a NIS is to increase spray retention, but at a lesser degree, may function in herbicide absorption. Surfactants vary widely in chemical composition and in their effect on spray retention, deposition, and herbicide absorption. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum (PO) or methylated vegetable or seed oils (MSO) plus an emulsifier for dispersion in water. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of an oil adjuvant. Oil adjuvants enhance POST herbicides more than NIS and are effective with all POST herbicides, except Liberty and Cobra, and will antagonize Roundup. MSO adjuvants greatly enhance POST herbicides much more than NIS and PO adjuvants. MSO adjuvants are more aggressive in dissolving leaf wax and cuticle resulting in faster and greater herbicide absorption. The greater herbicide enhancement from MSO adjuvants may occur more in low humidity/low rainfall environments where weeds develop a thicker cuticle. MSO adjuvants cost 2 to 3 times more than NIS and PO adjuvants. The added cost of MSO and increased risk of crop injury when used at high temperatures have deterred people from using this class of adjuvants. Using reduced herbicide rates with MSO adjuvants can enhance weed control while lowering risk of crop injury. Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Hard water cations or micronutrients such calcium, magnesium, manganese, sodium, and iron reduce efficacy of all weak-acid herbicides. Calcium levels above 150 ppm and sodium bicarbonate levels above 300 ppm in spray water can reduce weed control in all situations. Ammonium nitrogen increases effectiveness of most weak-acid herbicides formulated as a salt. Fertilizers should always be used with herbicides unless prohibited by label. Ammonium ions greatly enhance herbicide absorption and phytotoxicity even in the absence of antagonistic salts in the spray carrier. However, enhancement of Roundup* and most other POST herbicides from ammonium is most pronounced when spray water contains large quantities of antagonistic cations. Herbicide enhancement by nitrogen compounds appears in most weed species but is most pronounced in species like volunteer corn and species that accumulate antagonistic salts on or in leaf tissue (lambsquarters, velvetleaf, and sunflower). AMS enhances phytotoxicity and overcomes salt antagonism for weak-acid herbicides formulated as a salt including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Ignite. The antagonism may be overcome by increasing the glyphosate concentration relative to the cation content or by adding AMS and some water conditioners to the spray solution. Effective water conditioners include EDTA, citric acid, AMS, and some acidic AMS replacements. Of these, AMS has been the most widely adopted.

Broad Spectrum Weed and Algae Control in Irrigation Canals Using Endothall

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Irrigation canals are a major source of water for agricultural production in the western United States. Control of aquatic vegetation and algae in irrigation canals is crucial for efficient water delivery in irrigation canals. While aquatic weeds can have a significant impact on water flow, the tools available to canal managers for control are limited. The In 2010, two endothall formulations were labeled for use in irrigation canals. Cascade is the dipotassium salt of endothall, and works to control a range of aquatic weed species. Teton is an amine formulation of endothall that can control both submersed plants and algae. Since their introduction in 2010, Cascade and Teton have been successfully incorporated into the programs of many irrigation districts. Sago pondweed [*Stuckenia pectinata*] was the main target species identified during the development of endothall for irrigation canals. During their first three seasons of use, differential susceptibility was identified, with some species being more difficult to control. Eldoea [*Elodea canadensis*] is one species that has been difficult to control. Additional studies conducted on elodea have indicated that Teton applied at 2 ppm or greater can significantly reduce elodea biomass, with longer exposure time resulting in greater control. Chara [*Chara spp*.] is an algae species that commonly occurs in the West, and is often difficult to control in flowing water systems. A trial evaluating chara control using Teton indicated that a concentration of 0.5 ppm for a minimum of 4 hrs can provide excellent control. These and other trials have been used to refine use rates for irrigation canals. Results from field applications and these ongoing trials indicate that Cascade and Teton provide a safer and more effective tool for controlling aquatic weeds and algae in irrigation canals compared to alternative control methods.

Management of Western Watermilfoil in the Friant-Kern Canal

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Background of the Friant-Kern Canal

The Friant Water Authority (Authority) oversees the Operation and Maintenance (O&M) of the Friant-Kern Canal (FKC). A principal feature of the Central Valley Project, the 152 mile long FKC conveys critical supplies of water to Water Contractors (Contractors) along the eastern side of the lower San Joaquin Valley. These Contractors utilize their supplies for agricultural, municipal/industrial, and groundwater recharge purposes within their service areas. Approximately 1,000,000 acres of highly productive farmland in the counties of Fresno, Tulare, Kern, and Kings are served by water supplied from the Friant-Kern Canal. This acreage is owned and cultivated by nearly 15,000 mostly small family farming operations. In addition, several municipalities including Fresno, Orange Cove, and Lindsay rely on water conveyed by the FKC for some or all of their domestic water supply

Myriophyllum Hippuroides or Western Watermilfoil. Source: Lars Anderson

Background of Invasive Weed

Friant Water Authority first noted the existence of a “new” invasive aquatic weed growing in the FKC in 1998. The location of the initial identification was near the transition from concrete lined to earthen canal at FKC MP 34.94. Over the past 14 years, the invasive weed has spread to entire sections encompassing 22.37 miles of earthen canal in Tulare and Fresno Counties, a 2.01 mile earthen section adjacent to Woollomes Equalizing Reservoir in Kern County, Woollomes Equalizing Reservoir, areas of the FKC that are concrete lined and contain silt accumulation, and numerous facilities including canals, laterals, and recharge basins operated by Contractors who take delivery of water from the FKC.

Identification of Western Watermilfoil

Efforts to identify the invasive weed began in 2001 and continued through 2004. Participants involved in the identification process included Friant Water Authority, United States Bureau of Reclamation, California Department of Food and Agriculture, University of California at Davis, and the United States Department of Agriculture - Agricultural Research Service. Ultimately, the invasive weed was identified as *Myriophyllum hippuroides* or western watermilfoil (WWM). Western watermilfoil is a perennial aquatic plant. Most of the plant grows submerged below the water surface, but stems which bear reproductive structures do penetrate the water surface. The plant is rooted in earthen sections of the FKC and on a more limited basis where silt has accumulated in concrete lined sections. Vegetative growth can be extensive, with plants having multiple stems of ten or more feet in length. WWM forms roots which store nutrient reserves to support the spread of vegetative growth in the water column. In addition to spreading by root growth, stem fragments that break off from plants can settle on the substrate. These fragments subsequently root and generate new plants. Spread by sexual reproduction is less common than by vegetative means.

Impacts on Friant-Kern Canal and Water Users

Infestation of WWM in the FKC causes many issues that impact proper operation of the facilities. Within the FKC, WWM's growth and spread has led to an approximately 10% reduction in capacity during peak flow periods which greatly affects the ability to convey flows to both agricultural and municipal/industrial contractors. Further, as WWM breaks apart, the fragments are transported in the water column to Contractors' turnouts. These fragments regularly impair deliveries as they accumulate on the face of Contractors' turnout trash racks. In some cases, WWM fragments have reduced deliveries by up to 50% in a 24-hour period. Such flow impediments restrict the Contractors' ability to deliver water to their customers.

Infestation of WWM also impacts distribution systems of Contractors who derive their supplies from the FKC. Contractors report that WWM has taken root in distribution canals, laterals, lift ponds, and groundwater recharge basins. Agricultural Contractors report WWM fragments delivered in the water supply regularly clog delivery meters, pumps, and micro irrigation equipment. Municipal contractors report lowered efficiencies of treatment plants, increased downtime, and additional maintenance due to WWM.

Western Watermilfoil in the Friant-Kern Canal Adjacent to a District Turnout.
Source: Friant Water Authority

Past Management Efforts

FWA has undertaken efforts to manage WWM in the FKC. Since 2003, on one occasion for each control chemical, FWA has applied diquat, glyphosate, and triclopyr on various limited and broad based control efforts. Observations of the treated areas suggested that existing WWM plants were only minimally affected, reportedly responding to the contact herbicides only by leaf-tip and terminal "burning and dieback"; complete dieback and plant death did not occur. Significant projects to remove silt accumulations which provide a substrate for WWM have been completed. Furthermore, intensive mechanical extraction efforts by hand and machine have aimed to remove WWM from the FKC. These efforts have had limited impact on the infestation of WWM in the FKC.

Past Mechanical Extraction of Western Watermilfoil. Source: Friant Water Authority

Further Research

Due to the spread of the weed, lack of successful control, impact to the FKC, impacts to Contractors, FWA sought to further evaluate WWM. In 2009, FWA entered into a research agreement with the United States Department of Agriculture - Agricultural Research Service at UC Davis. Dr. Lars Anderson headed the project in order to further understand WWM's life cycle, means of reproduction, growth characteristics, and susceptibility to various control chemicals.

Western Watermilfoil Chemical Trial Tanks. Source: Lars Anderson

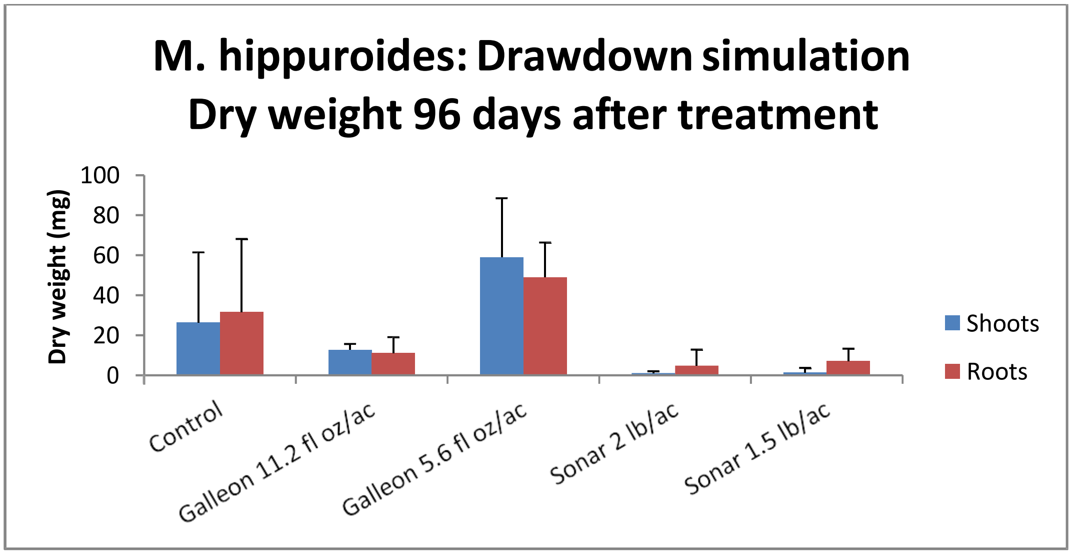
Further Management Options Presented

Chemical control options to address WWM while keeping the FKC in operation were presented to the FWA Advisory Committee for review in 2010 and 2011. The committee determined there was not sufficient consensus to pursue such an application given the varied interests served by the FKC. In 2011 and 2012, FWA staff pursued the potential permitting and introduction of triploid grass carp with the California Department of Fish and Game in order to utilize a non-chemical means of WWM control in the FKC. As a result of these efforts it was determined FWA would not be eligible to receive the necessary permits for the introduction of triploid grass carp in the FKC. In mid-2012, FWA staff presented to the Operation and Maintenance Committee and Board of Directors options related to potential chemical control options to address WWM during a drawdown of the FKC. This potential treatment was presented in order to address continued concerns and requests by Contractors to address the WWM issue in the FKC.

Chemical Treatment 2012/2013

The treatment in the drawdown FKC employed the use of fluridone and imazamox. Fluridone was identified by Dr. Anderson as having notable effect on WWM and imazamox was identified as having successful control on other watermilfoil species by SePRO Corporation.

FWA consulted with SePRO on the potential use of these chemicals in the FKC to determine if the chemicals would fit the uses and needs demanded by the water users. Fluridone, trade name Sonar Genesis, is manufactured and distributed by SePRO Corporation. Imazamox, trade name Clearcast, is manufactured by BASF and distributed by SePRO Corporation. Both are FIFRA labeled, EPA approved, and approved by the California Department of Pesticide Regulation for pre-emergent control of aquatic weeds in canals that are drawn down. Both chemicals are labeled for use in agricultural and domestic water systems with limited restrictions and limitations.



Effectiveness of Chemicals in Drawdown Simulation. Source: Lars Anderson

Consultation with Governing Agencies and Stakeholders

FWA submitted the WWM treatment plan to all Contractors on the FKC for input and comment. The plan was further submitted to the California Department of Public Health, United States Bureau of Reclamation, along with the Agricultural Commissioners of Fresno, Tulare, and Kern Counties. The California Department of Pesticide Regulation was consulted related to the acceptability of use and registration of the products. Contractors and regulating entities provided their respective comments, confirmation, and approval of the WWM treatment plan.

Location and Timing of the Application

Sonar Genesis and Clearcast herbicides were applied to the drawn down FKC invert and embankments beginning at MP 34.94 through MP 61.99 excluding intermittent concrete lined areas and siphons. Applications took place the last two weeks of 2012. Both labels call for a minimum 14 day hold time prior to reintroduction of water. FWA utilized hold times of roughly 30 days in order to allow for proper incorporation into the FKC embankments.

Herbicide Application

Sonar Genesis was applied at a rate of 2.0 lbs. active ingredient (ai) per acre or 4.0 gallons per acre. Clearcast was applied at a rate of 0.50 lbs. ai per acre or 0.50 gallons per acre. The two chemicals were tank mixed prior to application. Application to the FKC embankments was completed using truck mounted booms and the invert was sprayed by truck mounted boom, hand wand, and a spray highline suspended by two vehicles on opposite sides of the FKC. A spray solution of 30-120 gallons per acre was applied depending on the application method.

Herbicide Label Limitations on Domestic and Agricultural Uses

Requirements on the specimen labels for Sonar Genesis and Clearcast have limited use restrictions, precautions, and limitations. Sonar Genesis and Clearcast are approved by the EPA and the State of California Department of Pesticide Regulation for agricultural and drinking water use. The California Department of Public Health provided limitations on any residual levels of treatment agents However, Sonar formulations have been used extensively for over a decade to combat invasive aquatic weeds in the Sacramento-San Joaquin Delta by the California Department of Boating and Waterways.

Safety Protocols

As the FKC was in a dewatered state, the Contractors' turnouts were not in service. The FKC control structures within the treatment area were closed then locked and tagged out and a series of secondary containment was installed downstream of the treatment zone. Additionally, the turnout of the one municipal Contractor within the treatment zone was also locked and tagged out as an added precaution.

Canal Re-Watering, Depuration, and Water Quality Monitoring

SePRO was consulted by FWA to determine anticipated levels of depuration which may be expected upon reintroduction of water in the FKC. In their experience, depuration rates of 10% - 20% have been observed. Several calculations utilizing different refill scenarios were run to determine anticipated residuals. Upon reintroduction of water in the FKC, water quality will be monitored. Samples to determine any residual levels of the active ingredients found in Sonar Genesis and Clearcast will be collected. Samples will be taken from within the application zone 1 day (d), 2d, 5d, and 7d after water reintroduction. Water samples will also be taken at the site of municipal Contractors' turnouts within the treatment area and extending through Tulare County. Samples will be tested by SePRO's laboratory along with a third party laboratory. Water will not be released for use by Contractors until label restrictions are met.

Integrated Vegetation Management in Flood Control and Urban Creek Settings

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Introduction

Maintenance of urban creeks and flood control channels is a valuable and challenging activity. Proper maintenance of these facilities protects people, property, wildlife, and the environment. The challenge for agencies tasked with maintaining these resources is to successfully protect these assets while at the same time adhering to regulatory and permit conditions. Resource limitations (labor, equipment, contractors, funding) and public concerns are additional factors that managers must consider in their decision making process.

Discussion

There are significant differences between water conveyance facilities, and urban creeks and streams. The water level of conveyance systems can often be modified, and in some cases even de-watered as part of an integrated vegetation management plan. This method is not available when maintaining creeks and flood control facilities. Obtaining the necessary permits to de-water a creek or flood control facility is too time consuming and expensive to use for vegetation management.

While there is overlap, the spectrum of problematic weeds is usually different in each of these areas. Weed control in urban creeks and streams usually targets emerged, marginal, and riparian vegetation. Managers of water conveyance facilities focus most of their weed management on submerged and true aquatic vegetation.

Water conveyance facility slopes are often armored with concrete or rock to minimize erosion and water loss, and are seldom vegetated. Urban creek and stream slopes are usually vegetated, and only armored where necessary. The habitat and wildlife value of creek and flood control facilities is usually quite high compared to many (but certainly not all) water conveyance facilities.

The primary reason for active maintenance of urban creeks and streams is flood protection. In California, most counties make flood-related disaster declarations at least once a decade. Private property and infrastructure are often located adjacent to these resources, incurring heavy losses during even short duration flood conditions. Flood related losses in excess of $1 billion occur at least once a decade in California (California OES).

High flow events can damage flood control channels and slopes as well. High speed flow, often combined with debris, can erode and undercut slopes. Slope repairs and re-establishing low-flow channels to their original design is expensive and requires a lengthy permit process.

There seems to be no correlation between flood events and either El Nino or La Nina conditions (California OES). Since there is no way to know when heavy rain events will occur, maintenance of creeks and flood control facilities must be done to preserve maximum flood protection each year. Most flood events are associated with short duration, high intensity storms, and not necessarily with an above-average rain season.

Fuel load, or fire risk, is another concern for managers of these facilities. Homes and buildings are often located adjacent to urban creek and flood control facilities. Therefore, managers must reduce probability that a fire will escape from their facility. Local fire districts usually have fairly strict fuel abatement guidelines. These guidelines don't always take plant biology into account.

Re-vegetation projects in these facilities, while beneficial to the environment, make maintenance more expensive and time consuming. Maintenance crews need good training and close supervision to prevent damage to desirable vegetation. Maintenance activities need to be altered and adjusted as this vegetation matures.

In addition to maintaining flood capacity, 24 hour/365 day access for crew and equipment should be preserved to allow for quick response to storm-related problems. A clear line of sight of slopes and flow should be preserved as much as possible, allowing inspectors to quickly identify damage and blockages.

Another challenge faced by managers is associated with property rights. Many creeks have private maintenance in some sections, and public maintenance in others. Two or more agencies may have maintenance responsibilities in the same creek or watershed. This is especially challenging when conducting invasive weed control. Privately maintained creeks can be a source of excess organic debris, increasing the risk of blockages.

Most flood control facilities have O&M manuals (operation and maintenance). These give guidance for how much vegetation and silt can be allowed without compromising flood protection. This type of guidance is very helpful in urban creek maintenance. Visual aids and written plans can be used by maintenance crews and the general public.

Invasive weed exclusion and eradication is difficult near water. Once established, they can spread easily throughout the creek or facility. Permits are often required by the Regional Water Resources Control Board, and a limited number of compounds have aquatic registration in California. Introduction of these weeds can be from upstream sources or adjacent property owners. It is helpful to know where these sources are located when trying to limit their spread.

Public perception of pesticides, including herbicides, is decidedly negative. Fears regarding impacts on health are common. Choosing materials with low human and environmental toxicity, and making that information public, can reduce concerns. Political and regulatory opposition to the use of herbicides is difficult to answer effectively. Having written information available on training, licensing, safety precautions can be helpful. Creating an integrated vegetation management plan specific to each area you maintain can help to educate these groups as to the complexity of managing these resources.

Documenting maintenance costs, by method, can be helpful in the education process. It is important to capture all costs when making these calculations. Labor, benefits, equipment, contractors, supervision, inspection, contract administration and administrative overhead are all components of the total cost of maintenance.

Deferred maintenance should be documented and communicated to the managers who have the authority to allow or prohibit specific vegetation management techniques. The underlying reasons for deferred maintenance should be documented as well. Don't assume that elected officials or district managers know and understand all of the reasons for deferred maintenance.

Grazing, manual mowing or removal, machine mowing, and the use of herbicides are all common tools used in urban creek and flood control channel maintenance. Disking is usually not appropriate due to sedimentation concerns. Much is only appropriate when used near or at the top of bank. Fabric barriers can be useful when placed around desirable plants, but is difficult to install correctly and often washed away during high flow events. The use of competitive plantings can be effective in certain circumstances but requires high amounts of labor to maintain during establishment.

A NPDES permit may be required for the use of herbicides in urban creeks and flood control facilities. And depending on how close and what type of application method is used, aquatically approve herbicides may be required as well. Permits may be required by other regulating agencies as well. This can complicated the use of herbicides and increase overhead costs.

The use of low impact application methods (cut-stump, basal bark, low-volume foliar, and directed/spot applications) are often preferable to broadcast applications when treating invasive plants. These methods limit damage to surrounding vegetation. Selective herbicides are also helpful when trying to control specific or closely related weeds species.

Plant species requiring control share some or all of the following characteristics:

- Spread rapidly via fruit or vegetative reproduction
- Grow rapidly in riparian habitats
- Produce large amounts of biomass
- Growth habit impedes the flow of water
- Crowd out native species and/or form a monoculture
- Produce a high fuel load or present a high fire hazard
- Spread easily from urban and suburban landscape

Conclusion

- ❖ Thorough record-keeping is essential

- ❖ Know the plants in each facility which require control
- ❖ Outline your decision-making process to inform management and public
- ❖ Document the risks of not managing vegetation
- ❖ Tailor management and treatments to fit each resource
- ❖ Review and alter management techniques as needed
- ❖ Keep records of resource limitations and deferred maintenance

Integrated Herbicide Program for Control of Aquatic Weeds and Algae in Irrigation Canal Systems

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Herbicides are an effective part of integrated aquatic plant management programs. Aquatic vegetation management has been slow to change over the years, due in part to the inherent difficulty in finding new molecules that will have effective control on aquatic weeds while remaining selective to desirable species and still allowing the use of the treated water body for irrigation, recreation or domestic use. Since 2007, **Sonar® AS** has been registered for use on dry or de-watered irrigation canals in an off-season application. In an effort to increase the range of control options and mode-of-action portfolio available to the irrigation market, there has been a recent expansion of available pre-emergent aquatic herbicide products for this use.

This presentation will discuss a short history of aquatic weed control. From mechanical to in-season applications. Best Management Practices that have shown by utilizing a pre-emergent program followed by in-season treatment products as needed, either stand alone or in combination, has improved overall efficacy while reducing maintenance costs for irrigation system operators.

Management of algae will also be discussed. Reduction in submersed aquatic weeds has increased the need to do algae control independently during the irrigation season.

Best Management Practices for Aquatic Weed Control in Canals

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Weed control specialists must consider many factors when deciding on the management practices to utilize for control of aquatic weeds in irrigation canals. Management practices are generally limited to mechanical removal, hand removal and herbicide treatments. However the factors that need to be considered when adopting a management practice can be very diverse and unique for each canal system. These factors include the standard of control that is required, minimization of environmental impact, the customers that the canal services, the resources that are available, employee and public safety and cost. In addition, historical records of past practices are important for refining and revising management practices as conditions or weeds species change. As new herbicides are introduced into the market, the weed control specialist must determine if the herbicide has a place in their "tool box," based on the many factors unique to the situation. This presentation will highlight the decision making process in development of best management practices for aquatic weed control in canals at Solano Irrigation District.

Biopesticides Role in Organic Weed Control

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Abstract

Surveys of organic growers indicate that weed control is the number one cost of organic production. Conventional grower surveys are inhibited from transitioning to organic production due to the cost and difficulty of weed control. As such there is an unmet need in the market for companies to discover and develop more effective and cost effective alternatives for weed control in organic production. Marrone Bio Innovations (MBI) was founded with one of its core focus areas discovering, developing and marketing natural products for weed control. After entering and exiting the market with products based on essential oils, MBI embarked on discovery and in-licensing of novel microorganisms and plant extracts that produce natural compounds with novel modes of action that control weeds. This talk will discuss MBI's herbicide discovery and development process and also three products in MBI's pipeline, Opportune (tm) (MBI 005) cellulose biosynthesis inhibitor, MBI 011 burndown herbicide and MBI 010 systemic herbicide. These products have potential for both organic and conventional production. The speaker will also provide an overview of the biopesticide market and the drivers behind double digit growth of biopesticides and the intense interest by large agrichemical companies and growers in this fast growing sector.

Organic Herbicides Performance in Field Trials

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In recent years, several organic herbicide products have appeared on the market. These include Weed Pharm (20% acetic acid), C-Cide (5% citric acid), GreenMatch (55% d-limonene), Matratec (50% clove oil), WeedZap (45% clove oil + 45% cinnamon oil), and GreenMatch EX (50% lemongrass oil), Final-San-O (22% ammoniated soap of fatty acids), Biolink (80% Caprylic-Capric acid), among others. These products are all contact-type herbicides and will damage any green vegetation they contact, though they are safe as directed sprays against woody stems and trunks. These herbicides kill weeds that have emerged, but have no residual activity on those emerging after application. Additionally, these herbicides can burn back the tops of perennial weeds, but perennial weeds recover quickly.

Organic herbicides only kill contacted tissue; thus, good coverage is essential. Initial greenhouse studies found that spray volumes of 70 gallons per acre (gpa) were superior to 35 gpa, regardless of the organic herbicide tested. In test comparing various spray volumes and product concentrations, we found that high concentrations at low spray volumes (20% concentration in 35 gallons per acre) were less effective than lower concentrations at high spray volumes (10% concentration in 70 gallons per acre). Applying these materials through a green sprayer (only living plants are treated), can reduce the amount of material and thus the application and material cost (http://www.ntechindustries.com/weedseeker-home.html).

Also, we observed that adjuvant addition improved organic herbicide performance. Among the organic adjuvants tested thus far, Natural wet, Nu Film P, Nu Film 17, and Silwet ECO spreader have performed the best. The Silwet ECO spreader is an organic silicone adjuvant which works very well on most broadleaf weeds, but tends to roll off of grass weeds. The Natural wet, Nu Film 17 and Nu Film P work well for both broadleaf and grass weeds. Although the recommended rates of these adjuvants is 0.25 % v/v, we have found that increasing the adjuvant concentration up to 1% v/v often leads to improved weed control, possibly due to better coverage.

Field testing has further confirmed greenhouse observations. These products are effective in controlling weeds when the weeds are small and the environmental conditions are optimum. In a large field study, we found that weeds in the cotyledon or first true leaf stage were much easier to control than older weeds (Tables 1 and 2). Broadleaf weeds were also found to be easier to control than grasses, possibly due to the location of the growing point (at or below the soil surface for grasses), or the orientation of the leaves (horizontal for most broadleaf weeds) (Tables 1 and 2).

Because organic herbicides lack residual activity, repeat applications will be needed to control new flushes of weeds or to further suppress perennial weeds. Perennial weeds wre found to recover after a single treatment with an organic herbicide. However, treating a second time 15 to 21 days after the initial application resulted in almost complete top kill of the perennial (field bindweed or yellow nutsedge), and slowed recovery.

Temperature and sunlight have both been suggested as factors affecting organic herbicide efficacy. In several field studies, we have observed that organic herbicides work better when temperatures are above 75F. Weed Pharm (acetic acid) is the exception, working well at temperatures as low as 55F. Sunlight has also been suggested as an important factor for effective weed control. Anecdotal reports and our own observations indicate that control is better in full sunlight. However, in a greenhouse test using shade cloth to block 70% of the light, it was found that weed control with WeedZap improved in shaded conditions (Table 3). The greenhouse temperature was around 80F. It may be that under warm temperatures, sunlight is less of a factor, or that cool, shaded conditions, the products are less effective.

Organic herbicides are expensive at this time and may not be affordable for broadcast applications in cropping systems. However, for spot treatments, they may have a fit. Mulches are a common method used to control weeds in organic crop production systems. Mulches are generally effective for the first year or so after installation, but weed growth on or next to the mulch can reduce its value. In small field test, we found that wood chip mulches could be kept in good condition by periodic spot treatment of weeds with organic herbicides. Organic herbicides were able to kill the weeds growing on the mulch without disturbing the mulch.

Table 1. Broadleaf (pigweed and black nightshade) weed control (% control at 15 days after treatment), when treated 12, 19, or 26 days after emergence.

	-----------------Weed age---------------------		
	12 Days old	19 days old	26 days old
GreenMatch Ex 15%	89	11	0
GreenMatch 15%	83	96	17
Matran 15%	88	28	0
Acetic acid 20%	61	11	17
WeedZap 10%	100	33	38
Untreated	0	0	0

Table 2. Grass (Barnyardgrass and crabgrass) weed control (% control at 15 days after treatment), when treated 12, 19, or 26 days after emergence.

	-----------------Weed age---------------------		
	12 Days old	19 days old	26 days old
GreenMatch Ex 15%	25	19	8
GreenMatch 15%	42	42	0
Matran 15%	25	17	0
Acetic acid 20%	25	0	0
WeedZap 10%	0	11	0
Untreated	0	0	0

Table 3. Weed control with WeedZap (10% v/v) in relation to adjuvant, spray volume and light levels. Plants grown in the greenhouse in either open conditions or under shade cloth, which reduced light by 70%.

	Pigweed control (%)		Mustard control (%)	
	Sun	Shade	Sun	Shade
WeedZap + 0.1%v/v Eco Silwet (10 gpa)	31.7	93.3	26.7	35.0
WeedZap + 0.5%v/v Eco Silwet (10 gpa)	31.7	48.3	43.3	71.7
WeedZap + 0.5%v/v Natural Wet (70 gpa)	26.7	94.7	26.7	30.0
Untreated	0.0	0.0	0.0	0.0
LSD.05*	5.7		11.5	

* Values for comparing any two means. Pigweed and mustard were each analyzed separately.

Evaluation of Options for Weed Control in Organic Vineyards, Vegetables, and Berry Cropping Systems

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Abstract: Studies were conducted in organic vineyards, broccoli, spinach, blackberry, and strawberry cropping systems. Treatment comparisons included steam, plow, cultivator, and an organic herbicide in the vineyards; white mustard and soybean seed meal at 0.5 and 2 t/ac in broccoli and spinach; recycled paper mulch of two thicknesses (1 and 2 mm) in blackberry; and recycled paper mulch and black plastic mulch in strawberry. In the vineyards, the mechanical weed control treatments were the most cost-effective. In the broccoli and spinach study, mustard seed meal at 2 tons/ac provided considerable weed control and reduced hand weeding time compared to the other treatments. In the blackberry study, the recycled paper mulch provided up to two months of weed control. In the strawberry study, both plastic and recycled paper mulch provided similar weed control. However, the soil temperature under the paper mulch was on average 1° C cooler than under the plastic mulch.

Introduction: Weed management in organic cropping systems is a challenge due to the lack of registered herbicides that are effective and economic as in conventional cropping systems. Therefore, alternative tools for weed management need to be evaluated in organic cropping systems. These tools include mechanical and thermal weed control, use of mulches, and use of allelopathic substances to name a few. Similarly, there are a few new postemergence broad-spectrum herbicides labeled for use in organic cropping systems. However, the efficacy and economics of these tools have not been tested adequately in field studies. This paper will summarize the findings of several separate field studies conducted in organic vineyards, spinach, broccoli, blackberry, and strawberry cropping systems.

Materials and Methods, Results, and Discussion:

***Organic vineyards*:** Studies were conducted in 2010 and 2011 in organic raisin and wine grape vineyards in Fresno and Madera County, respectively. Treatment comparisons included non-weeded control, two mechanical weed control methods (French plow and Bezzerides tree and vine cultivator), steam, and an organic herbicide (d-limonene; Greenmatch®). The experiments were designed as split-plots with these treatments as main-plots followed by an additional weed control treatment one month later as sub-plots. By far, the greatest level of weed control was provided by the mechanical treatments. When the plots were hand hoed as the sub-plot treatment, compared to the time required for hoeing in the non-treated plots, the plowed plots required 55 to 75% less while the cultivated plowed plots required 30 to 60% less time to hoe in the raisin grape vineyards. Similarly, in the wine grape vineyard, hoeing time was reduced by 50 to 75% in the cultivated plots compared to those non-treated plots. Such differences did not occur in the herbicide or steam treated plots as the time required to hoe the plots with these treatments was generally similar to the non-treated control. However, none of the treatments affected vine growth, grape yield, or quality in either of the vineyards indicating that established vineyards had a higher threshold for weeds. Total weed control costs in the plowed, cultivated, steam-treated, and the herbicide-treated plots in the raising vineyard was approximately $80, $85, $170, and $250/acre, respectively. In the wine grape vineyard, the total weed control costs in the cultivated, steam-treated, and herbicide-treated plots were approximately $55, $125, and $200/ac, respectively. Therefore, the mechanical treatments were by far the best weed control treatment and may remain the most cost-effective weed control method in organic vineyards till better alternatives are developed.

***Organic blackberries*:** Studies were conducted in 2011 and 2012 in the certified-organic plots at the Fresno State University farm. The objective of the study was to compare recycled paper mulch (EcoCover LLC, Huntington Beach, CA 92647) of two thicknesses (1 mm and 2 mm) with non-treated plots during blackberry establishment phase. Square mulch mats measuring 0.2 m^2 were placed around each blackberry plant on the soil surface immediately after crop planting in April and staked. The plants were surface drip irrigated and the mats were placed on top of the drip tape. Weekly measurements on plant height, soil water content and soil temperature (at 12 cm depth) were taken. At the end of each month, weed density and weed biomass was evaluated.

Weed biomass in May (one month after planting) was 51% and 49% lower in the 2 mm and 1 mm mulch, respectively compared to the plots without mulch. Weed densities in June (two months after planting) were also lower by 72% and 65% in the 2mm and 1mm mulch, respectively compared to no mulch. However, there were no differences in weed density or weed biomass between the two mulch types. There were no differences in weed density or biomass between any of the treatments thereafter. Therefore, the mulches were successful in providing weed control during the first few months of this experiment. Weed emergence in all the plots was very low after June, hence no differences were found between the treatments. Although data was not taken on weed control, the mulch was still intact till the end of the year providing some level of weed control. Therefore, it is possible that the paper mulch will provide weed control for a longer period of time.

***Organic broccoli and spinach*:** Studies were conducted in 2010 and 2011 in the certified-organic plots at the Fresno State University farm. The objective of the experiment was to compare the effects of white mustard and soybean seed meals on weed control in broccoli and spinach. Mustard and soybean seed meals were soil-incorporated at two rates (0.5 and 2 tons/ac) two weeks prior to crop planting. Weed densities and hand-weeding time were recorded twice during the growing seasons and weed biomass was determined at crop harvest. Total weed emergence was reduced by approximately 50 to 95% and 40 to 45% 3 and 6 weeks after planting (WAP) of broccoli and spinach, respectively, in the 5 ton/ac mustard meal treated-plots compared to the 0.5 ton/ac soybean seed meal-treated plots. Time required for hand-weeding at 3 and 6 WAP was also reduced by up to approximately 80% and 50%, respectively with the 2 ton/ac mustard meal compared to the 0.5 ton/ac soybean seed meal treatment. Although the mustard seed meal provided substantial weed control, the treatment still will have to be supplemented with other weed control methods for season-long weed control.

***Organic strawberries*:** Studies were conducted in 2012 in the certified-organic plots at the Fresno State University farm. The objective of the study was to compare recycled paper mulch (EcoCover LLC, Huntington Beach, CA 92647) with black plastic mulch. Each plot was covered with either black plastic or recycled paper mulch. Both these materials were staked to the ground. Some plots were left without any mulch for comparative purposes. The experiment was designed as a randomized complete block. The plants were surface drip irrigated and the tapes were placed under the mulch. Weekly measurements on soil temperature and water content (measured at 12 cm depth) were taken in early part of the growing season and in late summer. Weed density and weed biomass was taken several times during the growing season.

Both mulch types provided complete control of weeds except for a few weeds next to the plants in the planting holes. Differences in soil temperature and moisture content were observed at various timed during the growing season (Fig. 1). Soil temperature under the recycled paper mulch was generally lower than under the plastic mulch or the non-mulched plots on average by about 1° C. Soil moisture content was generally similar between the two mulch systems, but in late summer the soil moisture under the plastic mulch was much lower than in the other treatments (Fig. 1). These differences in soil temperature and moisture, however, did not affect crop yield as there were no differences between the two mulch systems in berry yield over the growing season.

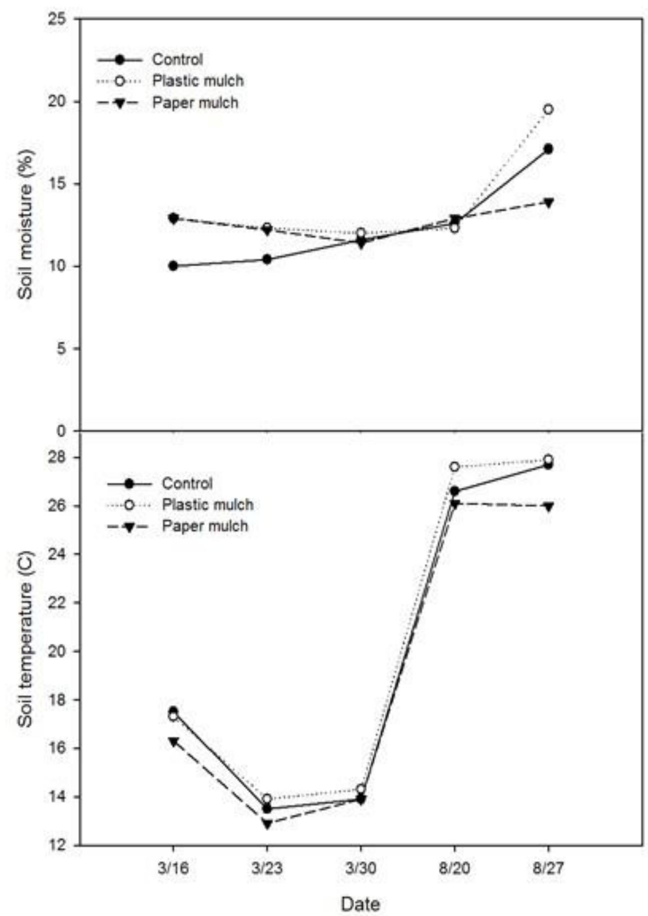

Figure 1. Soil moisture and temperature at 12 cm depth in the various treatments at various times of the year.

Manuka Oil as a Potential Natural Herbicide

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In 1977, Gray observed that bottlebrush plant (*Callistemon citrinus*) repressed the growth of plants in its surroundings. Crude extracts from this plant caused the bleaching of grass weeds. He identified the active component as leptospermone, a natural triketone structure with no known biological activity that had been reported in a number of Australasian shrubs. Leptospermone was moderately active in greenhouse tests, controlling mostly small-seeded grass weeds. This natural product and a small number of synthetic structural analogs were patented as herbicides in 1980. A few years later, a separate group at the Western Research Center was generating analogs of the cyclohexanedione herbicide sethoxydim, an inhibitor or acetyl-coenzyme-A carboxylase. Some of the second generation herbicidal derivatives with a dimedone backbone caused bleaching symptoms similar to leptospermone. Combination of the syncarpic acid of leptospermone to this chemistry ultimately served as the basis for the development of the triketone synthetic herbicides (Fig. 1).

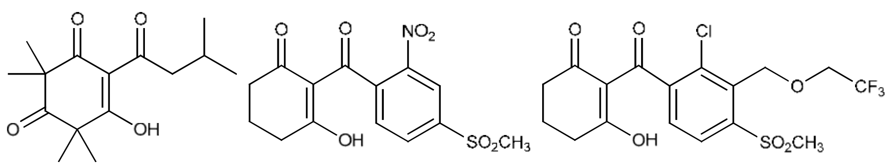


Fig. 1. Structures of the natural triketone leptospermone and two synthetic analogues that are sold as commercial herbicides.

Natural β-triketones are common in many Australasian woody plants (e.g., *Leptospermum*, *Eucalyptus*, *Melaceuca*, etc...). Steam distilled manuka oil account for 0.3% of the dried weight of *L. scoparium*. However, the amount of β-triketone present in these oils varies wildly across New Zealand. Some chemotypes contain as little as 0.1% triketone while others can accumulate up to 33%.

β-triketone herbicides (e.g., sulcotrione and mesotrione) cause bleaching of newly emerging tissues. This symptom was traditionally associated with inhibitors of phytoene desaturase but triketone herbicides do not inhibit this enzyme. It was later found that these herbicide inhibit *p*-hydroxyphenylpyruvate dioxygenase (HPPD), a key enzyme involved in the biosynthesis of prenyl quinones and tocopherols. Plastoquinone (a prenylquinone) is an essential cofactor for phytoene desaturase. In the absence of plastoquinone, phytoene desaturase activity is reduced which results in bleaching of young foliage and accumulation of phytoene typically observed with phytoene desaturase inhibitors develop (Fig. 2). Chlorophyll levels are also affected because the photosynthetic apparatus is no longer protected from the reactive oxygen species generated under high light intensity.

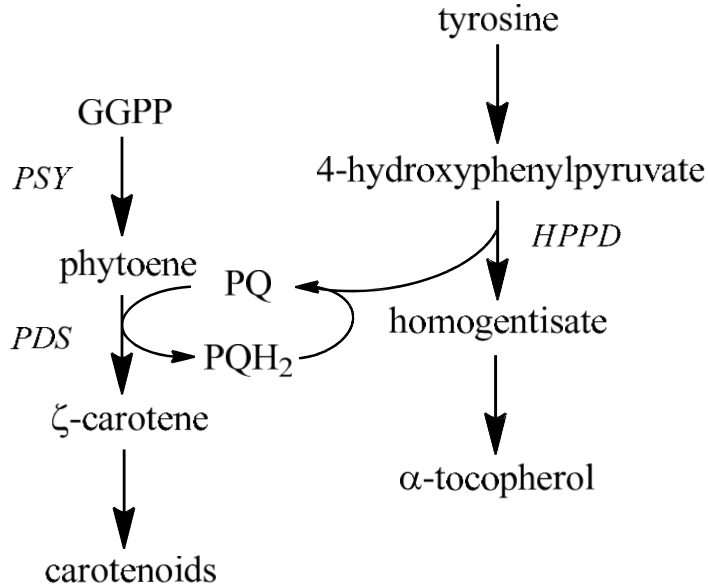
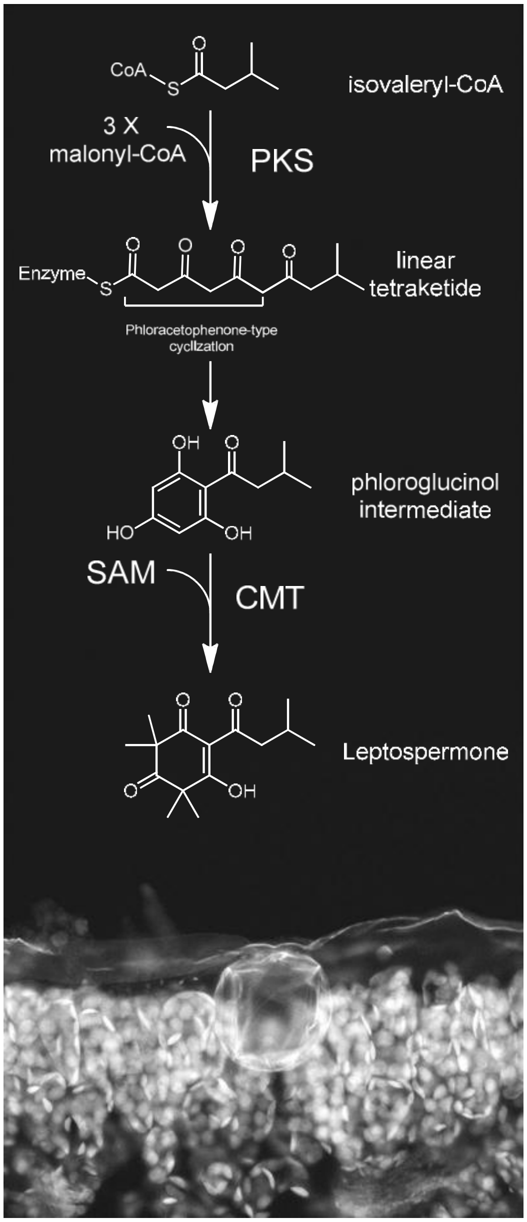


Fig. 2. Mechanism of action of leptospermone. *PSY* = phytoene synthase; *PDS* = phytoene desaturase' *HPPD* = p-hydroxyphenylpyruvate dioxygenase; PQ = plastoquinone.

Gray observed that leptospermone also caused bleaching of plant tissues. Work with the bioactive components of manuka oil demonstrated that some natural β-triketones also inhibit plant HPPD. Most of the activity of manuka oil was due to leptospermone because it was the most abundant triketone in the oil. However, grandiflorone, a minor constituent with has a more lipophilic side chain, was much more active on HPPD. Conversely, the short methyl side chain of flavesone nullified the activity. The important role of the lipophilicity of the side chain was confirmed with a structure-activity study with a series of natural and synthetic leptospermone analogs.

Manuka oil is active both when applied on the foliage and on the soil surface. While most essential oils have little to no soil activity, preemergence application of manuka oil controlled the growth of large crabgrass at a rate of 3 L/ha. The soil activity of manuka oil is due in part with the relatively slow dissipation of leptospermone, which remained active in soil for at least two weeks.

Triketones and other phytotoxic natural products are often produced and stored in specialized structures which may serve in part as a mechanism to prevent autotoxic effects. In the leaves of members of the Myrtaceae family, which encompasses most of the known herbicidal triketone-producing species, specialized schizogenous glands (Fig. 3). In the genus *Leptospermum*, the gland is covered by two to four cells which have thin, straight walls and are generally of the



same approximate size. These cells are encircled by five to 14 unspecialized epidermal cells in a spiral orientation. Schizogenous formation proceeds by the division of single cells within the epidermis or mesophyll layer with the oil cavity forming as an intracellular space. The schizogenous cavity is lined with a single layer of 4 to 6 epithelial cells that are thought to be responsible for the production of the volatile oils stored within the cavity.

Fig. 3. Proposed biosynthesis of leptospermone (top) and micrograph of a representative *Leptopermum scoparium* (manuka) schizogenous gland connected to the cuticle and extending into the mesophyll.

The chemical synthesis of natural β-triketones has been well studied, but much work remains to unravel the *in vivo* biosynthesis of these molecules. Although an *in planta* biosynthetic route has yet to be established, a hypothetical pathway can be proposed based on the structure of the final compounds (Fig. 3). In a series of conversions analogous to the well-examined chalcone synthase enzyme, a type III polyketide synthase (PKS) sequentially condenses three malonyl CoA molecules into a polyketide chain extending from an isovaleryl CoA starter molecule. The enzyme subsequently cyclizes the linear tetraketide intermediate via a Claisen type condensation to generate a phloroglucinol intermediate. A PKS enzyme, valeropenone synthase (VPS), with this activity has been purified to homogeneity and biochemically characterized from *Humulus lupulus* L. (hops) cone glandular hairs. VPS is thought to be involved in the production of the beer flavoring iso-acids of hops which have been shown to contain a β,β-triketone moiety. Subsequently, a gene for this enzyme has been identified and characterized. Efforts are currently underway to isolate and characterize enzymes homologous to VPS from *Leptospermum scoparium* as an initial effort to characterize the leptospermone biosynthetic pathway.

After the production of the phloroglucinol intermediate, the compound would be proposed to undergo spontaneous keto-enol tautomerization, and subsequently to undergo methylation by an as-of-yet unidentified C-methyltransferase (CMT). Early work with methionine-methyl-C^{14}

labeled adult *Dryopteris marginalis* ferns, demonstrated that the C- and O-methyl substituents of isolated phloroglucinols were derived from methionine. If these findings are consistent with leptospermone, the biosynthetic methyltransferases are likely to be similar to S-adenosylmethionine using CMTs identified in other species.

Suggested literature

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Tracking Herbicide Movement- Post Application

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Introduction – Explain Caltrans' Policy and Objectives of IVM, Integrated Vegetation Management. Emphasis is to suggest Post and Pre-Emergent Application Considerations for weed, tree, brush and growth management, suppression, and/or control, to help avert possible problems. Caltrans' primary focus is for safety of applicators, support crews, and traveling public, and the environment.

By using sound 'Application Objectives and Considerations' before applications, the idea is to help enhance overall application efficacy. This may reduce mitigation issues, and help avoid "Off Site" movement, and then the subsequent need to track herbicide movement 'off target'.

Caltrans IVM- Integrated Vegetation Management/ IPM:

Includes biological, cultural, mechanical, and other methods when "Practical, Feasible, and Economically sound". Thus resulting in the proposed chemical a.i. reduction. The current focus is for lowering pesticide usage for the Caltrans A.I. Reduction "Plan", now in it's peak of the 20 year proposal to reduce chemical usage by 80%. These commitments are for maintenance and vegetation management for landscaped areas and roadsides. This includes esthetics, fire control and suppression, and reduced water usage. Again, the focus is to enhance development of reduced worker and public exposure to chemicals, and reduce possible adverse environmental aspects. There is a strong emphasis on "stormwater" contamination reduction.

"I.V.M Plan" objectives:

Introduce lower a.i. chemicals, manage use and include surfactants for efficacy,

Modify cultural and mechanical practices to enhance efficacy, ie, mowing, mulching, other physical weed suppression, hardscapes, mats, cobble, concrete, etc.,

Advance planning and design to limit safety issues and increase efficacy through design.

Presentation includes suggestions for tracking herbicide movement "post application". If "issues, accusations, or complaints" arise, the objective is to repudiate 'blame' if complaint is not valid, analyze actual causes, or minimize subsequent settlement, and/or fines and violations. Also expecting to reduce monetary, environmental, or "collateral damages". This would help reduce "reputation issues", and help plan to avoid reoccurrence and reduce problem potentials in the future. The subsequent need for tracking and calculating "off-site" movement will be mitigated or reduced with prior assessment, planning, and precise documentation of chemical applications.

Documentation is imperative, as proper applications, safety and protective devices, and overall knowledge of the specific chemicals and their potential, will help divert "accusations" by presenting fact. The appropriate appearance and implementation of care and safety, from the viewpoint of regulatory entities, and may help mitigate further losses, in event the problem becomes a ‘misfortune’.

If an actual ‘misapplication’ occurs, or consequences from factors like weather conditions, which are out often of your control, better results of the events and attempted mitigation to avoid inherent problems, may help result in a more positive outcome.

For tracking evidence and damages, research into adjacent areas or other local applications from use reports, making observations of surroundings and layout or topography, and sampling and history of affected plant physiological, soils, and other factors may be useful. If a claim is filed for crop loss or damage with the State, D.P.R., or local County Agricultural Commissioners’ Office, samples will be evaluated due to regulations. That may or may not work in your favor. The manufacturer of the product in question will help mitigate, take samples, or help investigate to avoid perceived product negativity, loss of the product(s) registration, or counter-suits and monetary damages. These companies have long running expertise and advisors for these situations. Note: Not everyone is aware of the time and costs necessary to research, develop, and register new products, and keeping them on the market is vital to the industry. Continued or sporadic problems with these products may result in revised registrations or research costs, re-registration, or complete removal from the market. Farm Advisors and other crop and soil experts also shine a light on problems that may not be chemical related. UC Davis and other scholastic entities have some sharp people along with other associated institutions, so reach out! Don’t be afraid to ask, …they can only say NO! There is a possibility of negative response for assistance though, as there may be affiliation issues with people not wanting to “cross” anyone or get involved.

Conclusion: All said factors and implementation, as seen before, will likely reduce need for tracking of chemical movement post application, but the presentation will include case history.

The Basics of Herbicide-Resistant Weeds

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My program at UC Davis is focused on management of weeds, especially herbicide-resistant weeds, in orchard and vineyard cropping systems. So, how does that apply to this California Weed Science Society session dedicated to managing weeds in roadsides, utilities, and industrial sites? Simple, although the details may differ slightly, the concepts of herbicide-resistance are pretty much the same regardless of whether herbicides are used in annual crops, perennial crops, or non-crop sites!

Herbicides can provide impressive levels of weed control in many crop and non-crop situations; however, not all weedy species are equally controlled due to varying levels of natural tolerance or evolution of herbicide-resistant weed biotypes. Herbicides impose a great degree of "selection pressure" on weed populations and if the same herbicide or herbicides with the same mode of action are used repeatedly, herbicide-resistant or -tolerant species can build up in the population after several generations

Herbicide tolerance and weed shifts: Weedy plants can be tolerant of herbicides due to a variety of temporal, spatial, or physiological mechanisms. For instance, a weed that emerges after a burn down herbicide is applied or completes its lifecycle before a post-emergence herbicide is applied may avoid control efforts. Similarly, large-seeded or perennial weeds can emerge from deeper in the soil and may avoid germinating in soil treated with a preemergence herbicide. Other weedy species have physiological mechanisms of tolerance and avoid control through reduced herbicide uptake or translocation, rapid detoxification, or insensitive target sites. Regardless of the mechanism of tolerance, repeated use of an herbicide can lead to "weed shifts" in which weed populations become dominated by species that are not affected by the weed control measures used.

Herbicide resistance: Herbicide resistance in weeds is an evolutionary process and is due in large part to selection with repeated use of the same herbicide or products with the same mode of action. Herbicides do not "cause" resistance; instead they select for naturally occurring resistance traits. On a population level, organisms occasionally have slight natural mutations in their genetics; some of these are lethal to the individual, some are beneficial, and some are neutral. Occasionally, one of these chance mutations affects the target site of an herbicide such that the herbicide does not affect the new biotype. Similarly, mutations can affect other plant processes in a way that reduces the plant's exposure to the herbicide due to reduced uptake or translocation or through more rapid detoxification. Whatever the cause, under continued selection pressure with the herbicide, resistant plants are not controlled and their progeny can build up in the population. Depending on the initial frequency of the resistance gene in the population, the reproductive ability of the weed, and competition, it may take several (or many) generations until the resistance problem becomes apparent.

Target-site resistance: Herbicides usually affect plants by disrupting the activity of a specific protein (enzyme) that plays a key role in plant biochemical process. Target site resistance occurs when the target enzyme becomes less sensitive or insensitive to the herbicide. The loss of sensitivity is usually associated with a mutation in the gene coding for the protein and can lead to conformational changes in the protein's structure. These physical changes can impair the ability of one or more herbicides to attach to the specific binding site on the enzyme; thus reducing or eliminating herbicidal activity. Certain herbicide groups are particularly vulnerable to developing target site resistance, because resistance can be endowed by several mutations, thus increasing the probability of finding resistant mutants in weed populations - even in those not previously exposed to that herbicide group. For example, specific mutations resulting in seven different amino acid substitutions in the acetolactate synthase (ALS) gene are known to confer resistance to ALS-inhibiting herbicides in weed biotypes selected under field conditions. Something similar occurs with the grass herbicides that inhibit the enzyme acetyl coenzyme A carboxylase (ACCase) for which at least five point mutations causing amino acid substitutions within the gene are associated with cross-resistance patterns observed at the whole plant level involving four classes of ACCase inhibiting herbicides. The existence of so many mutations conferring resistance is reason resistance to these herbicides is frequently found and can evolve rapidly. Resistance to glyphosate can also be target-site mediated in some cases.

Non-target-site resistance: Several mechanisms confer resistance to herbicides without involving the active site of the herbicide in the plant. Of these, the best known is the case of metabolic resistance due to an enhanced ability to metabolically degrade the herbicide. Non-target-site resistance can evolve from the intensive use of diverse and unrelated selective herbicides that are similarly effective on a certain weed species and share a detoxification pathway or a mechanism precluding their accumulation at the target site (exclusion or sequestration) that is relatively common in plants. The management of non-target-site herbicide resistance often represents a greater challenge than target-site resistance because a simple change in herbicide mode of action may not alleviate the problem. Reduced herbicide absorption and/or translocation can contribute to resistance in certain biotypes. These have generally been accessory mechanisms that contribute towards resistance in addition to a major resistance mechanisms. However, recent evidence suggests that changes in absorption and/or translocation are an important contributor to glyphosate resistance in several weed biotypes.

Current status of herbicide-resistance in weeds: Herbicide resistant weeds are an issue around the world; but the greatest problems with resistance tend to be found in countries with highly industrialized agricultural cropping systems due to greater reliance on herbicides. Herbicide resistant weed biotypes have been reported in at least 60 countries and include about 396 unique species-herbicide group combinations worldwide. Herbicide resistant weeds around the world and throughout the U.S are dominated by the photosystem II inhibitors and by ALS inhibitors due to the widespread use of these diverse herbicide classes in broad acreage cereal and grain crops. Some of the most troubling herbicide resistant biotypes are multiple resistant biotypes – one population of rigid ryegrass in Australia is reported to be resistant to 9 different modes of action!

Management of herbicide-resistant weeds: A number of factors affect the degree of selection pressure for herbicide resistant weeds. However, if preventive measures are taken to reduce selection pressure, herbicide resistance can be avoided or delayed. As outlined previously, repeated use of the same herbicide or herbicides with the same mode of action can select for weeds that are resistant or tolerant to that mode of action. As an herbicide controls the susceptible biotypes, with repeated use of the same herbicide, the resistant biotype gradually builds up in the population. Therefore, a major goal of herbicide resistance management is to reduce selection pressure. In this context, herbicide rotation and tank mixes become important resistance management tools and often are used as the first line of defense against the selection of herbicide-resistant weeds.

Non-crop areas such as roadsides, canal banks, and industrial sites have few crop rotational alternatives. Therefore, in these systems, rotation or tank mixes of herbicides with different modes of action should be a part of the management plan to prevent the buildup of weeds that are resistant to that particular mode of action. When herbicides with different modes of action are used in rotation or mixtures, the selection pressure for any one herbicide is reduced. Thus, the weeds will have difficulty adapting to this continuous alteration in selection pressure.

Studies have found that the selection pressure on susceptible weeds from herbicides with longer residual activities is higher than that from herbicides with shorter or no residual activities because one treatment can result in exposure of multiple weed cohorts (ie. flushes) to the herbicide. However, when herbicides with no residual activity are used multiple times in a season, selection pressure is equally high and can lead to selection for herbicide-resistant weeds as has been observed with glyphosate-only weed control programs. In fact, short-term residual herbicides in combination with post-emergence herbicides are being recommended for management of glyphosate-resistant weeds in many cropping systems.

Herbicide resistant weed conclusions: Resistance mitigation seeks to diversify weed control methods in order to delay the evolution process by reducing the selection pressure exerted through the use of herbicides. Target-site resistance is conferred by an alteration causing loss of plant sensitivity to herbicides with a specific mechanism of action. It is, therefore, clear that one way of dealing with the problem is by switching to another herbicide effective on the same weed species, but having a different mechanism of action. The use of herbicide mixtures or sequences involving herbicides with different mechanisms of action can protect the herbicides and delay the evolution of resistance to both, since mutants with resistance to one herbicide would be controlled by the other herbicide and vice-versa. However, the recurrent use of the same herbicide mixture could theoretically select for biotypes with resistance to both herbicides (multiple resistance).

Non-target-site resistance may involve different herbicides and the enhanced expression of mechanisms that are common in plants and thus easily selected for. If several herbicides share a common degradation route, such as the ubiquitous P450 monoxidation, their use will select for the same mechanism of resistance in biotypes that will be resistance to all even if these herbicides are used in mixtures or sequences with each other. Thus, combining or changing herbicides to control non-target-site-resistant biotypes becomes very difficult. Non-target-site resistance may involve the accumulation of genes contributing partial resistance levels.

From this discussion of resistance mechanisms in herbicide resistant weeds, it should be clear that resistance cannot be mitigated only by switching or combining herbicides in production systems that rely solely on the intensive use of selective herbicides for weed control. Instead, herbicide resistance management requires the integrated diversification of chemical and non-chemical weed control methods to reduce selection pressure for resistant weed biotypes. Herbicides are one of the most effective tools for weed management; however, they must be used judiciously. They should be 'one of the many tools' in a weed management toolbox rather than the only tool, else we are at risk of losing effective herbicides due to the evolution of herbicide-resistant weeds.

For more resistance info: http://www.ipm.ucdavis.edu/IPMPROJECT/glyphosateresistance.html or the UCWeedScience blog at http://ucanr.edu/blogs/UCDWeedScience/index.cfm

Biotic or Abiotic Damage: Herbicide or Something Else

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Herbicide drift occurs when applications are made during suboptimal environmental conditions – generally this means too much wind. When herbicide injury does occur, diagnosis is often difficult since injury symptoms vary considerably in appearance for different herbicides, plant species, amount of drifted material, and application timing. Insects, disease, nematodes, nutrient stress, excess heat or cold, and chemicals other than herbicides can also cause symptoms that appear similar to those caused by herbicides. All too often when injury symptoms are observed, the first question is "What herbicide caused this?" Careful observation can often distinguish the cause of the symptoms and determine if herbicides are at fault. The purpose of this presentation is to describe symptoms of common herbicide and to show how other stresses can look similar. General symptoms of herbicide injury are given and may be of help in eliminating certain herbicides as the probable cause of injury.

ACCase inhibitors

Compounds in this group include fluazifop (Fusilade), fenoxaprop (Whip, Puma), diclofop (Hoelon), cyhalofop (Clincher), sethoxydim (Poast), and clethodim (Select, Prism). Symptoms are generally only observed on grasses since most broadleaf plants are tolerant. Injury has been observed on flowers (reduced petal size and spotting of petals) of broadleaf ornamentals. Cyhalofop has also been observed to spot peach leaves and fruit. The spotting can result in dead spots that form holes in the leaves (somewhat similar to shothole disease). Leaf spotting has also occurred on some azaleas and tip burn on Bar Harbor juniper with fluazifop. Symptoms are temporary and regrowth is normal.

In grasses, the first effect is a cessation of top growth, followed by yellowing (without pattern) in young leaves within 7-10 days. Later the older leaves become yellowish and may show some purple. Internodes just above the node (meristemmatic area) turn necrotic brown and appear to "rot". The young shoot can easily be separated from the remainder of the lower shoot.

ALS inhibitors

The herbicides in this class are used at very low rates and are extremely active in broadleaf plants. The principal ALS herbicides used in California are chlorsulfuron (Glean, Telar), sulfometuron (Oust), bensulfuron (Londax), nicosulfuron (Accent), halosulfuron (Sandea), Mesosulfuron-methyl (Osprey), rimsulfuron (Matrix), imazapyr (Arsenal), imazethapyr (Pursuit), imazamox (Raptor), pyrithiobac (Staple) and bispyribac-sodium (Regiment) and imazamethabenz (Assert). Foliar and root uptake can occur with these herbicides.

Symptoms are generally observed in new foliage. Growth generally slows and chlorosis and necrosis of the meristematic region occurs. In new growth, internode length is shortened and small chlorotic leaves appear in small, sometimes distorted whorls. Purplish pigmentation also sometimes is observed in mature foliage. In new growth, symptoms may appear somewhat similar to glyphosate. When drift occurs on the mature leaves of trees, symptoms may appear the following spring, with new growth having shortened internodes.

Soil residual varies considerably between materials, with some lasting a year or more.

Photosynthetic Inhibitors

This broad group of chemicals blocks photosynthesis and includes materials applied primarily preemergence. However, some materials (metribuzin, linuron, diuron, propanil) have some postemergence activity when used with surfactants or oils. Herbicides in this group include metribuzin (Sencor), prometryn (Caparal), simazine (Caliber 90, etc), hexazinone (Velpar), diuron (Karmex), linuron (Lorox), propanil (Stam, etc.), tebuthiuron (Spike) and bromacil (Hyvar).

In perennial crops such as almonds, apples, walnuts, peaches, grapes, many woody ornamentals, etc., symptoms from low rates of the photosynthetic inhibitors start as a yellowing around the leaf margins on mature leaves. Young leaves do not show symptoms. As time elapses, interveinal areas of leaves also turn yellow. Progressive injury includes marginal leaf necrosis with more interveinal yellowing. Iron chlorosis also causes these symptoms. Symptoms are rate dependent with higher rates giving greater and more rapid symptoms. Perennial plants retain the leaves with symptoms until normal senescence. Excessive rates can be observed to reach new foliage before symptoms of chlorosis occurs in mature leaves. These symptoms appear as a rapid progression of chlorosis followed by necrosis, similar to drought. Another pesticide (metalaxyl – a fungicide) will also give similar symptoms.

Prometryn, Karmex, Hyvar, or Lorox drift results in the reverse of these symptoms. Veins become chlorotic with the intervein remaining green. .

Bromacil is used as preemergence, soil applied material. Since this herbicide is relatively soluble in water (815 ppm), there is a tendency to leach into the root zone of perennial plants. Annual horticultural plants do not tolerate bromacil. The more tolerant plants (citrus, apples, peaches, almonds) show symptoms on mature leaves as a striking veinal yellowing, and less commonly, the leaves will also have blotchy chlorosis. Sensitive trees such as walnuts or figs develop necrotic leaves. This necrosis frequently appears rapidly, with no veinal chlorosis. These leaves normally fall and new leaves are formed. Depending on rate of the material present in the soil these new leaves may be smaller and chlorotic at low rates or they may also drop if high rates are still present. If trees are healthy, they can drop a set of leaves and develop new leaves at least two times in a season. If the trees are not healthy, they may be killed by high rates of these herbicides.

If soil applied (drift or direct application) prior to seeding or seedling emergence, seedlings may germinate and appear to grow normally for a number of days (7-10) before the leaves turn chlorotic and necrotic and the seedlings collapse. In transplants, root uptake occurs until mature leaves show yellowing with some leaves showing a partial leaf chlorosis (blotchy appearance). Depending upon rate and susceptibility of the plant injury can range from crop death to mild chlorosis.

PPO Inhibitors

PPO inhibitors includes oxyfluorfen (Goal, GoalTender), carfentrazone (Shark, Aim), sulfentrazone (Zeus), oxadiazon (Ronstar), and flumioxazin (Chateau). Although these herbicides are used primarily as preemergence herbicides (except for Shark), they all can have some postemergence activity on exposed leaf tissue. Oxyfluorfen symptoms frequently appear on young leaves, apparently due to low wax content in the leaf cuticle. Oxyfluorfen causes tip dieback on new growth in conifer species, while older foliage is not generally affected, except at excessive rates. On a sensitive plant like petunia, silvery spotting and a glazing appearance occurs, somewhat like smog damage. When applied preemergence to crucifer crops such as broccoli the tips of the cotyledon leaves are frequently cupped, as if the leaves are burned, as they push through the treated soil, leaving the cotyledons distorted. Girdling of the shoots of annual plants, principally broadleaves, is common and appears almost as if there is insect feeding at the soil surface. This symptom is sometimes observed on seedlings after rainfall or irrigation moves treated soil in contact with stem tissue.

Chateau can cause foliar symptoms that often appear to look similar to oxyfluorfen or paraquat symptoms. Ronstar or Zeus can cause desiccation and necrosis if they contact foliar parts of the plant. Susceptible plants emerging from the soil turn necrotic and die after exposure to sunlight. Shark drift, at low concentrations, results in necrotic spots on leaves, with the spots dropping out of the leaf. Fruit of plums will show brown spots and gumming from the spots. If sprayed so coverage is uniform it acts as a contact burn on leaves. Shot hole disease looks similar, but does not affect the fruit.

Paraquat, considered a Photosystem I inhibitor, can cause foliar symptoms similar in appearance to the PPO inhibitors. Injury symptoms from paparquat is usually the result of drift, since it is a contact herbicide, and would not be intentionally applied to a desirable plant. Depending upon concentration, chlorotic or necrotic spots may appear on young or mature foliage. These spots normally don't "fall out" of tree foliage thus it should not be confused with "shot hole" disease. Symptoms progress more rapidly on bright, sunny days. Necrotic spots caused by hail or sand blasting may sometimes be confused with the symptoms seen following PPO Inhibitor or paraquat drift.

Auxinic Acids

Phenoxys include 2,4-D, 2,4-DB (Butyrac), MCPA, and mecoprop (MCPP). Dicamba (Banvel, Clarity) is the only benzoic acid in this group. The carboxylic acids currently in use include picloram (Tordon), triclopyr (Turflon, Garlon, Grandstand), and clopyralid (Stinger, Transline). These compounds can be grouped together because of similar symptoms. Though each may have a characteristic symptom on an individual plant and have a greatly different rate response, symptoms generally cannot be differentiated unless directly compared.

With phenoxys, symptoms appear in new growth of broadleaf plants (annual or perennial). The time interval can be 3-10 days after application before symptoms appear. Interval is generally temperature dependent with a faster response at increasing temperature. Leaves lose their planar angle, the petioles twist and there is general disorientation of growth in new foliage. Old leaves and stems in woody plants such as peaches, grapes, etc., do not appear affected. Leaves of broadleaf plants take on various changes in development patterns. Using grapes as an example, leaves become abbreviated at the tips where there are major veins. This may become so extreme as to cause "fan-shape" or "strap" leaves. Veins become very prominent with the reduction or absence of the interveinal area. High rates kill the young tissue causing necrosis. Stems of immature woody plants may develop splits or "corky" zones.

In grape, symptoms of 2,4-D have often been confused with fan-leaf virus. In diagnosis there should be a different field pattern from 2,4-D drift or accidental application as compared to the sporadic occurrence of diseased plants.

Annual broadleaf plants exhibit similar leaf symptoms as perennials; leaf petioles and stems twist severely. In carrots, root growth appears as irregular thickening giving a "warty" appearance or in some cases splitting occurs because of the irregular growth. Splitting alone is not a characteristic symptom of phenoxy damage, because it can be caused by lack of proper water management. San Jose scale can also cause bark to split, which looks similar to phenoxy damage. Leaf bases are enlarged with a reduction of length of new leaves and some twisting of the leaves can be observed following drift from this group of herbicides.

ESPS Inhibitor (Glyphosate)

Symptoms from glyphosate are variable, depending on timing and method of exposure. Exposure must take place through leaves or young, thin or green bark. Soil exposure is minimal to nil if the soil has been tilled before planting or there is soil over roots. In perennial crops, symptoms from a spring to summer exposure (new to maturing growth) have varied from chlorosis with no specific pattern in new growth when sprayed on older leaves to interveinal chlorosis. Overall leaf chlorosis can occur and new growth following exposure to older foliage is commonly distorted, puckered, and glossy small leaves.

Exposure to mature foliage in the fall may not result in symptoms until the following spring when new growth initiates. Trees with glyphosate exposure can have delayed leaf emergence, reduced leaf size, loss of apical dominance and shortened internodes. Depending upon exposure it may appear on one branch or cane or the total plant may show the effect. As growth occurs, depending upon date and amount of exposure, new growth may be normal and even mask the early symptoms. High rates of exposure, however, cause symptoms to persist during much of the season. These symptoms may appear in new foliage each spring for 2 to 3 years without additional exposure. Unless exposure is very high on mature foliage normally a tree or vine survives. This also depends upon the original health of the plant. In grapes it does not appear to reduce fruiting greatly, even though foliage symptoms may be severe. In pines and firs, the new candles or growth tips become necrotic and die forcing secondary whorls.

After exposure to high glyphosate rates, annual plants leaves turn light green and chlorotic about 7 to 14 days after application, depending upon temperature and sunlight, and then the plant collapses. Plants may survive low rates of glyphosate, showing chlorosis in new growth, and possibly some stunting of subsequent growth. Young tomato leaves can show interveinal chlorosis, whereas the mature leaves may not show symptoms. Some glyphosate symptoms (chlorosis of young growth and shortened internodes) could resemble the sulfonylurea or imidazolinone herbicides.

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Use of Less-Toxic Herbicides and Sheet Mulching in Landscapes

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Abstract:

Sheet Mulching and the use of less-toxic herbicides reduce the need for stronger herbicides on commercial landscapes. The way landscapes are commonly designed, built, and maintained favors the growth of weeds. Compaction, the removal of organic matter, excessive turf areas, and salty fertilizers all create an environment that stresses plants and requires many pesticides to maintain. These pesticides, including herbicides, cause collateral damage and help create conditions that require repeat applications. This cycle should be broken by reducing turf areas, building soil through the addition of organic matter, and using less-toxic herbicides. Sheet mulching smothers existing weeds, inhibits new weed growth, helps build soils, and composts existing turf in place. Less-toxic herbicides are continually improving and landscape managers must stay abreast of new and improved products and methods to maximize efficiency. Transitioning turf areas through sheet mulching and the strategic use of less toxic herbicides can help improve return on investment while reducing pollution, improving ecological stability, and naturally inhibiting weed growth.

Commercial landscapes in California are at a huge disadvantage when it comes to weeds. If one were to design and maintain the perfect environment to promote weed growth, it would look much like your typical commercial landscape. Organisms seek out and prefer certain niches in which to establish themselves. The perfect niche habitat for weed growth is one that mimics early trophic level disturbed soils, soils that have had their structure destroyed through compaction or inundation, or those that have had their supporting organisms wiped out by toxins. Weeds are nature's "first responders". They have evolved to be able to quickly establish themselves in disturbed or "injured" habitat situations, heal the soil, and provide an organic cover layer. They quickly establish themselves to inhibit erosion and build up organic matter that provides food for fungal organisms, thus reducing the pH of the soil. This prepares the way for woody perennials to move in and bump the ecology of the niche habitat into the next successional trophic level. Different weeds serve different roles in the process. Leguminous weeds fix nitrogen and deep tap-rooted weeds help to break up compacted soils and bring up mineral nutrients from lower soil horizons. Other weeds are adept at sequestering and/or breaking down toxins. Weeds have a purpose in the landscape ecology.

Weeds put all their efforts into fast, efficient growth and seed production. When they have done their work, and the niche habitat has been "healed", the weed population naturally declines as a healthy, diverse "O" soil horizon is established and woody perennials take over. In doing their important work, weeds actually go against what one would think best in terms of natural selection: they create and promote an environment that decidedly favors against their well-being. If they have done their job well, their seeds may not even be able to germinate in the environment they have created. One has to take a much greater holistic viewpoint to see the genius in their work, and see how their work fits into the scheme of ecological succession. Their purpose is to fix, repair, and heal land that has been abused and then move on to the next crisis, their seeds being able to travel far and wide and/or to remain dormant for long periods of time until their services are needed again.

The abuse of land reaches an apogee in commercial landscapes. To paint a picture of the archetypical situation, we start at the beginning: Whether it is a new development for a sub-division, a shopping center, an office complex, a new HOA, or an apartment complex, the same procedure usually ensues:

First, the land is surveyed and any vegetation or topsoil is removed. More and more, this topsoil is saved for future use, but many times, and certainly historically, it is simply pushed aside or used as non-structural fill. Secondly, the sub soil is compacted, sometimes limed, and "engineered" soils are generated that are fantastic for roads, foundations, and light pole footings.

Thirdly, after the built structures are in place, the landscape installation is awarded to the low bidding landscape contractor. The low-bidding contractor, having likely underbid the project, moves forward using the least amount of effort to decompact the landscape areas, if at all, depending on the specifications. The least amount of top soil is then put in to achieve the target grade. Minimum-sized holes are then dug for the proposed plant material, a thin layer of topsoil is laid under proposed sod areas, and the minimum amount of mulch is applied, and only if specified. To maintain appearance through the establishment period, chemicals such as Oxadiazon (Ronstar) and Oryzalin (Surflan) or perhaps Pendimethalin (Pendulum) are applied.
–Or maybe a mix of Trifluralin (Treflan for grasses) and Isoxaben (Gallery for broadleafs) is used, such as the mixture in Snapshot. Then surviving weeds are hit with Glyphosate and maybe Diquat as in the concoction in QuickPro.

To make matters worse, the plants generally proposed are those that evolved in woodland environments or bred in European gardens. They are better adapted to different soils and climates. The other problem is that many of them will get much larger than the spaces allotted to them on the plans due to the desire to have a quick mature appearance to entice would be tenants into the new development.

Enter the landscape maintenance contractor. After the establishment period, the maintenance contractor adds insult to injury by flooding the phylosphere of the roots of the plants with a toxic mix of salty urea-based fertilizers blended with chelated minerals to make up for the deficiencies shown in the plant material's leaves, usually iron due to the high pH. The plants respond like they're on plant growth drugs and put on fast succulent growth that is immediately attacked by fungal pathogens, mollusks, and insects. The experienced maintenance contractor, however, is already a step ahead of the game and has injected the trees and sprayed the shrubs with Imidicloprid (Merit) and applied the fungicide Mefonoxam (Subdue) to the color beds. The planting areas have been spread with Metaldahyde and any mammalian pests have gotten a dose of Strychnine or several of Diphacinone. The Landscape now looks "Clean & Green", a masterpiece of sterility and order.

Over time, along with a good deal of fossil fuel use and noise pollution, the maintenance contractor then endeavors to blow, rake, vacuum, and remove any and all organic matter from the site. New mulch, since it's not in the maintenance specs and can be expensive to spread, or might be seen as messy or collecting debris, is often not used, or if it is, only "colored bark" is applied at the minimum amounts necessary to cover the ground. Those plants that are outgrowing their allotted space are routinely hedged into neat little boxes and/or spheres, and many times coated with a PGR, or Plant Growth Regular. It might have an exciting name like Methylchlorohydroxyfluorene. These practices can go on for YEARS.

When the plants eventually (or quickly) give in and decline and weeds amazingly get through the onslaught of chemical herbicides, a new, low bidding landscape contractor is selected to "fix the problem" (… something the weeds could have done if allowed the chance and a decade or so). The "revolving doors" of landscape service providers then begins. Any let down in herbicide defenses invites an onslaught of weeds desperate to heal the habitat niches that are so wildly out of balance.

On a side note, but one that is pertinent to this topic is the overuse of turf in commercial landscapes. Here we have a monoculture of a plant that necessitates roughly 75% more water to be happy than the area in which it is grown generally receives. To maintain this water hungry monoculture, we provide roughly 5% of our air pollution by constant mowing, edging, and blowing. The EPA estimates that roughly 18 MILLION gallons of fuel are SPILLED each year in the process of keeping these monocultures of climate inappropriate plants looking "Clean & Green". The "Clean" part of commercial turf involves more than mowing and edging. Weeds are constantly trying to fix the problem presented by the unnatural monoculture. 2,4-D, Dicamba, and Mecoprop are the chemicals of choice to keep these ecowarriors at bay. While very little of these turf areas is used for actual recreation, many commercial landscapes contain many acres of turf for purely ornamental reasons. It is such an obvious target for water conservation that the state of California is actively promoting the removal of turf through incentive programs identified in the WELO or the Water Efficient Landscape Ordinance (AB1881), and many "cash for grass" conservation programs throughout the State.

When you add up the initial soil destruction, the inappropriate plant selection, the systematic removal of organic matter, the compaction, the regular application of salt based fertilizers, and the unintended collateral damage caused by a mix of chemical herbicides, fungicides, insecticides, and even mammalian toxins used on these commercial landscape sites, there is little wonder why nature has sent in the early responders, the weeds, to fix the problem. That's their job! These soils need help and we keep killing the organisms that are there to take care of it. Unfortunately, the process of natural pedogenesis, that of building soil structure, takes time and our culture has developed an aversion to seeing weeds doing their job.

While it is easy to show a Return on Investment in water savings to promote the transition of wasteful turf monocultures to more climate-appropriate plants on efficient in-line drip systems controlled by ET/Weather-based controllers, the process needed a sustainable procedure that would help the soil and new plants. It had to be quick, efficient, and not involve the use of weeds. Sheet mulching is the answer. Many people have used sheet mulching for permaculture projects and home garden areas, and it has been around as a “fringe” landscape tool for generations but the last five years or so have seen a huge increase in the number of large, commercial-scale sheet mulching projects that have been very successful. It is now taught in UC approved Master Gardener Classes, Bay- and River-Friendly Landscaper Qualification courses, and promoted by many preeminent professional landscapers.

Sheet Mulching is a process that can be used to not only transition turf areas, but also ivy and other monoculture perennial beds such as Hypericum. It is also effective to control weeds in other areas. The beauty of the process is that it minimizes the use of chemical herbicides, completes the cycle of the use of post consumer waste paper products, keeps old sod out of the land fills, and composts the old turf in place. With a little grading around hardscape elements, layers of compost, recycled cardboard, and organic wood chip mulch feeds the soil, inoculates it with microorganisms, smoothers the weeds, and provides a chemical-free, biologically diverse environment to promote water conservation, nutrient cycling, and healthy plant growth. It also inhibits weeds because it does the same work as weeds: It quickly covers the area to mitigate erosion, it builds up the organic content of soils, thus promoting fungal populations, the creation of humus, humic and fulvic acids, and thus lowering the soil pH and making nitrogen available as ammonium. It also establishes a healthy, diverse “O” soil horizon.

There are many different ways to Sheet Mulch. Depending on the existing weeds (which could be turf!) that involve a number of variations on the “lasagna” approach to layering compost, cardboard, and mulch. Blackberry, Poison Oak, and even Eucalyptus can be sheet mulched with enough layers of cardboard and a deep enough layer of organic wood chips. Bindweed, Yellow NutSedge, and Bermuda can all be successfully composted in place using this technique –without the use of herbicides, and while building healthy, biologically diverse soils and promoting the healthy growth of perennial woody plants.

The ones that get away, the weeds that still try to do their work on the dirt, can be addressed with less-toxic herbicides. These are natural oils and acids. Over the last decade, many products have tried to fill the niche market for those who want to avoid the common synthetic herbicides such as 2,4-D, or make a stand against Monsanto and their plans to dominate the food production of the planet. The landscape market is based on customer needs and desires. More and more the landscape maintenance contractor is hearing the customer plead “Please don’t use pesticides on my landscape anymore.” -and many of them are prepared to pay the difference. Municipalities, school districts, parks and rec; they are all getting pressure to reduce or eliminate the use of pesticides. In Canada, where 2,4-D is now not allowed, for example, a strong market has been created for alternative, selective broadleaf weed control.

While some less-toxic herbicide products have done all right, and some have required surfactants to get the job done, several are proving very efficacious. The methods to improve their efficacy are being developed and the landscape maintenance professional who is catering to the desires of the new eco-literate customer are formulating best management practices to implement true IPM that first goes to the cause of the weeds, but also uses multiple control strategies to hit the weeds with a strategic approach using the least toxic controls in effective and cost effective programs. This is a moving target. New products and new methods are being developed while the customers push for cost effectiveness.

There are no organic trans located herbicides. Corn gluten does not work very well on the West coast. No OMRI listed material will kill Bermuda in fescue. There are certainly limits as to what these burn-down products can offer. They are, however, the leading edge in landscape weed management for the customer who increasingly, care. While an intelligent discussion about the aesthetic threshold level can be good for the site manager-landscape service provider relationship, the bottom line is that as our potable water and oil-based fertilizers and maintenance practices get more expensive and huge expanses of turf are looked at more as wasteful instead of bucolic, the trend towards a sustainable, ecologically responsible way to transition them to more climate-appropriate plants on drip with mulch will intensify. The use of less-toxic herbicides as an adjunct to the process as well as to address weeds in recreational turf and shrub beds will continue to be a growing profit center for those landscape service providers who are prepared to meet the challenge.

Chemical Strategies for Overseeding Success

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Overseeding is common practice on desert golf courses for winter color and playability. Yet, many superintendents are faced with transitioning from warm- to cool-season turf at a time of the year that is not favorable to either species. Traditionally, irrigation was withheld and aggressive cultivation practices such as flail mowing and verticutting were employed to slow down bermudagrass growth and encourage cool-season turf establishment. However, these practices can be deleterious and even prohibitive in terms of air quality standards, green waste transportation and management, and spring transition of bermudagrass. A growing trend on golf courses in the Coachella Valley is toward chemical suppression of bermudagrass during overseeding. Triclopyr is commonly used to suppress bermudagrass regrowth "on the other end" of overseeding or during establishment of cool-season turf. Prior to overseeding, a non-selective contact or burn down herbicide could offer several benefits including:

1. Suppression of bermudagrass competition
2. Reduction of green waste
3. Reduction of labor and transportation costs
4. Improvement of air quality
5. No adverse effects on germination/establishment of overseeded species
6. No adverse effects on spring transition of bermudagrass

The objectives of this research were to compare Scythe (pelargonic acid), Reward (diquat), and Finale (glufosinate) alone and in various combinations for bermudagrass suppression [with or without prior application of Turflon Ester Ultra (triclopyr)], green waste reduction, and spring transition vs. flail mowing as a standard control.

Study One: How long do burn down herbicides suppress bermudagrass and how does prior application of triclopyr affect suppression in combination with these herbicides?

Location:	18 North Fairway, Toscana Country Club, Indian Wells, CA
Species:	Tifway II hybrid bermudagrass
Mowing Height:	0.425 inches
Application Dates:	Burn down herbicides (14 Sep 2011)
	Turflon Ester Ultra (16 oz/A 5 days prior to burn down herbicides)
Spray Information:	50 GPA
	Burn down herbicides applied with single, even flat fan 8003 nozzle
Design:	Randomized complete block; 3 replications
	Study was conducted on two areas of turf, one that was pre-treated with Turflon Ester Ultra and the other received no Turflon Ester Ultra

Results:

- ✓ With the exception of Finale, all other burn down herbicides were more effective in suppressing bermudagrass when the turf was pre-treated with Turflon Ester Ultra (Table 1).
- ✓ Scythe>Reward>>Finale for speed of activity.
- ✓ Finale>Reward>>Scythe for longevity of bermudagrass suppression.
- ✓ These results demonstrated that overseeding preparation (scalping and seeding) should take place within 1-2, 2-5, and 5-12 days of application of Scythe, Reward, and Finale, respectively.
- ✓ The study area was not overseeded until 29 Oct 2011 and, during that time, bermudagrass appeared to recover equally well among all treatments.

Study Two: How do burn down herbicides affect green waste, ryegrass germination, and bermudagrass spring transition?

Location:	18 North Fairway, Toscana Country Club
Species:	Tifway II hybrid bermudagrass
Application Dates:	Burn down herbicides (11 Oct 2011)
	Turflon Ester Ultra (16 oz/A 5 days prior to above date)
Mowing Height:	0.425 inches
	0.250 inches (scalping) and/or flail mowing on 13 Oct 2011
Spray Information:	50 GPA
	CO_2-powered sprayer with flat fan 8003 nozzles
Design:	Randomized complete block; 4 replications
Plot Size:	7 ft x 15 ft; 5-ft alleys
Overseeding:	Perennial Ryegrass, 800 lbs/A, 29 Oct 2011

Results:

- ✓ All treatments resulted in significantly less green waste production compared to the flail and scalping control. Consequently, the data were reported as a percent reduction compared to that treatment (Table 2).
- ✓ Although few significant differences in green waste were found among the scalping and chemical treatments, both rates of Reward reduced green waste the most (74% and 76% reduction).
- ✓ After flail mowing and/or scalping and 48 hours after chemical application, Reward or treatments containing Reward provided the best bermudagrass suppression as evidenced by the percentage of brown bermudagrass turf.
- ✓ Overall, the results of these studies suggest that Reward (diquat) is the best burn down herbicide for use on fairways prior to overseeding based on cost, speed of activity, green waste reduction, and bermudagrass suppression. To ensure maximum safety to all

turfgrass species, application of Reward is recommended at 32 oz/A between 2-5 days before scalping and overseeding and not withholding irrigation prior to overseeding.

- ✓ Scythe (pelargonic acid) is tried and true for overseeding preparation on putting greens where cost is less of a factor due to area. Furthermore, it has already been used with success on fairways in the Coachella Valley. Other advantages include its speed of activity, thus shortening the window between times of application and overseeding preparation. However, our results suggest that the other burn down herbicides are more cost effective and equally or more effective in function on fairways and other large areas of turf.
- ✓ Finale (glufosinate) is the least studied burn down herbicide for this application. However, Finale appears to offer the greatest potential for bermudagrass suppression even without pre-treatment with Triclopyr. In the second experiment, Finale was at a disadvantage since it requires a longer period of time than 48 hours to suppress bermudagrass. However, again it provides the longest suppression. And, like Reward, it is very cost effective. The recommended application rate for this function is 32 oz/A.

Study Three: How does application timing of burn down herbicides affect green ryegrass germination and bermudagrass spring transition?

Location:	18 North Fairway, Toscana Country Club
Species:	Tifway II hybrid bermudagrass
Application Dates:	Burn down herbicides (7, 5, and 2 days before overseeding) Turflon Ester Ultra (16 oz/A 5 days prior to application of burn down herbicides)
Mowing Height:	0.425 inches 0.250 inches (scalping) on 17 Oct 2012
Spray Information:	50 GPA CO_2-powered sprayer with flat fan 8003 nozzles
Design:	Randomized complete split block; main plots = burn down herbicide treatments; sub-plots = Turflon Ester Ultra; 4 replications
Plot Size:	7 ft x 14 ft; 4-ft alleys
Overseeding:	Perennial Ryegrass, 800 lbs/A, 18 Oct 2012

Results:

- ✓ There were no adverse effects of Scythe (7% v/v), Reward (32 oz/A), or Finale (32 oz/A) applied 7, 5, or 2 days before overseeding on establishment of perennial ryegrass (data not shown). Herbicide effects on spring transition of bermudagrass will be evaluated in spring 2013.

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Table 1. Percentage of brown bermudagrass turf 5 and 12 days after treatment with burn down herbicides, and with or with pre-treatment of Turflon Ester Ultra at 16 oz/A. Indian Wells, CA.

				5 DAT		12 DAT	
No.	Treatment	Rate	Cost/Acre[1]	Brown Turf (%) + Turflon	Brown Turf (%) - Turflon	Brown Turf (%) + Turflon	Brown Turf (%) - Turflon
1 1	Scythe MSO	5% v/v 1% v/v	$120	72 cde	25 f	48 cdefg	17 gh
2 2	Scythe MSO	5% v/v 0.5% v/v	$115	85 abcd	38 f	65 abcde	34 efgh
3	Scythe	7% v/v	$154	88 abc	60 e	68 abcde	36 efgh
4 4	Scythe MSO	7% v/v 0.5% v/v	$159	90 abc	78 bcde	71 abcde	65 abcde
5 5	Reward NIS	16 oz/A 0.5% v/v	$15	94 ab	65 de	78 abcd	17 fgh
6 6	Reward NIS	32 oz/A 0.5% v/v	$25	96 ab	89 abc	88 ab	44 defgh
7 7	Reward NIS	64 oz/A 0.5% v/v	$45	98 ab	88 abc	91 ab	55 bcdef
8	Finale	16 oz/A	$10	80 abcde	63 e	70 abcde	72 abcde
9	Finale	32 oz/A	$20	98 ab	96 ab	90 ab	93 ab
10	Finale	64 oz/A	$40	99 a	99 a	98 a	97 a
11 11 11	Scythe Reward NIS	5%v/v 16 oz/A 0.5% v/v	$125	97 ab	65 de	84 abc	13 gh
12 12 12	Scythe Finale MSO	5% v/v 16 oz/A 0.5% v/v	$125	96 ab	90 abc	88 ab	65 abcde
13 13 13	Reward Finale NIS	16 oz/A 16 oz/A 0.5% v/v	$25	98 ab	86 abc	92 ab	64 abcde
14 14 14 14	Scythe Reward Finale NIS	3% v/v 8 oz/A 8 oz/A 0.5% v/v	$82	96 ab	62 e	87 ab	8 h

Means followed by the same letter in a column are not significantly different ($\propto$ = 0.05).
[1]Cost/acre of all ingredients is approximate and meant for comparison purposes only.
DAT = days after treatment. MSO = methylated seed oil. NIS = non-ionic surfactant.

Table 2. Percentage of bermudagrass green waste reduction and brown turf following flail or reel mowing on 13 Oct 2011. Herbicide treatments were applied 48 hours earlier. Indian Wells, CA.

No.	Treatment	Rate	Cost/Acre[1]	Green Waste Reduction (%)[2]	Brown Turf (%)
1	Untreated Flail + Reel	--	--	0 a	85 ab
2	Untreated Reel	--	--	62 bc	41 d
3 3 3	Scythe MSO APSA 80	5% v/v 0.5% v/v 0.5% v/v	$130	64 bc	71 bc
4 4 4	Scythe MSO APSA 80	7% v/v 0.5% v/v 0.5% v/v	$167	67 bc	86 ab
5 5 5	Scythe Reward MSO	5% v/v 10 oz/A 0.5% v/v	$121	68 bc	94 ab
6 6	Reward NIS	32 oz/A 0.5% v/v	$25	74 c	99 a
7 7	Reward NIS	64 oz/A 0.5% v/v	$45	76 c	99 a
8	Finale	32 oz/A	$20	60 bc	35 de
9	Finale	64 oz/A	$40	66 bc	41 d
10 10 10	Scythe Finale MSO	5% v/v 16 oz/A 0.5% v/v	$125	67 bc	78 ab
11 11 11	Reward Finale NIS	16 oz/A 16 oz/A 0.5% v/v	$25	69 bc	87 ab
12	Flucarbazone	0.6 oz/A	--	54 b	14 e
13	Flucarbazone	1.2 oz/A	--	67 bc	40 d
14	Flucarbazone	2.4 oz/A	--	70 bc	46 cd

Means followed by the same letter in a column are not significantly different ($\propto = 0.05$).
[1]Cost/acre of all ingredients is approximate and meant for comparison purposes only.
[2]Green waste reduction values were calculated as a percentage of clippings harvested from the untreated flail and reel mowing treatment.
MSO = methylated seed oil. NIS = non-ionic surfactant.

Roundup Ready Technology Overview

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Glyphosate was first discovered to have herbicidal activity in 1970 by John E. Franz, while working for Monsanto. Roundup first appeared on the market in 1973. It has been called the herbicide of the century. Glyphosate herbicides eliminate more than 125 weeds and are non-toxic to animals.

Franz spent his entire 36-year career at Monsanto in St. Louis.

From 1960 to 1988, Franz received over 840 patents worldwide, including approximately 50 in the U.S. Franz published more than 40 papers and wrote the book *"Glyphosate: A Unique Global Herbicide.*" In a bit of irony, considering the firestorm ignited by environmental radicals that has swirled around glyphosate and Roundup Ready technology, later in his career he went back to the organic division to concentrate on environmentally friendly products until he retired in 1991.

For you researchers who have had your pockets stuffed with $100 bills from Monsanto just like I have, you might be interested to know that Franz reportedly received $5 for his first patent from Monsanto.

As we all know, this discovery had an incredible impact on weed management, allowing farmers and urban dwellers to easily and effectively control weeds.

I recall interviewing legendary weed scientists Harold Kempen and Bill Fischer in the mid-1970s talking about this new herbicide. Kempen told me it was so safe that Monsanto said you could wear sandals when applying it, but he said he would opt for boots. I also recall the admonition from researchers that Roundup would not work on stressed weeds. I forget where the story originated, but there was a tale about an irrigation ditch that broke or overflowed and some recently glyphosate-treated weeds died when nearby treated, stressed weeds did not. Scientists and growers also marveled at how it translocated into the roots. It was truly the herbicide of the century.

Remember, it cost about $100 per gallon. It was the most stolen agchem product of the day. Retailers and farmers stored it behind alarmed, chain link fence enclosures with razor wire ringing the top or behind bolted doors.

The technology that eventually melded glyphosate and plants began in 1946, when scientists first discovered that DNA can transfer between organisms. The first genetically modified plant was produced in 1983, using an antibiotic-resistant tobacco plant. In 1994, the transgenic tomato was approved by the FDA for marketing in the US--the modification allowed the tomato to delay ripening after picking.

In the U.S. in 1995, a basketful of transgenic crops received marketing approval: modified oil composition (Calgene), (Bt) corn/maize (Ciba-Geigy), cotton resistant to the glyphosate and, Bt cotton (Monsanto), Bt potatoes (Monsanto), soybeans resistant to the glyphosate (Monsanto), virus-resistant squash (Asgrow), and additional delayed ripening tomatoes (DNAP, Zeneca/Peto, and Monsanto). In 2000, with the production of Golden rice, scientists genetically modified food to increase its nutrient value for the first time. At least 25 GM crops have received regulatory approval to be grown commercially.

Genetically modified crops have become the norm in the United States. In the most recent survey I could find, 70% of all the corn that was planted was herbicide-resistant; 78% of cotton, and 93% of all soybeans. Those percentages were likely much higher in 2012.

Biotech crops reached 400 million acres worldwide in 2011, an 8 percent growth, from 2010. 2011 was the 16th year of commercialization of biotech crops. This growth continued after a remarkable 15 consecutive years of increases.

A 94-fold increase in acreage from 4.2 million acres in 1996 to 400 million in 2011 makes biotech crops the fastest adopted crop technology in the history of modern agriculture.

However, problems with glyphosate-resistant weeds may result in a slight reversal of those percentages. Earlier this month I attended the Beltwide Cotton Conferences in San Antonio, where there were many presentations on the subject of how to grow conventional cotton and the use of yellow, pre-plant herbicides. How soon we forget. Guess what’s the hottest new piece of equipment in cotton production; hooded row-crop sprayers.

Roundup Ready crops started coming to market in 1995 with RR Canola followed by RR modified soybeans a year later and with RR cotton first available in limited quantities in 1997; RR corn in 1998; RR alfalfa and RR ready sugar beets were released in 2005. However, legal challenges were filed against both beets and alfalfa and seed sales were halted. After exhaustive legal wrangling, RR alfalfa was re-deregulated in 2011 and sugar beets followed in 2012. The legal battle over RR alfalfa continues with a suit in Northern California where opponents claim the USDA did not take into consideration the Endangered Species Act when deregulating RR alfalfa. Oral arguments were heard last October, and we await a decision. However, I am not sure what the impact would be if the opponents win, since I am told 25 percent of the sales of alfalfa seed last year nationwide was Roundup Ready alfalfa varieties. According to Seth Hoyt, respected hay market analyst, 50 percent of alfalfa seed sales in California for planting last fall were Roundup Ready varieties.

There’s RR ready wheat. It was put on the shelf in 2004 due to export marketing concerns. There is an effort afoot now to bring it back. There is RR lettuce. I recall reporting on University of Arizona cooperative extension’s Kai Umeda’s work on RR lettuce probably 10 years ago. Vegetable producers would not touch that one with a 100-foot tractor boom because of consumer concerns, and it went on the shelf. Roundup Ready rice was field tested for a couple of years before it was put on the shelf in 2000, again fearing market backlash from export customers.

Through all this, as I indicated earlier, GMO crop acreage continues to expand and have significant influence over world agriculture.

Robert Wilson, weed specialist at the University of Nebraska Panhandle Research and Extension Center, says "The adoption rate of Roundup Ready crops in the United States has been one of the major changes in agriculture in the last 20 years."

The use of Roundup Ready crops has changed farming practices throughout the country, he says. No-till or reduced-tillage practices have increased dramatically and are closely associated with the adoption of Roundup Ready crops.

During the first 10 years of growing Roundup Ready crops, growers relied heavily on glyphosate as the only herbicide used for weed management, despite repeated admonitions that this would eventually lead to resistance. However, as long as glyphosate was cheap and easy to use, growers did not listen. Now growers are paying a high price for that, as the respected researchers who follow me will attest.

If growers have had a problem controlling a specific weed, you generally have their undivided attention. However, when glyphosate is working well, it is only human nature to resist change as long as possible. Some growers are not worried about anything but surviving next year and are not thinking about change.

Doug Munier pointed out, as I was putting this talk together, that "Some people talk about super weeds and Roundup resistance, but don't consider that if Roundup no longer works we are just back to the decades of weed control before Roundup. Super weed implies nothing controls it. Although Roundup resistance is not catastrophic, we will lose the most valuable herbicide ever developed when resistance gets to the point Roundup is no longer used. At some point in the future, growers may look back and say they didn't know how good we had it when RR crops were effective."

There is an attitude among farmers that agchem manufacturers will come up with an alternative to glyphosate. I recall several years ago attending a cotton grower tour stop at the Bayer CropScience research facility in Fresno. The growers were from the Mid-South, as part of a producer information exchange program. At a lunch where growers were asked if they had any questions, one grower asked, "When are you guys going to come up with something to control pigweed?" This was just two years after the resistance issue with palmer amaranth first became widely evident. I am not sure how pervasive that attitude is among growers, but I am afraid it is more widespread than we want to admit.

Switching gears a bit, I find the topic of biotechnology totally fascinating and a bit perplexing at times. As effective as the RR technology has been, to me the insect pest resistance element of GMO is perhaps the most spectacular.

I find it interesting that more than 15 years after the Bt technology was introduced, there has been no field resistance confirmed. Resistance has been confirmed in the lab, but never in a commercial field. What is even more remarkable about this is that much of the refuge specifications initially required have been modified or abandoned to the point where 100 percent Bt cotton was a key element in eradicating pink bollworm from the Desert Southwest and Mexico...and still no field resistance.

I also find it interesting that herbicide resistance--in this case weed resistance to glyphosate—has emerged as somehow a new issue, when weed resistance to herbicides was documented almost 50 years ago.

According to weed science.com, there are 396 Resistant Biotypes, 210 Species (123 dicots and 87 monocots) in more than 670,000 fields.

My question is why did glyphosate resistance became so widespread so quickly, yet there has been no resistance to the Bt biotech technology after almost 20 years of commercial use

I readily acknowledge I am not a scientist and am mixing apples and oranges by comparing weed science to entomology, but it is an interesting comparison.

The gospel of resistance management is not new, either. It is the cornerstone of many pest management strategies, none more than in fungicides for disease control. Some of you may recall Bayleton use in the late 1970s, early 1980s. It was a brand new fungicide that promised to give long term control of powdery mildew in grapes with far fewer trips through the field. It was so successful, growers treated heavily and often. After only two seasons, Bayleton was useless against powdery mildew, due to resistance from the pathogen. Growers experienced powdery mildew fungicide resistance firsthand really for the first time, since Bayleton was the first synthetic fungicides to reach the market. The only product used for mildew control before the fungicides were introduced was sulfur, and there has never been an issue of resistance to sulfur. Bayleton was a rude wake up call.

Since then, resistance management has been the gospel in control of diseases in not only grapes, but all horticultural crops. There are currently more than 20 products registered for disease control in tree and vine crops and six different fungicide classes. Over-use and resistance is still an issue, but it is not widespread. When it is identified, growers usually take a pro-active approach to mitigating it. Yet despite repeated warnings about glyphosate resistance, growers don't seem to take that seriously until it is almost too late.

And finally, people often ask me why I am so passionate in my commentaries and other articles about GMOs. My wife reads my articles before I send them in. She has remarked more than once someone is going to paint a white X on the roof of our home, so the whackos will not miss the target.
I admit to name-calling. I also acknowledge that there are intelligent, educated scientists who have raised issues about GMO technology. However, most of the controversy in the media has

been generated by radicals who simply do not want to accept sound science and are self-serving socialists who are more interested in halting technology than even considering its benefits.
Let me give you an example. Several years ago I received a call from a man who spearheaded the anti-GMO movement that resulted in several northern California counties symbolically banning GMO crops. He asked if he could just visit with me off the record. I said sure. He began his spiel. He was articulate, calm and convincing. Local newspaper reporters loved him and seldom checked his credentials or his facts. He obviously thought he was convincing me. When he finished, I asked him where he got his degree. He said he did not have a degree, but learned about GMO from "going to a lot of classes."

When it came time for me to respond, I decided it would be a waste of time challenging his facts. Rather, I said let me tell you a story.
When Bt cotton was introduced into Arizona for the first time, I said, PCAs who checked cotton fields would exit Bt variety cotton fields smiling and covered with insect webbing. I asked him if he understood the significance of that. He did not.

I have a long history of writing about Arizona cotton and the history of the pink bollworm. I have seen cotton so devastated by pinkies that the plants were 8 and 9 feet tall with no bolls on them, even after a grower treated every 3 days.

I explained to this so-called environmentalist that the webbing covering the PCAs was from beneficial insects, which had come back into cotton because it was no longer being sprayed with harsh insecticides. He still did not understand nor did he want to understand.
When the GMO controversy began to boil over, Dr. Tom Kerby, then University of California cotton specialist, got in my face one day at a meeting in Visalia, upset at why there was so much angst over Bt cotton. "It's only protein," he protested. I told him that that does not hold water with radicals and that if he wanted to defend the technology, he would have to become a junkyard dog. "I cannot do that; I am a scientist," he said.

As I read about biotechnology, I discovered that scientists were trying to use it to increase the amount of insulin in the whites of chicken eggs to benefit insulin dependent diabetics. My granddaughter has been a Type 1 diabetic since she was 7 years old. She is now 23 and has struggled with diabetes for a long, long time.

When I read about the insulin research, I decided to be the junkyard dog when it came to defending science, defending men and women who are using biotechnology for the betterment of man and the environment.

To me, those radicals who attack biotechnology are no different than those who opposed smallpox and polio vaccines. It is almost criminal what they get printed in the newspapers and reported on television. They do not deserve respect or acknowledgement.
So as long as I am able, I will defend the right of scientists and professionals like most of you here to pursue biotechnology or other scientific endeavors to meet the challenges John Jachetta talked about yesterday in feeding the 9 billon people who will be on this planet in 2050.

Rather than letting the radicals control the future, it behooves us all to defend biotechnology with the words of Nobel Laureate Dr. Norman Borlaug, the father of the Green Revolution, who is credited with saving 1 billion people from starvation by developing higher-yielding wheat and rice varieties that tripled food yields per acre across most of the world after 1960.

"I believe genetically modified food crops will stop world hunger," he said in one interview. That should be on the wall of every university campus ag science building in the world.

Thank you for allowing me to be a little personal and passionate in this presentation.

Glyphosate-Resistant Weeds Worldwide

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The intent of the International Survey of Herbicide-Resistant Weeds is to document practical cases of field selected, genetically inherited resistant weed biotypes that survive a rate of herbicide to which the indigenous population was controlled. This information assists farmers and academics in the development of effective weed control systems for the field and assists herbicide manufacturers in the development of appropriate stewardship programs for their products. The survey currently (1/24/2013) records 396 unique types of herbicide-resistant weeds in 210 weed species (123 dicots and 87 monocots). The herbicide sites of action most prone to resistance are the ALS inhibitors (129 resistant species) the triazines (69 species), and the ACCase inhibitors (42 species). Glyphosate has generally been considered a low risk herbicide for selection of resistance, but low risk does not mean "no risk", and given the massive area treated with glyphosate annually it is not surprising that 24 weed species have evolved glyphosate resistance (Table 1).

In 1996 Roundup Ready Soybeans were introduced in the United States and since then there has been a rapid adoption of Roundup Ready crops (primarily soybean, maize, cotton, canola and sugar beet). Figure 1 shows the correlation between the increase in Roundup Ready crops and the evolution of glyphosate-resistant weeds. Roundup-Ready crops are not entirely responsible for the selection of glyphosate-resistant weeds, 12 weed species have evolved glyphosate-resistance in orchard and non-crop situations.

The USA leads the world in the area planted to Roundup Ready crops and consequently has the highest number of glyphosate-resistant weed species (13) Table 2. Brazil and Argentina also have large areas planted to Roundup Ready Crops and both have 5 glyphosate-resistant weeds. Australia has selected 6 glyphosate-resistant weeds, primarily through the repeated use of glyphosate in summer fallow situations and orchards. Spain and South Africa have selected 5 and 3 glyphosate-resistant weeds respectively in orchards as well.

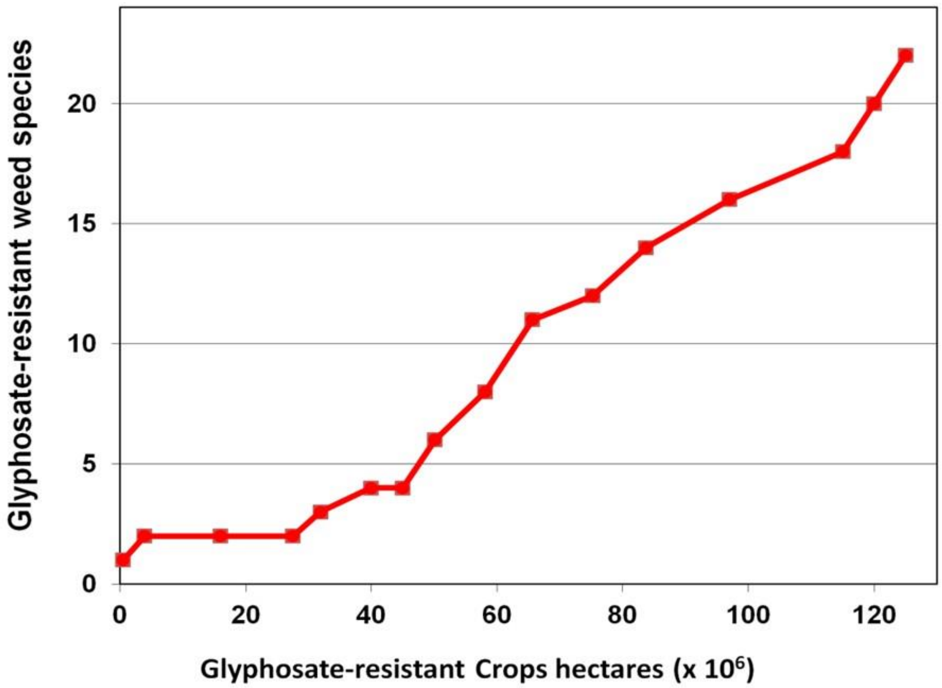
Table 1. Global list of glyphosate-resistant weeds.

#	Species	Year	Countries	Crops
1	*Lolium rigidum*	1996	Australia, France, Israel, Italy, South Africa, Spain, USA	11
2	*Eleusine indica*	1997	Colombia, Malaysia, USA	4
3	*Conyza Canadensis*	2000	Brazil, China, Czech Republic, Spain, USA	10
4	*Lolium multiflorum*	2001	Argentina, Brazil, Chile, Spain, USA	11
5	*Conyza bonariensis*	2003	Australia, Brazil, Colombia, Greece, Israel, Portugal, South Africa, Spain, USA	10
6	*Plantago lanceolata*	2003	South Africa	2
7	*Ambrosia artemisiifolia*	2004	USA	1
8	*Parthenium hysterophorus*	2004	Colombia	1
9	*Ambrosia trifida*	2004	Canada, USA	3
10	*Sorghum halepense*	2005	Argentina, USA	1
11	*Amaranthus palmeri*	2005	USA	5
12	*Amaranthus tuberculatus*	2005	USA	4
13	*Digitaria insularis*	2006	Brazil, Paraguay	6
14	*Echinochloa colona*	2007	Argentina, Australia, USA	5
15	*Kochia scoparia*	2007	Canada, USA	4
16	*Urochloa panicoides*	2008	Australia	2
17	*Lolium perenne*	2008	Argentina	4
18	*Conyza sumatrensis*	2009	Brazil, Spain	2
19	*Poa annua*	2010	USA	2
20	*Chloris truncate*	2010	Australia	1
21	*Leptochloa virgate*	2010	Mexico	1
22	*Bromus diandrus*	2011	Australia	1
23	*Cynodon hirsutus*	2012	USA	1
24	*Amaranthus spinosus*	2012	Argentina	1

Table 2. Number of Glyphosate-Resistant Weeds in Countries

Country	# GRW	Country	# GRW
USA	13	Malaysia	1
Australia	6	Chile	1
Brazil	5	France	1
Spain	5	China	1
Argentina	5	Paraguay	1
South Africa	3	Czech Republic	1
Colombia	3	Greece	1
Israel	2	Poland	1
Italy	2	Portugal	1
Canada	2	Mexico	1

Figure 1. The Relationship between the adoption of Roundup Ready Crops and the evolution of glyphosate-resistant weeds.



Three plant families (Poaceae, Asteraceae, and Amaranthaceae) account for 92% of the reported cases of glyphosate-resistant weeds even though they only account for about 60% of weeds in crops. Grass weeds account for 13 of the 24 glyphosate resistant weeds and three of these are in the genus *Lolium* (*L. rigidum, L. multiflorum,* and *L. perenne*). Similarly there are three cases of glyphosate resistant weeds in the genus *Amaranthus* (*A. tuberculatus, A. palmeri,* and *A. spinosus*) and *Conyza* (*C. canadensis, C. bonariensis*, and *C. sumatrensis*). In addition there are two *Ambrosia* sp. (*A. artemisiifolia* and *A. trifida*). The lesson to be learnt from this is that if a weed evolves resistance to glyphosate then it is highly likely that close relatives will evolve resistance to glyphosate and should be managed accordingly.

The occurrence of glyphosate resistance is often associated with farming systems that rely upon glyphosate alone for weed control, minimum tillage, and the use of low rates glyphosate.

Glyphosate is the most useful herbicide ever developed and it is important that its effectiveness is maintained for as long as possible. Rotation of herbicide modes of action, the use of tank mixes with different modes of action, and integrated weed management are the primary tools that growers have to preserve glyphosate.

Southeastern Experience with Herbicide Resistance

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Glyphosate-resistant Palmer amaranth has changed agriculture forever in the Southeast. To combat this pest, growers rely heavily on herbicides, tillage, and hand weeding. Herbicide use has increased sharply with 2.5 times more herbicide active ingredient applied in cotton today as compared to before resistance. Use of most herbicides, except glyphosate, have risen sharply, although the residual herbicides (acetochlor, diuron, flumioxazin, fomesafen, pendimethalin, *S*-metolachlor, trifluralin) and glufosinate have increased the most. Although growers spend $68/A on herbicides, control is not adequate. Thus, ninety-two percent of Georgia cotton growers are hand weeding 52% of the crop with an average cost of $11.40 per hand weeded acre. In addition to increased herbicide use and hand weeding, growers are relying on soil disturbance for the control of Palmer amaranth; presently, in-row cultivation, deep turning, and tillage for the incorporation of herbicides are each being used on 20 to 30% of the cotton acreage. Current management programs are diverse, complex, and expensive, but were more successful at controlling glyphosate-resistant Palmer amaranth in 2012 as compared to the strategies employed during the previous eight years. In fact, hand weeding costs were reduced by half in 2012 as compared to 2011, saving Georgia cotton growers nearly $7.7 million. Several factors were critical in obtaining better management during 2012, but growers being more aggressive and making wise decisions had the greatest influence.

Although these management programs are more effective, they are not economically sustainable and are still too dependent on herbicides. Therefore, an effort is underway to help growers integrate a heavy rye cover crop into their weed management program. Research results show that, if an adequate stand is achieved, rye itself, after being rolled, can reduce Palmer amaranth emergence 65 to 95%. Although the rye cover does not provide sufficient control when used alone, the rolled rye cover in conjunction with a sound herbicide program has proven extremely effective. In two large on-farm (4-8 A) dry land cotton studies conducted during 2012, the addition of a heavy rye cover crop reduced Palmer amaranth populations at harvest 70 to 95% and increased yields 16 to 23%, when all other variables, including herbicide program, were held constant. In addition to improving Palmer amaranth control and increasing yields, the rye cover crop system also has the potential to reduce herbicide input overtime, prevent or at least delay additional herbicide resistance, reduce labor needs compared to conventional tillage, mitigate wind and water erosion, improve moisture conservation, and likely reduce impact from other pests such as thrips, ryegrass, and horseweed. Although numerous benefits from this system exist, there are challenges that must be addressed including: finding time to get the rye cover established, increased nitrogen requirements, purchasing or building a roller, and obtaining a uniform cotton stand. Large-acreage on farm studies will be used to determine the overall economics of the heavy rye system and these results should be available by winter of 2013/2014.

Lessons Learned From Glyphosate-Resistant Palmer Amaranth

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The production and profitability of cotton has been greatly improved by the development and release of genetically-modified, herbicide-tolerant cultivars, particularly those resistant to glyphosate. The proposed benefits of glyphosate-resistant (GR) crop technology include: improved weed control (including difficult-to-control flora such as perennials and volunteer crop plants) and reduced crop injury. Improved crop safety and weed control efficacy can, in turn, result in higher crop productivity, a reduction in total herbicide input, and decreased weed management costs. The adoption of GR cultivars has also allowed US cotton growers to engage, more readily, in conservation tillage. This transition has been especially beneficial for farmers in the SE Coastal Plain, where the soils are sandy, compacted, nutrient-poor and have low moisture-holding capacities.

Unfortunately, the widespread use of glyphosate across space and time has resulted in the development of GR weeds. In 2004, the existence of GR Palmer amaranth was confirmed at a 250 ha field site in Macon County, Georgia; production at this site had been a monoculture of GR cotton where glyphosate, often applied at reduced rates, was used, singly, for at least seven years. Within three years of its discovery, GR Palmer amaranth became the single greatest threat to the economic sustainability of cotton production. As of 2012, GR Palmer amaranth populations have been confirmed in at least 16 US states (http://www.weedscience.org/In.asp). Biotypes that are resistant to other herbicide classes (ALS-inhibitors, DNAs, 4-HPPD-Inhibitors and PSII-inhibitors have been documented throughout the US; Palmer amaranth biotypes with multiple-resistances have been identified in GA (glyphosate and ALS-inhibitors), MS (glyphosate and ALS-inhibitors) and KS (ALS-inhibitors, PSII-inhibitors and 4-HPPD-inhibitors) (http://www.weedscience.org/In.asp).

When acceptable weed control is not realized and Palmer amaranth is allowed to set seed, population densities can become quite high in infested fields. Research conducted at the University of Georgia indicated that Palmer amaranth seed densities exceeded 35,000 seeds per m^2 in a field where the GR biotype was ineffectively managed. Palmer amaranth seed are very small (approximately 1 mm in size) and possess limited nutrient reserves. Therefore, Palmer amaranth plants that become established in the field are likely germinating and emerging from relatively shallow depths within the soil profile. Results from a recent study in GA showed that the majority of Palmer amaranth seedlings emerged from depths up to 2.5 cm; less than 2% emergence was observed for Palmer amaranth seeds buried at depths greater than 10 cm.

Weed management has historically focused on the prevention of seedling establishment and growth (e.g. PRE and POST herbicides, cultivation, etc.); little attention has been provided to strategies that maximize seed depletion from the soil seedbank. A reduction in the number of seed reduces the number of individuals that will be subjected to chemical weed management, as well as the potential number of weed management survivors that can then replenish the seed bank. Recent research initiatives at the University of Georgia have evaluated the efficacy of a single deep tillage event to bury surface/near surface Palmer amaranth seeds to depths below their optimal emergence zone, thereby removing these individuals from the germinable seedbank. Results suggest that GR Palmer amaranth seed bank densities and emerged seedling densities can be reduced by 40 to 60%, as compared to undisturbed soil. However, the ultimate success of this proposed strategy for reducing weed populations is dependent, in part, by the dormancy and longevity of seeds in the soil.

In 2007 and 2008, a study was initiated to evaluate Palmer amaranth seed longevity in the soil seedbank. Glyphosate-resistant and -susceptible seed were hand-harvested and -cleaned and divided into replicate seed-lots of 100 seed each. Each seed-lot was mixed with sand, placed in nylon bags, and buried in a Tifton sandy loam at depths of 1 cm to 40 cm for up to three years. By 36 months, seed viability ranged from 9% (1 cm depth) to 22% (40 cm depth). Results suggest that seeds near the soil surface will not be as persistent as those that are more deeply buried. Results also suggest that deep burial of Palmer amaranth seeds may reduce in-field population densities, but only if the seeds that are present at the lowest depths have been buried for a sufficient period of time before the next soil inversion event.

In addition to seedbank depletion, research efforts in GA have also focused on reducing seed inputs within farming systems. Growers are advised to remove Palmer amaranth plants that have escaped weed control measures (but prior to them achieving reproductive maturity) in order to prevent seed set and return. Subsequently, GA cotton growers have engaged in significant hand-weeding efforts (92% of growers hand-weeded, on average, 52% of their cotton acreage) in order to maintain their fields as weed-free as possible. Unfortunately, growers, extension agents, and university research personnel have observed instances where: 1) previously pulled Palmer amaranth plants have re-rooted and become reestablished in a field and 2) plants that have been cut back (using hoes or machetes) have re-sprouted from dormant buds and resumed normal growth. Therefore, studies were developed to evaluate the potential of Palmer amaranth to grow and develop following defoliation occurring during a simulated hand-weeding failure.

Experimental plots were established in fields planted to glufosinate-tolerant cotton in 2010 and 2011. At flowering (June to August), Palmer amaranth plants were assigned to one of four defoliation treatments: no defoliation, removal of all stem and leaf tissue to the soil line (2011 only), removal of all stem and leaf tissue to a height of 2.5 cm above the soil line and removal of all stem and leaf tissue to a height of 15 cm above the soil line. Floral tissues from all plants in the trials were harvested when seeds were 50 to 75% mature and total seed mass and number were determined. Results from these experiments showed that Palmer amaranth plants cut back (all stem and leaf tissue removed) between 2.5 and 15 cm above the soil line were able to successfully regrow and achieve reproductive maturity. Although none of the defoliated plants achieved the same size as their intact counterparts, they were still able to produce significant amounts seed. Palmer amaranths that were allowed to grow and develop normally produced an average of 435,000 seeds per plant (in 2011); plants cut back to 2.5 and 15 cm above the soil line produced an average of 28,000 and 116,000 seeds per plant, respectively (in 2011). As a consequence, growers need to be aware that ineffectual salvage attempts could negate efforts designed to manage the size of Palmer amaranth populations in the field.

Results from studies conducted in Georgia suggest that practices aimed at altering the weed seedbank (either by enhancing removal or reducing inflow) may be useful for reducing in-field population densities. An analogous strategy is currently being evaluated in CA to determine if seed production by GR weeds can be similarly altered. Each year, orchard growers in California devote a considerable amount of their physical and financial resources towards herbicide applications. Unfortunately, complete (100%) weed control is not assured, even when the most effective chemical programs are employed. Weed escapes can occur for numerous reasons including: improper herbicide selection or inappropriate timing of chemical applications, unfavorable weather conditions, and the development of herbicide resistance in the target weed population, among others. As was stated previously, weeds that survive control operations are a significant concern for growers; seed produced by rogue plants can be returned to the soil may become management problems in subsequent seasons.

Herbicide efficacy is often diminished when products are applied to mature plants; however, there is evidence to suggest that weed seed production can be significantly reduced by late-season, pre-harvest chemical applications. A project was initiated in 2012 to evaluate the effects of POST (glyphosate, glufosinate, paraquat and saflufenacil) herbicides on the growth and seed production of GR weeds common in California orchards. Specifically, we evaluated the effects of sub-lethal and labeled application rates on the seed production and regrowth potential of hairy fleabane in a series of greenhouse and shade-house experiments. As anticipated, small plants (pre-bolting) were injured more than larger plants, regardless of herbicide used. Even when substantial regrowth occurred, weed seed production was reduced by the late season treatments. Interestingly, even glyphosate reduced seed head production in GR hairy fleabane by nearly two-thirds and caused malformations of the flowers and heads that were produced. In the coming year, the fleabane work will be validated in orchard studies, the effects of herbicides on fleabane seed viability will be evaluated, and the effects of late-season herbicides on junglerice seed production will be determined.

Integrating Weed Management in California

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RR cotton was the first genetically engineered herbicide tolerant crop used in California. The acreage of herbicide tolerant cotton has increased dramatically in the United States. They account for approximately 95 percent of the cotton in other cotton-producing states; whereas, in California RR cotton is grown on approximately 50 percent of the upland and 85 percent of California Pima cotton. The acreage of herbicide tolerant cotton will likely continue to increase as higher yielding varieties are developed with these traits and as genetically engineered crops with resistance to more than one herbicide are developed.

RR technology has provided growers with an excellent tool for managing most annual and perennial weeds, including weeds such as nightshades, annual morningglory, and nutsedge. Before the adoption of RR cotton, purple and yellow nutsedge were widespread problems in California cotton fields and existing control measures were only marginally effective at best. Using a combination of glyphosate and cultivation, now nutsedge is seldom a serious problem. Additional advantages of this system include the following: Glyphosate can be applied post emergence so growers can delay application to observe the weeds present and their density. There are no plant-back restrictions. This technology has allowed growers to reduce tillage operations and experiment with ultra-narrow row systems. Cost savings from RR technology typically range from $25 to $200/acre.

Concerns have already surfaced in California regarding reduced control of barnyardgrass, sprangletop, pigweed, and lambsquarter with continual use of RR systems. Amaranth species (pigweed) is becoming more difficult to control. Volunteer RR corn in RR cotton is now a major problem. Resistance management will become a greater part of our production systems. Sprangletop, palmer amaranth, horseweed, and hairy fleabane have now infested most canals, roadsides, and field edges throughout the San Joaquin Valley. In some cases these weeds are beginning to encroach into cotton fields. Liberty Link systems that use Rely 280 (glufosinate) are being used on a limited basis on upland seed fields.

Even if growers use an herbicide tolerant system, it is still advisable to use a preplant incorporated herbicide in cotton. The cost is low ($6-$8/A) and these herbicides control most annual grasses and many broadleaves. Rotating glyphosate or tank mixing with ET, Chateau, Diuron, Shark, or Rely is an effective way to control annual morningglory at layby. Ultimately the decision of which herbicide tool(s) to use and how to integrate different herbicides into the weed management system will depend on their cost and effectiveness. The solution is to avoid using a single approach.

When RR cotton was the only glyphosate tolerant crop in California, crop rotation in itself was usually enough to avoid problems with weed shifts or resistant weeds. However, now with the commercialization of other glyphosate-tolerant crops like RR corn, cotton, and alfalfa the potential for the evolution of herbicide resistant weeds is greater. The more crops relying on glyphosate for weed control the greater is the selection pressure. A major concern for an increase in GR weeds is that cotton is often rotated with RR corn and often RR volunteer corn becomes a problem in RR cotton or vice versa. In addition, there has been considerable interest in reduced tillage corn, a system that relies on glyphosate for weed control. A crucial component of no-till corn production should be effective weed management.

Corn growers have access to a variety of different herbicide programs due to the sheer number and effectiveness of herbicides registered for use in corn. Despite the abundance of available herbicides for conventional corn, the RR system continues to gain popularity because it is the easiest to use in terms of weed management, especially when tillage is completely eliminated or reduced. Most no-till corn growers who use the RR system do not use a pre-emergence herbicide, preferring instead to rely on over-the-top applications of glyphosate, often alone but sometimes in tank mixes with 2,4-D, dicamba, halsulfuron (Sempra) or in conjunction with separate treatments of these herbicides. As a result in RR corn where glyphosate-alone is used GR jungle rice, pigweeds, and RR alfalfa is becoming a common problem. Corn growers using dairy manure to fertilize fields need to be particularly diligent to stay on top of weed control. Some tillage once in a while, combined with use of herbicides with a different mechanism of action, may be necessary for effective weed control especially where dairy manure is applied to fields.

Effective Farmstead Weed Management

Sound stewardship practices to avoid weed shifts and the evolution of herbicide-resistant weeds is not restricted to weed control practices within the actual crop fields. As mentioned earlier, many of the GR weeds did not evolve in agronomic crop fields themselves. Instead many evolved in non-crop areas or orchards and vineyards and subsequently invaded crop fields. Many of these annual weed species are dispersed by wind and/or water and can therefore easily move from field borders and fence-lines into cropland. For example, sprangletop, horseweed, and hairy fleabane have now infested most canals, roadsides, and field edges throughout the San Joaquin Valley and in many cases these weeds are now encroaching into crop fields. Growers should be more diligent in their weed control practices and be sure to control weeds along field edges and border areas using mechanical practices or other effective control measures. It is imperative for growers to have a lower tolerance threshold and control weeds around fields so that these herbicide-resistant biotypes don’t get a foothold in crop fields.

Summary

A sound approach to resistance management must incorporate crop and herbicide rotation and control of weed escapes through tillage or hand weeding. An integrated weed management system supplements an existing transgenic or conventional weed control program and uses a variety of the available pre-plant, selective over-the-top and layby herbicides along with tillage. Although herbicide tolerant crops provide an easy-to-use and effective tool, it will continue to be necessary to use a range of weed management strategies in the future to economically and effectively control weeds and prevent to the greatest degree possible weeds from building up in the seed bank to infest future crops.

New Weed Management Handbook for Natural Areas

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While there are several publications that provide information on the management of weeds in agricultural systems, there is currently no comprehensive book that provides control options for invasive and weedy species in natural areas. However, in January of 2013, the first such book will be published by the Weed Research and Information Center at the University of California. The book, entitled *Weed Control in Natural Areas in the Western United States*, will cover about 340 species of weeds that invade or cause problems in wildland and natural areas, rangelands, grasslands, pastures, riparian and aquatic areas. The scope of the book is the 13 western states that include Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. The species chosen were those that were on the state noxious weed lists of the western states, as well as other non-crop weeds that are frequently problematic in natural areas of the western United States. Within the book there are control options, both non-chemical and chemical, provided in full write-ups for nearly 242 species, with a little under 100 additional species included in a susceptibility table only, again both non-chemical and chemical options. Although the vast majority of species are non-native, some native species are included, as they occasionally are problems in certain human use areas, both terrestrial and aquatic.

While the bulk of the text is dedicated to providing control options, it also includes additional information on the variety of control techniques and equipment used in natural areas, as well as safety and environmental considerations, herbicide characteristics, rainfast periods and grazing and haying restrictions for terrestrial herbicides, a list of species with biological control agents either available or under development, and helpful conversion tables. The chemical control options include the recommended rate, timing and any helpful remarks or cautions. There are some instances when the data for control was lacking on the particular species, but through inference with a very closely related species, it includes options the authors feel should be effective.

The authors of the book comprise many individuals within California and other western states that conduct research on the control of invasive plants and other non-crop weeds. Though the project was led by Dr. Joe DiTomaso and Guy Kyser at UC Davis, it also includes Drs. Lars Anderson, Tim Prather from the University of Idaho, Tim Miller from Washington State University, George Beck from Colorado State University, Corey Ransom from Utah State University, Celestine Duncan in Montana, and several other UC Cooperative Extension experts, including Scott Oneto, Steve Orloff, John Roncoroni, Rob Wilson, Steve Wright, Katie Wilson, and Jeremiah Mann. The information in the book comes from a number of sources, including personal experience of the authors, peer-reviewed literature, and non-peer reviewed literature, herbicide labels, and reviews in books. In addition, the authors conducted extensive internet searches for credible websites that contained information on weed and invasive plant control and management. All forms of control, including chemical and non-chemical were included. With this information, the authors summarized what they considered to be the most relevant and practical control options for each weed.

It is the intention of the authors to provide as many options as possible, with the hope that at least a few can achieve the desired objection and be implemented without restrictions. The choice of any option should be weighed against its desirable or undesirable impact on the ecosystem and the desired function of that system. Finally, because weedy and invasive plants are dynamic with new species appearing each year and new control techniques being developed by researchers and field practitioners around the west, the objective is to update and reprint the handbook about every three years so the information stays current.

Aminocyclopyrachlor: A New Active Ingredient for Non-Crop Weed Control

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Aminocyclopyrachlor (hereafter referred to as MAT28) is a new generation synthetic auxin herbicide in the pyrimidine carboxylic acid class of chemistry. It has activity on a wide spectrum of broadleaf weeds and brush with quick uptake and translocation. MAT28 is taken up both through foliage and roots and is active post and pre-emergence. MAT28 is used at low use rates (approximately 0.5 to 4 oz ai/A) and has favorable environmental and toxicity profiles. Products have been and are being developed which combine MAT28 with complementary active ingredients such as chlorsulfuron, metsulfuron, 2,4-D, imazapyr and triclopyr to offer weed control tailored to non-crop and rangeland weed control needs. At the time of this presentation, MAT28 is available in formulated products (Perspective®, Streamline® and Viewpoint®) for non-crop weed control only outside of California and is not yet available in California.

Research conducted recently in California and Oregon on brush and tree species has demonstrated the excellent spectrum and efficacy that MAT28 possesses for uses in the utility right-of-way market. This research was done primarily by Mr. Ed Fredrickson (Thunder Road Resources, Redding CA) and included a wide spectrum of brush and tree species and application methods (broadcast, individual plant spray, basal spray, cut stem and hack-and-squirt

A broadcast spray of MAT28 at 4 oz ai/A was effective for control of several brushy species such as bear clover (*Chamaebatia foliolosa*), deerbrush (*Ceanothus integerrimus*), poison oak (*Toxicodendron diversilobum*), whitethorn (*Ceanothus leucodermis*), chamise (*Adenostoma fasciculatum*), buckbrush (*Ceanothus cuneatus*) and French broom (*Genista monspessulana*), but was not effective for control of greenleaf manzanita (*Arctostaphylos patula*) or whiteleaf manzanita (*Arctostaphylos manzanita*).

Individual plant treatment (directed spray) with MAT28 at 16 oz ai/100 gallons of water plus 5% MSO adjuvant increased activity on greenleaf manzanita to 60% control after one year and also provided excellent control of deerbrush, black oak (*Quercus kelloggii*), California hazel (*Corylus cornuta*), bitter cherry (*Prunus emarginata*), whitethorn, snowberry (*Symphoricarpos albus*), gooseberry, madrone (*Arbutus menziesii*), bear clover, poison oak and buckbrush.

Hack and squirt testing was conducted by injecting 0.5 or 1 ml of undiluted 2 lb ai/gallon liquid MAT28 formulation into hacks at one hack per 2, 3 or 4 inch diameter at breast height on big leaf maple (*Acer macrophyllum*) and live oak (*Quercus chrysolepis*). Big leaf maple was very sensitive to MAT28 and rapidly defoliated with complete control at one year after treatment with all hack spacings with the 1 ml per hack rate. Big leaf maple was also completely controlled at 0.5 ml per hack at the 2 and 3 inch hack spacings but control declined at the 4 inch hack spacing. Live oak was less susceptible and the greatest control achieved was approximately

80% with the 1 ml per hack and 3 inch diameter spacing and with both rates at the 2 inch diameter spacing.

Basal trunk application with 10% MAT28 360SL in basal oil resulted in 100% control of live oak and coyote brush (*Baccharis pilularis*).

In conclusion, MAT28 has excellent activity on several brush and tree species commonly encountered in utility right-of-ways including difficult to control species such as live oak and has excellent application method flexibility.

The Search For New Melon Herbicides

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Weed control in melons is difficult due to the limited availability of registered herbicides. Field trials over the past five years have examined a range of herbicides for potential melon tolerance and weed control. The herbicides evaluated included Lorox, Dual Magnum, Château, Prowl H_2O, Zeus (also called Spartan), Reflex, Matrix, Sandea, and Command (granular form is Cerano). Two cantaloupe varieties (Esteem and Oro Rico), a honeydew melon (Saturno) and a watermelon variety (Paradise 2008-2011, Charleston Grey 2012) were tested for tolerance and weed control with these herbicides. Herbicide applications were made after planting, but prior to crop emergence and incorporated with sprinkler irrigation (0.5 to 0.75 inches) in some years or with a shallow mechanical incorporation in other years.

Melon stand was measured for each variety during the establishment period, followed by melon vigor ratings made later in the season. Melon vigor was visually assessed (0 to 10 scale, with 0 = no melons, and 10 = good melon stand and growth), in each plot, noting chlorosis, leaf abnormalities, and any reduction in stand, growth or vigor. Weed control by species was visually assessed (0 to 100 scale, with 0 = no control). Mature marketable melons were harvested (1 to 7 times), counted and weighed for each plot.

Mechanical incorporation appeared to be safer than sprinkler incorporation for most of the herbicides tested. Sprinkler incorporation often resulted in greater reductions in melon stand, and loss of early season vigor. Sprinkler irrigation likely allowed the herbicides to move deeper into the soil profile than mechanical incorporation, and thus the loss of stand and the reduction of growth. Weed control with Chateau and Reflex was also compromised by mechanical incorporation, as these herbicides are similar to Goal, in that mechanical incorporation dilutes the herbicide concentration at the soil surface and reduces weed control. Mechanical incorporation also seemed to lower weed density. This may have been due to the mechanical incorporation, killing any weeds that had emerged or were near the soil surface and about to emerge. Additionally, watermelon is far more tolerant of herbicides than honeydew melon. Cantaloupe is the least tolerant of herbicides among the melon types tested.

Overall weed control was good in most years with Zeus, Dual Magnum, Matrix or Sandea treatments. Sandea is currently labeled for melons and in numerous trials, has provided excellent, broad-spectrum weed control when applied preemergence, but only seems to control nutsedge when applied postemergence. Prowl H_2O was highly effective against the grass weeds in this trial, but weaker on pigweed or purslane in some years. Zeus was generally among the best of the experimental herbicides in terms of broadleaf weed control and duration of weed control, but weak on grasses. However, Zeus often caused some stand loss and reduction in early season vigor. Mechanical incorporation of Zeus appeared to reduce injury to melons with no loss of weed control.

Dual Magnum appeared to be safe on melons, regardless of the method of incorporation. Weed control was good in all years but best in the years where sprinkler incorporation was used. Among the treatments, Dual Magnum was easily the best in terms of yellow nutsedge control. Command is registered in all states other than California for weed control in cucurbits. In preliminary trials, rates were very low and weed control was poor. In the past two years, rates have been increased and weed control has been very good to excellent, with the exception of pigweed, which has been only moderately controlled by Command. Matrix appeared safe on melons and weed control was very good, however, DuPont was not willing to support this registration in California, and thus was only included in one of the past five years of study.

FMC, makers of both Zeus and Command, is currently moving forward to register these products in melons in California.

Melon yields have been closely related to melon tolerance and weed control, with higher yields where little or no injury occurred, and where most weeds have been controlled. Cantaloupe yields were highest with Zeus in most years, in spite of some early season injury, indicating that weed control was more important than early season melon tolerance in terms of yield.

Weed Management Options in Transplanted Bell Peppers in California

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Weed control in pepper production fields in California can be challenging:

- peppers are slow growing and do not effectively compete with weeds for the first 40-60 days in the crop production cycle;
- peppers have a long growing season (e.g. April-May planting to September-November harvest) that subjects them to infestation with cool as well as warm season weeds;
- weed removal operations must be continued throughout the long growing season to maintain the yield and quality of the crop, so weed control costs can easily be $500/Acre.

Common weeds in peppers include several species of nightshades and pigweeds, but also lambs-quarters, purslane, sowthistle, and grasses, especially barnyardgrass and junglerice. Depending on the location in the state, specific weeds can make weed control in peppers more difficult. In particular, yellow nutsedge and field bindweed are problematic in nearly all production districts. Puncturevine is troublesome in the Central Valley, and on the Central Coast little mallow (*Malva parviflora*) is difficult to control, particularly late in the growing season. The difficulty of late-season weeds is that growers have already spent a large portion of their weed control budget to control weeds earlier in the season. Additionally growers are reticent to send crews into pepper fields with significant weed pressure late in the season because the crop plant becomes brittle and damages easily. The good news is that there are a number of cultural practices as well as registered herbicides that are now available to help manage weeds profitably. Peppers are produced in two ways: with the use of plastic mulch on the beds and on bare soil (without the use of plastic mulch). Weed control in these two systems varies considerably.

Plastic mulch culture: Opaque plastic mulches are used in pepper production and do not allow light through to the soil that can stimulate weed germination. As a result, the mulch provides a barrier to weed growth over a large portion of the bed. However, weeds can emerge through the planting holes and in the furrows. Preplant fumigants such as metam sodium (Vapam, K-Pam) are commonly used to control both weeds and soilborne pathogens. In addition, oxyfluorfen (Goal Tender) is registered for use under the plastic and provides additional control of weeds such as little mallow, which is not controlled by fumigants. Weeds can be problematic in the furrows if moisture becomes available from late-season rains or irrigation water. Flumioxazin (Chateau) was registered under an indemnified 24c label in 2011 for use as a spray directed to the furrow and can provide control of a wide spectrum of broadleaf weeds. Weed control in plastic culture can be very good, but hand weeding is used to control escaped weeds.

Bare soil culture: Transplanting is the most common method of establishing peppers in bare soil culture on beds. Beds are treated a number of ways prior to transplanting depending on the growers schedule, but significant weed control and reductions in weed control expense can be achieved with preplant cultural practices such as preirrigation and selection of sites with low populations of problematic weeds such as yellow nutsedge and field bindweed. Preplant fumigation can be carried out with materials such as metam sodium applied through the drip system and can help reduce weed pressure as well as soilborne diseases. The full range of preplant and preemergence materials listed in Table 1 is available for use on transplanted peppers. They can be selected based on the weed spectrum present at the site (Table 2). Early season weeds can generally be successfully controlled with the combination of preplant cultural practices, herbicides and mechanical cultivation; as a result, hand weeding costs can be minimized at this point in the growth cycle. Approximately 30-40 days after transplanting, before the crop canopy begins to close, the layby herbicide treatments are generally made. The available materials provide good control of a wide spectrum of broadleaf and grass weeds.

Table 1. Registered herbicides for use on peppers

Preplant	Preemergence	Layby	Post Emergence
glyphosate	oxyfluorfen [1,2]	DCPA	halosulfuron
paraquat	bensulide	pendimethalin	clethodim
oxyfluorfen [1,2]	napropamide	s-metolachlor	sethoxydim
carfentrazone	trifluralin		carfentrazone [3]
pelargonic acid	s-metolachlor		pelargonic acid [3]
metam sodium	pendimethalin		flumioxazin [4]

1 – applied to beds up to 30 days prior to planting, beds must be thoroughly tilled before planting; 2 – applied to shaped beds under plastic mulch; 3 – applied as hooded application between rows to burn down weeds; 4 – applied to row middles to provide preemergence weed control.

Table 2. Susceptibility of weeds to pepper herbicides

Weed Species	bensulide	DCPA	S-metolachlor	napropamide	pendimethalin	trifluralin
Chickweed	P	C	C	C	C	C
Nettleleaf goosefoot	P	C	P	C	C	C
Groundsel	N	N	N	C	N	N
Henbit	N	P	-	N	C	C
Lambsquarters	C	C	P	C	C	C
Little Mallow	N	P	P	P	P	N
Burning nettle	P	P	C	P	N	N
Black nightshade	N	P	C	N	N	N
Hairy nightshade	N	P	C	N	N	N
Yellow nutsedge	N	N	P	N	N	N
Pigweed	C	C	C	C	C	C
Purslane	C	C	C	C	C	C
Shepherd's purse	N	N	P	P	P	N
Sowthistle	N	P	P	C	N	N

N = no control; P = partial control; C = controlled

There are several postemergent herbicides registered for use on peppers that can control specific weed problems in established peppers: the grass materials, clethodim (Select) and sethoxydim (Poast) as well as the nutsedge and broadleaf material halosulfuron (Sandea).

Since 2004 tandem field studies have been conducted in two of the four major growing regions of California (Central Valley and Central Coast) looking for selective preemergence herbicides suitable for use in transplanted bell pepper production on unmulched beds. Application timings include at planting and at layby. At planting applications have looked at pre-transplant, post-transplant over the top, and post-transplant directed spray for some of the herbicides in order to achieve better crop safety. Crop phytotoxicity and weed control ratings, weed counts and bell pepper yields were collected. Pigweeds (prostrate, tumble and redroot), nightshades (black, hairy, and groundcherry), common lambsquarters, common purslane, common groundsel, puncturevine and junglerice were the main weeds tested. Trial results investigating weed control and crop safety of flumioxazin, oxyfluorfen, s-metolachlor, and pendimethalin compared to DCPA and napropamide have led to changes in label registrations for California.

One weed that escapes control is little mallow. Over the past several years we have experimented with flumioxazin (Chateau) as a layby material for use on the pepper beds to control this weed. It controls mallow better than the currently available materials (Table 3). One of the difficulties has been finding an effective way to get the material to the soil surface without damaging pepper foliage or fruit. We looked at a number of techniques (granular formulation, applying the herbicide to dry fertilizer, through the sprinklers, etc.), but we have not found a way to apply the herbicide without it causing too much damage to the pepper plant. As a result, flumioxazin is only registered for use in peppers in the furrow, but not on the bed.

Table 3. Comparison of layby weed treatments

Treatment	**Application**	**Material/A**	**Mallow per 6 ft^2**	**Total weeds per 6 ft^2**
Untreated	---	---	5.0	39.0
S-metolachlor + pendimethalin	Directed	1.5 pints 2.0 pints	5.3	12.0
flumioxazin[1]	Directed	3.0 oz	1.0	9.0

1 – not registered for this use

San Joaquin Valley Layby Experiments with Preemergence Herbicides: Field trials investigating six preemergence herbicides at 1x and 2x rates were compared to an untreated check and two standard herbicide treatments in transplanted bell peppers in 2011 and 2012. One herbicide (Outlook) was applied at a 4x rate. All applications were made at layby and the crop had no previous (at planting) herbicide applications. The herbicide trials were conducted at the UC West Side Research and Extension Center in Five Points in Fresno County. Soil type is a

Panoche Clay Loam. Bell peppers were transplanted in single rows into 40" beds using a commercial transplanter. Within row spacing was 10" between plants and stand establishment was very good. Weed pressure at planting was significant as there was no preemergence herbicide applied at planting.

At layby the entire field was mechanically cultivated and hand weeded so that preemergence herbicides could be applied as layby treatments to weed free plots. The treatments were replicated 4 times in a randomized complete block design in the field. Plot size was either one or two 40-inch bed(s) wide by 70-feet of row length. The sprayer was a CO^2 backpack sprayer at 30 psi with a two nozzle wand outfitted with 2 XR Teejet nozzles 8003 evs and a water volume of 30 GPA. The herbicide application was aimed at the base of the plants (not over the top), but drop nozzles were not used for a directed spray. The herbicides were set with sprinklers, but the trial was grown under furrow irrigation. The herbicides tested at layby included:

Trade name	Common name
Dual II Magnum	s-metolachlor
Outlook	dimethenamid-p
Prowl H2O	pendimethalin
Sandea	halosulfuron
Sonalan (2011)	ethalfluralin
Nortron (2012)	ethofumesate
Dacthal (2011)	DCPA
Devrinol (2011)	Napropamide

Weed control results are shown in Tables 4 and 5. Nortron, Outlook, Sonalan, and Zeus are not currently registered for use in transplanted bell peppers. These trials show that layby applications of Outlook provide excellent weed control and crop safety. Where Nortron and Zeus contacted the foliage they caused initial phytotoxicity on the leaves, however these symptoms were greatly reduced with time. A 4x application of Outlook resulted in less phytotoxicity to pepper leaves than a 2x rate of Nortron or a 1x rate of Zeus. An application of a 2x rate of Outlook showed the same pepper phytotoxicity as a 1x application of Prowl H_2O, both of which diminished as the peppers grew. In all trials Dual Magnum, Prowl H_2O and Outlook provided excellent results in broadleaf and grass weed control. Sandea is weak on nightshades and Sonalan is a weaker dintiroaniline than Prowl and less effective on weeds in general. Zeus was weak on purslane and grasses. Populations of nutsedge and puncturevine were too erratic to include in these results.

Summary: As with all vegetable crops, there are very few new herbicides in development for use on peppers, so research strives to find new uses for older herbicides. In general the array of weed control tools available for use on peppers is varied and effective. A key challenge for the pepper industry moving forward is to keep the current herbicide registrations. Through careful selection and use of these herbicides, hopefully they will be available for use by the pepper industry for many years to come.

Table 4. 2011 Layby Application: Phytotoxicity, Weed Control, and Weed Counts in San Joaquin Valley Trial

				June 22	July 8		August 9					
	Preemergence Herbicide			Pepper	Ratings (1-10)*		----------------- Weed Counts (~100 ft^2) ---------------					Total
Code	Treatment	Layby	Rate/Acre	Stand #	Phyto	Weed	PIGs	Night	Grndcherry	Purslane	Lambs	Brdlvs
1	Untreated	-		67.3	0.1	10	0.3	7.5	7.8 a	5.5 b	0.5	**21.5 a**
2	Dual Magnum 7.63	**1x**	1.5 pts	72.3	0.1	10	0.3	6.3	0.0 c	0.8 bc	0.3	**7.5 bcd**
3	Outlook 6.0	**1x**	10.7 ozs	68.8	0.1	10	0.3	4.3	0.3 c	1.5 bc	1.0	**7.3 bcd**
4	Prowl H_2O 3.8EC	**1x**	3 pts	68.5	0.9	10	0.0	4.5	0.0 c	1.0 bc	0.5	**6.0 cd**
5	Sandea 75%	**1x**	1.0 oz	73.8	0.8	10	0.0	12.5	0.3 c	3.0 bc	0.0	**15.8 abc**
6	Sonalan HFX	**1x**	3.7 pts	65.5	0.5	10	0.0	10.0	3.5 b	2.5 bc	0.3	**16.3 ab**
7	Zeus 4F	**1x**	3.2 ozs	68.5	2.0	10	0.0	7.8	3.0 bc	11.5 a	0.8	**23.0 a**
8	Dual Magnum 7.63	**2x**	3.0 pts	75.0	0.2	10	0.0	5.8	0.0 c	0.5 bc	0.5	**6.8 bcd**
9	Outlook 6.0	**2x**	21.4 ozs	71.3	0.1	10	0.3	4.8	0.3 c	1.8 bc	0.5	**7.5 bcd**
10	Prowl H_2O 3.8EC	**2x**	6 pts	70.5	1.6	10	0.3	0.5	0.0 c	0.0 c	0.3	**1.0 d**
11	Sandea 75%	**2x**	2 ozs	71.8	0.7	10	0.3	6.8	0.5 bc	1.3 bc	1.3	**10.0 bcd**
12	Sonalan HFX	**2x**	7.4 pts	72.8	2.0	10	0.5	4.8	0.8 bc	1.3 bc	0.8	**8.0 bcd**
13	Zeus 4F	**2x**	6.4 ozs	73.5	2.0	10	0.0	4.3	3.0 bc	5.0 bc	0.8	**13.0 abc**
14	Dacthal 75WP	**1x**	9.3 lbs	67.3	0.5	10	0.8	5.3	1.5 bc	1.0 bc	0.3	**8.8 bcd**
15	Devrinol 50DF	**1x**	4 lb	73.8	0.1	10	0.0	4.3	2.5 bc	3.0 bc	0.3	**10.0 bcd**
16	Outlook 6.0	**4x**	42.8 ozs	63.3	0.5	10	0.0	6.3	0.3 c	0.5 bc	0.5	**7.5 bcd**
			Average	**70.2**	**0.7**	**10.0**	**0.2**	**6.0**	**1.5**	**2.5**	**0.5**	**10.6**
			LSD (.05)	**NS**	**0.4**	**NS**	**NS**	**NS**	**3.1**	**5.3**	**NS**	**10.1**
			CV%	11.6	37.6		230.8	98.8	146.3	150.1	178.1	67.1

* One mechanical cultivation & hand in-row weeding on June 15-16, 2011. No herbicides applied until layby on June 17, 2011. Counts=70' row x 18" wide

Phytotoxicity (1-10): 0=No crop damage; 10=dead. Weed ratings (1-10): 1=No weed control; 10=100% weed control.

Not registered for use in peppers: Outlook, Sonalan, Zeus. Always follow the label.

Table 5. 2012 Layby Application: Pepper Stand, Crop Phytotoxicity, Weed Control Ratings in San Joaquin Valley Trial

Code	Preemergence Herbicide LaybyTreatments		Lbs a.i./A	Material/A	June 7, 2012 Pepper Stand		June 29 Phyto	August 16, 2012 Phyto	Broadleaf	Grass
					W bed	E bed	Rating	Rating	Control	Control
1	Dual Magnum 7.63	**1x**	1.43	1.5 pts	36.0	33.5	0.50	0	8.8	8.8
2	Dual Magnum 7.63	**2x**	2.86	3 pts	37.3	35.3	0.25	0.25	9.1	9.1
3	Nortron 4SC	**1x**	1.75	3.5 pts	35.0	33.0	2.00	0	7.0	7.0
4	Nortron 4SC	**2x**	3.50	7.0 pts	37.3	35.3	4.75	0	7.0	7.0
5	Outlook 6.0	**1x**	0.05	10.7 ozs	33.0	35.0	0.50	0.25	7.3	7.3
6	Outlook 6.0	**2x**	1.0	21.4 ozs	38.5	34.0	1.25	0.50	8.3	8.3
7	Prowl H_2O 3.8EC	**1x**	1.5	3 pts	31.8	32.8	1.25	0	9.0	9.0
8	Prowl H_2O 3.8EC	**2x**	3.0	6 pts	36.8	34.3	1.75	0	9.6	9.6
9	Zeus 4F	**1x**	0.094	3 ozs	36.0	31.8	3.50	0.50	4.3	4.3
10	Zeus 4F	**2x**	0.188	6 ozs	37.3	32.3	8.25	3.25	4.3	4.3
11	Outlook	**4x**	2.0	42.8 ozs	35.3	31.3	3.00	2.25	8.1	8.1
12	Untreated	**-**			34.5	34.8	0.75	0.0	3.5	3.5
				Average	**35.7**	**33.6**	**2.3**	**0.7**	**8.7**	**7.2**
				LSD (0.05)	**8.1**	**7.2**	**1.2**	**1.3**	**0.7**	**1.5**
				CV%	15.75	15.02	36.89	154.6	5.7	14.2
					NS	**NS**	**	**	**	**

* Weed Control Rating: 10 = perfect weed control; 1= no weed control
Phytotoxicity Rating: 10 = crop totally dead; 0 = no crop injury

Concerns of Transplanting Tomatoes into DNA-Treated Soil in Buried Drip Fields

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For decades, dinitroaniline (DNA) herbicides have been used in California in tomatoes and crops rotated with tomatoes with few negative issues reported, but reports of damage to tomatoes caused by DNA herbicides have greatly increased in Fresno County. We conducted a small-plot field trial in 2012 to look at possible cause(s) of why we were seeing this tomato injury where labeled rates of DNA herbicides were used.

Over the last two decades, processing tomato production in Fresno County has shifted from using sprinkler and furrow irrigation with annual deep tillage to buried drip irrigation with shallow tillage. Today, 100,000 acres of processing tomatoes in the county are transplanted and over 95% is farmed using buried drip irrigation and shallow tillage. High costs of surface water ($100-$300/ac ft) and expense of moving sprinkler pipe ($100/acre) have been the driving forces in this shift toward using buried drip in processing tomatoes. Growers save water, costs, and achieve yields of 60 tons per acre or more when buried drip irrigation is used. An added benefit of using buried drip is that the bed surface remains fairly dry during the growing season, so weed emergence is generally reduced, saving in hand-weeding costs.

To help reduce the cost of having to replace drip tape every time a new crop is planted and save in land preparation operations, the tape is buried about 10" deep and left in-place in "semi-permanent" beds for the life of the tape, which is usually three to five years. Once tomatoes are harvested, the beds are tilled shallow to destroy crop residues and prepare beds for the next crop planting. Under this type of production system, rotational crop options are limited, including tomatoes, cotton, dry beans, and melons, all of which DNA herbicides are routinely used in to help control weeds.

In 2009, we began observing commercial processing tomato fields in western Fresno County that showed stunted tomato plants with substantial root reduction. Field patterns of crop damage and plant symptoms expressed was consistent with injury caused by DNA herbicides. We determined that there were four factors common to nearly all of the fields we visited where crop injury occurred: 1) pendimethalin was used in the tomato crop and/or the previous crop(s), 2) tomatoes were produced using semi-permanent beds with buried drip irrigation and shallow cultivation, 3) deep tillage was not performed for bed preparation before tomato planting, and 4) tomato root plugs were planted shallow (<3" deep), although some fields showed damage even when tomatoes were planted at a depth of four to five inches. Furthermore, the number of fields showing tomato damage was greater during years when the region received below-normal winter rainfall amounts, particularly in 2009/10 and 2011/12.

We conducted a field trial in 2012 to determine whether or not planting tomatoes too shallow was the likely cause of crop injury observed in commercial fields treated with labeled preplant DNA herbicides. The trial was conducted at the UC West Side Research and Extension Center in Five Points, California in a clay loam soil. The trial was set up as a split-plot experimental design with four replications. Six preplant herbicides (trifluralin, pendimethalin, s-metolachlor, pendimethalin + s-metolachlor, sulfentrazone, and no herbicide) used at labeled rates were the main plot treatments and two planting depths (<2" and 4-5") were the sub-plot treatments.

Sixty-inch tomato beds were prepared in May and drip tape was placed 10" deep in the center of the beds with one drip line per bed. Herbicides were applied with a pressurized CO_2 backpack sprayer, and then incorporated 3" deep with a three-row bed shaper. Tomato transplants were planted with a hand trowel into treated beds in a single line, with plant root plugs placed either directly into the herbicide-treated zone (<2" deep) or below the herbicide zone (4-5" deep). Sprinkler irrigation was used to apply 1.5" of water immediately after planting, and then all plots were irrigated with buried drip the rest of the season. Effects on tomato growth were measured by visually rating above-ground growth and determining shoot and root dry weights (DW) at 7, 14, 21, and 35 days after treatment (DAT). To determine shoot and root DW, two plants per plot were removed with a shovel, the soil washed from the roots with water, and plants clipped at the top of each root plug. Shoot and root portions were oven-dried at 110 °F for seven days then weighed. Plots were not taken to yield.

Results from the study showed that plots not treated with a preplant herbicide had the best overall above-ground plant growth and produced the highest shoot and root DW (table 1). Although plots treated with DNA herbicides (trifluralin and pendimethalin) alone had significantly lower root DW than no herbicide plots at 35 DAT, top shoot DW were not different than the no herbicide plots. All other herbicide treatments produced significantly lower shoot and root DW and above-ground growth.

Planting depth had a significant impact on tomato growth and shoot and root DW at 35 DAT (table 2). Planting shallow resulted in a 12%, 37%, and 24% reduction in visual plant growth, shoot DW, and root DW, respectively. Results were similar when comparisons were made without including the no herbicide treatment in the evaluation (data not shown).

When we took into consideration both herbicide and planting depth effects, data at 35 DAT showed that all of the herbicides used resulted in a reduction in root DW, regardless of planting depth (table 3). However, shoot DW of trifluralin- and pendimethalin-treated plots were similar to that of no herbicide plots, except where tomatoes were planted shallow in pendimethalin-treated plots, in which case shoot DW was reduced. Similarly, plots treated with s-metolachlor, pendimethalin + s-metolachlor, and sulfentrazone had a lower shoot DW when tomatoes were planted shallow.

Table 1. Tomato growth and dry weights sorted by herbicide treatment

Herbicide	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
trifluralin	8.8 ab	9.4 a	11.80 a	113.86 a	2.32 b	5.93 b
pendimethalin	8.3 b	8.6 b	10.60 a	92.06 ab	2.28 b	4.29 cd
s-metolachlor	6.8 c	8.0 bc	6.98 b	73.63 bc	1.20 c	5.17 bc
pendimethalin+ s-metolachlor	5.5 c	7.5 c	4.88 c	77.78 b	0.76 d	3.44 de
sulfentrazone	5.7 c	6.8 d	5.24 c	49.83 c	1.14 c	2.60 e
no herbicide	9.8 a	9.9 a	12.15 a	113.08 a	2.67 a	8.39 a
P=0.05 CV (%)	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*
LSD	*1.35*	*0.68*	*1.70*	*24.74*	*0.34*	*1.82*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Table 2. Tomato growth and dry weights sorted by planting depth

Planting Depth	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
Normal (4 to 5" deep)	8.2 a	8.9 a	10.06 a	106.17 a	2.05 a	5.64 a
Shallow (<2" deep)	6.8 b	7.8 b	7.16 b	67.24 b	1.41 b	4.30 b
P=0.05 CV (%)	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Table 3. Tomato growth and dry weights sorted by herbicide treatment and planting depth

Herbicide	Planting depth	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
trifluralin	4 to 5"	9.8 a	9.8 ab	14.02 a	134.97 a	2.59 ab	7.01 bc
trifluralin	<2"	7.7 b	8.9 abc	9.57 bc	92.75 a-d	2.05 bc	4.85 de
pendimethalin	4 to 5"	9.7 a	9.5 ab	11.83 ab	111.18 ab	2.83 a	4.92 de
pendimethalin	<2"	7.0 bc	7.7 cd	9.37 bcd	72.95 b-e	1.72 c	3.67 efg
s-metolachlor	4 to 5"	8.0 b	8.2 bcd	8.91 cde	94.48 a-d	1.43 cd	5.77 cd
s-metolachlor	<2"	5.7 de	7.8 cd	5.04 fg	52.78 de	0.97 de	4.58 def
pendimethalin + s-metolachlor	4 to 5"	5.7 de	8.3 bcd	6.57 def	101.13 a-c	1.00 de	4.40 def
pendimethalin + s-metolachlor	<2"	5.3 de	6.7 de	3.19 g	54.43 de	0.52 e	2.48 g
sulfentrazone	4 to 5"	6.3 cd	7.5 cde	6.20 ef	60.16 c-e	1.57 cd	2.91 fg
sulfentrazone	<2"	5.0 e	6.0 e	4.27 fg	39.50 e	0.70 e	2.29 g
no herbicide	4 to 5"	9.8 a	10.0 a	12.80 a	135.12 a	2.86 a	8.85 a
no herbicide	<2"	9.8 a	9.8 ab	11.50 abc	91.04 a-d	2.47 ab	7.98 ab
P=0.05	*CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*
	LSD	*1.12*	*1.66*	*2.90*	*44.15*	*0.64*	*1.82*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Transplanting tomatoes shallow into soil previously treated with DNA herbicides can cause reduced shoot and root growth, although the amount of root growth reduction may not necessarily reflect an equal reduction in shoot growth. Not surprisingly, this confirms the fact that growers need to make sure tomato transplants are place below the herbicide-treated soil or shoot and root DW and above-ground growth will likely be reduced. This helps explain what we had observed in commercial tomato fields.

Surprisingly, it appears from this study that pendimethalin negatively affected shoot and root growth more so than trifluralin. Pendimethalin (Prowl H2O) was registered in California in 2008 as a preplant incorporated herbicide option for tomato growers. While DNA herbicides are not thought to be mobile in the soil, our data and observations suggest that downward movement of pendimethalin through the soil profile may have occurred, since water from the buried drip tape was not a limiting factor, and tomato roots in pendimethalin-treated plots was clearly reduced. A similar argument could be made where s-metolachlor and sulfentrazone were used. It's not clear if the initial sprinkler irrigation contributed to any downward movement of herbicides. Although the soil was not tested for the presence of DNA herbicides before or after treatment, no DNA herbicides were applied to this field location for at least 12 months before the project was started.

Additional work needs to be done where tomatoes are grown on semi-permanent beds with buried drip irrigation and shallow tillage to determine the extent to which this production technique (conditions of low soil surface moisture and reduced soil mixing) may have on DNA herbicide carryover and potential impacts on tomato growth and fruit yield.

Weed Control Strategies for Processing Onions

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From 2009-2011, we evaluated preemergence and postemergence herbicides applied at several rates and application times in small-plot weed control studies at the Intermountain Research and Extension Center (IREC). In 2012, Tulelake onion growers requested a larger-scale University study to evaluate promising herbicide treatments using commercial chemigation equipment at IREC and in Tulelake grower fields. Weed control data for kochia (the predominant weed at IREC), redroot pigweed, common lambsquarter, hairy nightshade, and clover was collected at IREC over the 4-year period. At grower sites, weed control data was collected for kochia, lambsquarter, redstem filaree, tumble mustard, hairy nightshade, and volunteer horseradish. DCPA (Dacthal), ethofumesate (multiple trade names), pendimethalin (Prowl H_20), and sulfentrazone (Zeus) were evaluated preemergence. Oxyflurofen (Goal), bromoxynil (Buctril), dimethenamid-p (Outlook), and fluroxypyr (Starane) were evaluated postemergence. Experiment results are summarized in IREC progress reports. Reports can be viewed and downloaded at:
http://ucanr.edu/sites/Intermountain_REC/Research_Progress_Reports978/

Preemergence Weed Control Summary

DCPA and ethofumesate applied post-plant and pendimethalin applied at the loop stage reduced kochia density compared to the untreated control in multiple trials. Unfortunately, these preemergence treatments did not reduce kochia density enough for control to be considered effective without a follow-up postemergence treatment. Pendimethalin applied at the loop stage was a versatile herbicide treatment. By itself, pendimethalin controlled or suppressed several grass and broadleaf weeds. When pendimethalin applied at loop stage was combined with ethofumesate or DCPA applied post-plant, pendimethalin had an additive effect on weed control compared to ethofumesate or DCPA used alone. Ethofumesate control of common lambsquarter was especially enhanced when used in combination with pendimethalin. When DCPA was used in combination with pendimethalin, the DCPA rate could be reduced (from 5 pt/A to 2.5 pt/A) without decreasing kochia, lambsquarter, and pigweed control.

Postemergence Weed Control Summary

Oxyflurofen (GoalTender) applied alone at the 1.5 leaf stage followed by oxyflurofen + bromoxynil at the 2.5 leaf stage was a top-performing postemergence herbicide program in multiple trials. The 1.5 leaf-stage timing of the oxyflurofen application improved control of most weed species compared to delaying the first application of oxyflurofen until the 2.5 leaf stage. At the 2.5 leaf stage, oxyflurofen + bromoxynil provided better kochia control compared to oxyflurofen + dimethenamid-p or oxyflurofen alone. Fluroxypyr applied between the 3-5 leaf stages gave greater than 90% kochia control in cases where kochia escaped oxyflurofen +

bromoxynil treatment. Fluroxypyr is currently not labeled for use on onions in CA. In trials with high weed pressure, applying DCPA or ethofumesate post-plant and pendimethalin at loop stage greatly improved postemergence herbicide weed control. The pre-emergence herbicides provided a dual benefit in that they controlled several weeds before onions reached the 1.5 leaf stage, and they stunted growth of weed escapes making them more susceptible to postemergence herbicides.

Influence of Herbicides on Onion Yield

Weed competition decreased onion yield in trials with moderate to heavy weed pressure. Thus, herbicide treatments with the best weed control typically had the highest onion yield regardless of herbicide injury. In trials with low weed pressure, some herbicides caused injury that resulted in onion yield reduction. In one of two trials on sandy loam soil, ethofumesate applied post-plant or at the loop stage reduced onion yield; ethofumesate applied post-plant did not reduce onion yield in trials located on silty clay loam soil. DCPA applied post-plant and pendimethalin applied at the loop stage did not reduce onion yield on any soil type studied. Almost all postemergence herbicides injured onions (stunting, leaf curling, or chlorosis), but the injury was usually temporary and did not influence onion yield. One exception was oxyflurofen + bromoxynil + dimethenamid-p applied as a three-way tank-mix at the 2.5 leaf stage. This treatment reduced onion yield in two of four trials at IREC.

Field Bindweed Management for Processing Tomatoes

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Field studies were conducted at UC Davis and West Side Research and Education Center (WSREC) near Five Points in Fresno County to evaluate the potential of registered herbicides to control field bindweed (*Convolvulsus arvensis*) in processing tomatoes under furrow and drip irrigation[1]. Field bindweed is a significant and growing problem for tomato growers in many areas of California. The large root system typical of field bindweed makes control very difficult, and the rapid adoption of drip irrigation in processing tomatoes, and the resulting minimal tillage practices required for this irrigation system, seems to have exasperated the problem.

At each location, a split-plot, randomized block design with 4 replications was used, with main plots as pre-plant and pre-emergent applications of Prowl H_2O (pendimethalin), Treflan (trifluralin), Zeus (sulfentrazone), Matrix (rimsulfuron), and untreated. Split plot treatments were post emergence applications of Matrix or Shark (carfentrazone). Adjacent to this trial, other herbicide treatment combinations were tested with a randomized block design, and included sequential POST applications of Matrix or Shark, Matrix + Sandea (halosulfuron), Treflan applied two times, a Treflan + Dual (metalochlor) combination that is commonly used in tomatoes, and untreated controls. The trials included a hand-weeded check plot. Total number of unique treatment combinations = (5 x 3) + 6 = 21. Tomatoes were transplanted using standard equipment and plant spacing, and were managed using standard production practices. The UC Davis site was furrow irrigated; WSREC employed drip irrigation. Weed control was evaluated 2 and 4 weeks after herbicide application, and at harvest. A listing of these treatments is shown in Table 1 and Figure 2.

At both locations, the herbicide combinations suppressed field bindweed growth, but none of the herbicides provided complete control. Main and split plot treatment affects for the WSREC location are shown in Figure 1, and show weed and crop phytotoxicity ratings based on a 0 – 10 scale, where 10 indicates all weeds/crop phytotoxicity. Thus, high ratings indicate high weed pressure. Best control of field bindweed was observed with pre-plant incorporated (PPI) Treflan at 2 pints/A. This treatment had significantly lower field bindweed on the May 30 and June 14 evaluation dates, but this effect was marginal on Aug 9. At that time, the untreated plots had a bindweed score of 7.3 compared to 4.3 for the Treflan treated area. Thus, the best PPI treatment provided only about 50% control of the bindweed by the end of the season. Results were similar with furrow irrigation at the UC Davis location.

Application of Matrix or Shark as a post treatment provided significant suppression of bindweed as compared to the untreated plots on all evaluation dates. Matrix performed better than Shark, but again by the end of the season average control was marginal – only about 50%. Best overall bindweed control occurred with the Treflan PPI + Matrix POST or Treflan PPI + Shark POST

[1] Both field sites funded by a grant from the California Tomato Research Institute.

treatment (Figure 1). All of the PPI treatments significantly reduced other broadleaf weeds (mainly puncture vine, pigweed, lambsquarters, purslane, and nightshades) as compared to the untreated control at all evaluation dates, though pigweed control at UC Davis was marginal in the Prowl treatments. Unlike with bindweed, the addition of post emergence herbicides did not improve control of other broadleaf weeds.

The main effect of the additional herbicide treatments are shown in Table 1. The application of Treflan both as a pre-plant and at layby gave best overall bindweed and other broadleaf control of all the treatment combinations tested in this trial. End of the season bindweed rating was 3.8, compared to the untreated at 7.3.

Crop injury was noted only at WSREC in the PPI Prowl, Treflan, and Zeus treatments and in any treatment where Shark was applied. Visible crop injury was gone by the end of the season, however, some areas where Shark and Treflan were applied resulted in the complete loss of plants because of overspray (Shark) or shallow transplant depth (Treflan).

Overall, the Treflan treatment has remained near the top among treatments for the past three years at studies conducted with furrow irrigation at UC Davis; these results were very similar when tested at WSREC under drip irrigation in 2012. Postemergence applications of Shark or Matrix also reduced field bindweed levels, but bindweed in the crop row could not be treated with the shielded application used with Shark. The combination of a preemergence herbicide and either Matrix or Shark applied postemergence, or applying Treflan both pre and at layby, were the best treatments for field bindweed in these trials. Future work will continue to examine treatment and timing combinations that optimize field bindweed management in processing tomatoes.

Table 1. Field bindweed, other weeds, and crop phytotoxicity ratings* as affected by additional herbicide treatments in processing tomatoes (harvest ratings not shown). WSREC, 2012.

				May 30			crop	June 14			crop
Herbicide Treatment and Use Rate:		Incorporation	Application date	Bindweed	BL (1)	Grass (2)	phyto	Bindweed	BL	Grass	phyto
1	Matrix (2 oz) post and again at 20 days	water	May 11 & 30	5.0	2.0	0.0	0.0	4.8	0.5	0.0	0.3
2	Shark (2 fl oz) post + 20 days	none	May 11 & 30	5.0	4.8	0.0	2.0	4.3	2.8	0.5	0.8
3	Matrix (2 oz) + Sandea (1 oz/A), post	water	May 11 & 30	4.5	0.0	0.0	0.0	4.5	0.5	0.0	0.0
4	Treflan (1 lb) pre + Treflan (1 lb) at layby	mechanical	Apr 24 & May 30	3.8	0.5	0.0	0.3	2.3	0.0	0.0	0.8
5	Treflan (1 lb) + Dual Magnum (1.5 pints/A) PPI	mechanical	24-Apr	4.3	0.3	0.0	0.8	7.8	0.5	0.0	1.8
6	Untreated, hand weeded control**	---	---	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
			Average	4.5	1.5	0.0	0.6	4.7	0.9	0.1	0.7
			LSD 0.05	**ns**	**1.25**	**---**	**1.28**	**2.2**	**1.5**	**---**	**ns**
			CV, %	24.6	54.1	---	139	29.7	117	---	135

* Ratings are based on a 0 - 10 scale, where 0 = no weeds/phyto and 10 = complete weed cover/crop death.

1) BL = broadleaf weeds other than field bindweed. Main species included puncture vine, pigweed, lambsquarters, purslane, and nightshades.

2) Grass = grassy weeds, dominated by Jungle Rice and Barnyard Grass.

** Hand weeded plots used for comparison and not included in the statistical analysis.

LSD 0.05 = Least significant difference at the 95% confidence level. Means within a column separated by less than this amount are not significantly different.

ns, --- Not significant, or insufficient data for statistical analysis.

CV = coeffecient of variation.

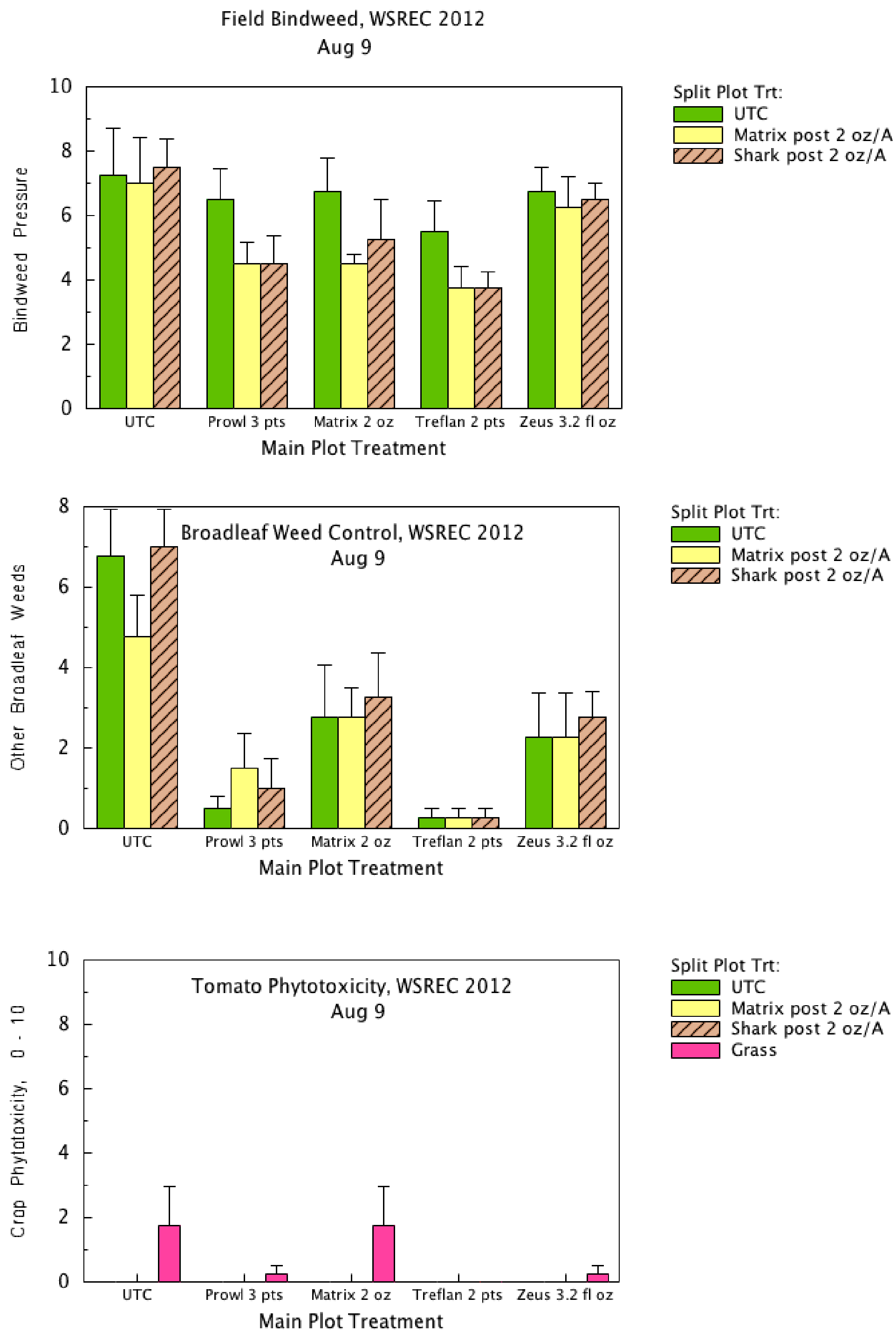

Figure 1. Field bindweed, other broadleaf weeds, and crop phytotoxicity ratings for all treatment combinations at WSREC on August 9, 2012.

Regulatory Update on Volatile Organic Compound Emissions from Pesticides

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Under the Clean Air Act, California must meet national standards for air pollutants and must specify how it plans to achieve these standards in a State Implementation Plan (SIP). SIPs require the control of emissions of nitrogen oxides and volatile organic compounds (VOCs) because they are precursors to ozone. Under California's SIP, the Department of Pesticide Regulation (DPR) must track and control VOC emissions from pesticide products used in agriculture and by structural applicators in five ozone nonattainment areas (NAAs): the Sacramento Metro area, the San Joaquin Valley, the Southeast Desert region, Ventura County and the South Coast area. Under the SIP, DPR is required to reduce pesticide VOCs during May-October (peak ozone season) by 12 percent in the San Joaquin Valley and 20 percent in the other four NAAs, compared to 1990 levels. The SIP goals have been met in all five NAAs since 2007.

The SIP reduction goals have been met primarily due to DPR's 2008 regulations that reduce VOC emissions from fumigant pesticides. These regulations require "low-emission" fumigation methods in the San Joaquin Valley, the Southeast Desert, and Ventura County NAAs during May-October. Additionally, Ventura County has a fumigant emission limit. The county agricultural commissioner enforces the limit through allowances issued to growers, or tracking and stopping fumigations once the limit is reached.

The fumigant regulations provide sufficient controls to meet the SIP goals in at least four of the NAAs, even for the highest pesticide use years. The San Joaquin Valley NAA may not meet the goal for the highest use years because most of its pesticide VOCs come from nonfumigant products. For this reason, the SIP requires DPR to implement restrictions on nonfumigant products for the San Joaquin Valley. DPR's proposed regulations would: 1) designate certain abamectin, chlorpyrifos, gibberellins, and oxyfluorfen products as "high-VOC" based on a product's VOC content; 2) require pesticide dealers selling high-VOC products for use in San Joaquin Valley to provide VOC information to purchasers; 3) require growers using high-VOC products in the San Joaquin Valley during May-October to obtain a pest control adviser recommendation prior to application to any of seven crops: alfalfa, almond, citrus, cotton, grape, pistachio, or walnut; and 4) prohibit most applications of high-VOC products to the seven crops in the San Joaquin Valley during May-October, if pesticide VOC emissions exceed a trigger level. The regulations should go into effect in November 2013.

NPDES Program Overview
And
Pesticides Permitting

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The National Pollutant Discharge Elimination System (NPDES) Program is a Federal Regulating Program that began with the 1972 Amendments to the Clean Water Act (CWA). The main objective of the NPDES Program is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The United States Environmental Protection Agency (USEPA) is responsible for implementing the NPDES Regulations but it has delegated its authority to most states including California. In California, the State Water Resources Control Board is the agency responsible for implement the NPDES Program. CWA Section 101(a) has set several program goals including: 1) making the nation's waters fishable and swimmable by 1983, 2) eliminating the discharge of pollutants by 1985, and 3) prohibiting the discharge of toxic pollutants in toxic amounts. The NPDES Program has solved a lot of pollution problems by controlling the most obvious sources of water pollution such as industrial wastewater discharges and sewage discharges. However, we're still working towards achieving the anticipated National goals.

The NPDES regulations prohibit the discharge of any pollutant from a point source to US waters unless the discharge is allowed by an NPDES permit. The key to understanding the NPDES Program is to understand how the terms **pollutant, point source, and waters of the US** have been defined in Chapter 40 of the Code of Federal Regulations (CFR) section 122.2 and interpreted by the regulations.

- A pollutant is defined as any dredged spoil, solid waste, incinerator residue, filter back wash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and Agricultural waste **discharged into water**. It does not include sewage from vessels or water, gas or other material that is injected into a well to facilitate production of oil or gas. However because of recent court decisions, biological pesticides as well as residues of chemical pesticides are now considered pollutants.
- A Point source is defined as any discernible, confined, and discrete conveyance, including but not limited to: Any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft **from which pollutants are or may be**

discharged. However, it does not include return flows from irrigated agriculture or agricultural storm water runoff.

- Waters of the U.S includes all waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce including all waters which are subject to the ebb and flow of the tide. All interstate waters, including interstate wetlands. All other waters such as intrastate lakes, rivers, streams, lakes, mudflats, sandflats, ponds, wetlands, sloughs, prairie potholes, intermittent streams, territorial seas, etc. In addition, all tributaries to these mentioned waters are also considered waters of the U.S.

In drafting NPDES Permits, the State Water Board and Regional Boards use Federal and State Regulations, local Water Quality Control Basin Plans, and established policies. Some of the most important tools used when drafting NPDES Permits include:

- The California Toxics Rule which lists toxicity criteria for aquatic life and human health for 126 priority pollutants.
- The Thermal Plan which lists temperature criteria applicable to the different waters of the state.
- The State Implementation Policy which provides the procedures to follow in determining requirements for toxic priority pollutants.
- The applicable Regional Water Board Basin Plans which establish local water quality standards and objectives.
- In addition if a discharge is to the Ocean, then the Ocean Plan applies, which also contains water quality objectives for a number of pollutants and implementation procedures.

An NPDES Permit is an authorization to discharge and has a five-year lifecycle. There is no right to an NPDES Permit, so it can be revoked at any time. To get coverage under an NPDES Permit, an application is required. An NPDES Permit can be issued either as an individual permit or a General permit. An NPDES Permit will include Federal Standard Provisions, effluent limitations, receiving water limitations, monitoring requirements, and applicable pretreatment or sludge management requirements, and any needed special studies. Effluent limitations in an NPDES Permit can be of two types, technology based or water quality based. Technology based limits are established by USEPA depending on the type of industry and they can be found in 40 CFR sections 405 thru 409. Water Quality based limitations on the other hand are established to protect the receiving water beneficial uses and comply with water quality objectives under the California Toxics Rule, Ocean Plan, or the Regional Boards' Basin Plans. When writing an NPDES Permit one needs to consider the following aspects:

- The type of discharge, if it an industry or a Publicly Owned Treatment Works (POTW).
- The discharge flow, because it if is a POTW and is more than 5 million gallons per day (mgd), then the pretreatment regulations would also apply.

- The applicable beneficial uses of the receiving water. These can include Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Industrial Process Supply (PROC), Industrial Service Supply (IND), Cold Freshwater Habitat (COLD), Warm Freshwater Habitat (WARM), Water Contact Recreation (REC-1), Non-contact Water Recreation (REC-2), Marine Habitat (MAR), Estuarine Habitat (EST), Wetland Habitat (WET), Wildlife Habitat (WILD), Navigation (NAV), etc.
- The available dilution and assimilative capacity in the receiving water, both of which can have an effect on the stringency of the final effluent limitations. Dilution is available if flows in the receiving water are greater than the discharge flows, and assimilative capacity is available if the concentration of the pollutant in the receiving water is lower than the applicable water quality objective.

Effluent limitations are established where there is reasonable potential for a discharge to cause or contribute to an excursion above water quality standards protective of the applicable beneficial uses of the receiving water. Effluent limitations could be applied for individual pollutants or for whole effluent toxicity. Effluent limitations can result in increased monitoring and reporting costs, or the need for additional special studies for dilution or toxicity evaluation. Non-compliance with effluent limitations will signify penalties and liability as well as the need for additional controls or advanced treatment. There are the 3 triggers we evaluate when determining reasonable potential and the need of an effluent limitation for a specific pollutant:

- Trigger 1- If the maximum effluent concentration of a pollutant is greater than the applicable criteria, then an effluent limitation is needed.
- Trigger 2- If the maximum receiving water concentration of a pollutant is greater than the applicable criteria and the pollutant has also been detected in the effluent, then an effluent limitation is needed.
- Trigger 3- If there is any other information on the pollutant that warrants the need of an effluent limitation. Any other information that may be used includes : Facility type, discharge type, lack of dilution, history of compliance problems, potential toxic impact of discharge, fish tissue residue data, water quality and beneficial uses of the receiving water, CWA 303d listing of the pollutant, presence of endangered species or critical habitat.

With regards to pesticides, the understanding was that as long as pesticides were being used in conformance with USEPA's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) labeling directions, pesticides will not pose unreasonable risks to human health and the environment. Thus pesticides applications to waters of the U.S in the past did not require an NPDES Permit, however, because of recent court decisions (9th Circuit Headwaters v. Talent in 2001 and 6th Circuit National Cotton Council v. EPA in 2009), pesticides applications that discharge to waters of the U.S are now required to be covered under an NDPES Permit. In addition to the court decisions, the State Water Board also regulates pesticides because pesticides cause impairment in many surface water bodies in California, the public expects it, and the regulated community wants to be permitted. Here is a chronology of the permitting events in the last few years:

- It all started with the 9th Circuit court's decision on the Headwaters vs Talent Irrigation District case in March 2001. In Talent, the court ruled that the direct application of an aquatic pesticide into a surface water body or its tributaries is a discharge of a pollutant to waters of the U.S, thus, requiring coverage under an NPDES permit.
- Because of the court's decision, the State Water Board adopted an Emergency Pesticide Permit in July 2001.
- Later in May 2004, the State Water Board adopted the Vector and Weed Control General Permits to replace the Emergency Pesticide Permit.
- In September 2005, the 9th Circuit court ruled in Fairhurst v. Hagener that residual chemical pesticides are pollutants.
- In spite of the 9th Circuit court rulings, in November 2006, USEPA adopted the Aquatic Pesticide Rule. The rule stated that a pesticide applied directly into, over, or near water per FIFRA is not a pollutant, thus, an NDPES permit is not needed.
- However, in January 2009, the 6th Circuit court issued its initial ruling vacating USEPA's Aquatic Pesticide Rule.
- Six months later, in June 2009, the 6th Circuit court granted USEPA's request for a 2-year stay on the 6th Circuit court's January 2009 ruling to allow USEPA time to issue a national General NPDES permit on Aquatic Pesticides. The stay meant that the Rule will remain in place until April 9, 2011.
- In March 2011, the State Water Board adopted three pesticides permits, the Vector Control General Permit, the Aquatic Animal Invasive Species Control General Permit, and the Spray Applications General Permit, and that same month, the 6th Circuit court extended the stay for another 6 months ending on 10/31/2011.
- State Board is scheduled to adopt the Algae and Aquatic Weed Control Applications General Permit on February 19, 2013.

Therefore, since the court rulings and as of February 2013, the State Water Board will have the following General NPDES Permits adopted:

- A Vector Control Pesticide General Permit for control of mosquitoes and mosquito larvae.
- A Spray Applications Pesticide General Permit for pest management and eradication programs for invasive insects and terrestrial weeds, and applicable only to the California Department of Food and Agriculture and the United States Department of Agriculture Forest Service.
- An Aquatic Animal Invasive Species Control Pesticide General Permit for the control of invasive species such as the quagga and zebra mussels, New Zealand mudsnails, Chinese Mitten Crabs, etc.
- Aquatic Weed Control Pesticide for the control of algae and aquatic weed.

Court-Ordered Injunctions on Pesticide Use and the Protection of Endangered Species

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Over the last 9 years, three separate pesticide use injunctions have resulted from litigation between U.S. EPA and environmental advocacy groups such as Californians Against Toxic Substances (CATS), Washington Toxics Coalition, and the Center for Biological Diversity

The first injunction was put into place in February of 2004, and is known as the "Salmonid Injunction". It resulted from a lawsuit by environmental and fishery groups charging U.S. EPA with failure to solicit National Marine Fisheries Service (NMFS) formal consultation on the risks from 38 pesticides to 26 distinct populations of Chinook salmon, Coho Salmon and Steelhead. This injunction imposes prohibitions for use of 38 active ingredients 100 yards by air, and 20 yards by ground from "Salmon Supporting Waters". It also requires EPA to consult with NMFS on the potential hazards posed by the 38 active ingredients to Salmon populations.

The first round of consultations in 2008 resulted in a Biological Opinion for Chlorpyrifos, Diazinon, and Malathion. DPR expressed disagreement with the Biological Opinion and posted comments to the Public Docket. The Biological Opinion proposed buffers of 500 feet for ground applications and 1000 feet for aerial applications. Additionally, it imposes requirements for fish kill reporting, runoff prevention measures, and environmental monitoring. Consultations between U.S. EPA and National Marine Fisheries Service have continued and their completion expected in the Summer of 2013:

http://www.epa.gov/oppfead1/endanger/litstatus/effects/biop-revised-3-2012.pdf

In response, U.S. EPA decided to impose variable buffers depending on application rate + droplet size + size of adjacent body of water. Nevertheless, for aerial applications the resulting buffers are still almost 1000 feet. For ground applications, the resulting buffers can be a minimum of 100 feet.

In November of 2009, U.S EPA submitted 40 draft California Bulletins for Chlorpyrifos, Diazinon and Malathion. They were reviewed by DPR's Endangered Species Program staff and comments sent to U.S. EPA. In January of 2010 U.S. EPA submitted the revised bulletins, including a test version of an application intended to help pesticide applicators calculate the corresponding buffer for their intended application rate, droplet size and body of water adjacent to the application site. U.S. EPA is asking registrants of Chlorpyrifos, Diazinon and Malathion to voluntarily modify labels for pesticides containing these active ingredients and refer users to the Bulletins Live Web site at: http://137.227.242.131/espp_front/view.jsp in order to find out which buffer size applies to the product they intend to apply. Registrants will be granted 18 months to generate new labels or update existing product. If the registrants don't agree to modify product labels, they could face cancellation proceedings. The use limitations imposed by the bulletins will be voluntary until product labels are modified.

The second injunction in place is known as the "Stipulated Injunction and Order for Protection of California red-legged frog". It became effective on 10/20/2006. The lawsuit by the Center for Biological Diversity alleged that U.S. EPA failed to solicit U.S. Fish & Wildlife Service (FWS) formal consultation on the risks from 66 pesticides to California red-legged frog (CRLF). It imposes prohibitions for use of 66 active ingredients 200 feet by air, and 60 feet by ground from California red-legged frog's aquatic and upland habitats occurring in 33 counties.

As with the Salmonid injunction, the Ninth District Court in Seattle ordered U.S. EPA to initiate Formal Consultations with the FWS, and schedule it in such a way it can be completed in approximately 5 years. Since 2007, U.S. EPA has been working on effects determinations for all 109 active ingredients included in this and other injunctions. This information has been made available at: http://www.epa.gov/oppfead1/endanger/litstatus/effects/

The third and latest injunction is referred to as the "Bay Area Stipulated Injunction and Order". This lawsuit by the Center for Biological Diversity charges U.S. EPA with failure to consult U.S. Fish & Wildlife Service (FWS) on the risks from 75 active ingredients to 11 listed species in the San Francisco Bay Area. Eight counties are affected: Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano and Sonoma. The injunction imposes different "no-use" buffers for some of the 75 active ingredients, depending on the type of species. The species included are: Alameda whipsnake, Bay checkerspot butterfly, California clapper rail, California freshwater shrimp, California tiger salamander, Delta smelt, salt marsh harvest mouse, San Francisco garter snake, San Joaquin kit fox, tidewater goby and Valley elderberry longhorn beetle. The buffers imposed by this injunction range from 100 to 700 feet for ground applications, and from 200 to 700 feet for aerial applications.

During the public comment period, DPR recommended U.S. EPA replace the proposed interim buffer zones with use limitations specified in our WEB-based database PRESCRIBE.

U.S. EPA completed their review of public comments and posted the final injunction on May 17, 2010 in their Web site at: http://www.epa.gov/espp/litstatus/stipulated-injuc.html

All these injunctions share some common denominators:

1) They have resulted from the lack of consultation by U.S. EPA on the effects of "pesticide x" on "species y" with the U.S. Fish & Wildlife Service (FWS) or National Marine Fisheries Service (NMFS).

2) They impose a consultation schedule between EPA and The Services (FWS or NMFS) typically 4 to 6 years minimum.

3) Public vector control and invasive weed control programs are exempt. However, in the case of the Salmonid Injunction, the use limitations resulting from consultation don't provide exemptions for vector control or invasive weed control programs.

4) They can only be enforced through citizen lawsuits. Federal, State, County and other local authorities are "vacated' from enforcing them.

5) As products go through consultation, if deemed "not likely to adversely affect" a species they will be taken off the injunction list.

6) If deemed "likely to adversely affect" a species, EPA may impose restrictions to be enforced through labeling.

This process is very contentious, generating a great deal of mistrust between the regulated community and regulatory agencies – in this case U.S. EPA. It also affects DPR, since each injunction comes with its own set of buffers and species; DPR's comprehensive, programmatic approach to protection of endangered species is being impacted by the multitude of injunctions and their litigation-derived buffers. The imposition of court-ordered absolute buffers further discourages good land stewardship efforts, since growers who in previous years might have managed their fields to include field-edge vegetation cover, hedgerows, etc., see their habitat enhancement efforts as a potential liability if listed species move in. Under these injunctions - even with exemptions- some invasive weed programs are still facing no-use zones that become refuges for noxious weeds.

Protecting Urban Water Quality: New Surface Water Regulations of 2012

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The California Department of Pesticide Regulation adopted new surface water regulations on June 19, 2012. The regulations restrict outdoor urban applications of pyrethroid insecticides made by professional applicators. Pyrethroids are highly active insecticides that control crawling, chewing, and flying insects as cockroaches, ants, beetles, caterpillars, termites, mosquitos, and wasps; in addition they are highly active on arachnids as spiders, ticks, and mites. Pyrethroids are highly hydrophobic and sorb to soils and sediment; half-lives of pyrethroids range from weeks to more than a year. Pyrethroids are being regulated in urban (non-agricultural) areas because of the following characteristics:

1) high use in urban areas;
2) prone to runoff in urban areas due to the engineering design of urban areas, especially during rainstorms;
3) more frequently detected in urban areas than in agricultural areas;
4) highly toxic to aquatic invertebrates and fish;
5) cause aquatic invertebrate toxicity when detected in surface waters.

The new surface water regulations will reduce the amount of pyrethroids applied by limiting applications to spot applications, crack and crevice applications, pin stream applications, and by limiting applications to impervious surfaces. Because more pyrethroids runoff during rainstorm events, applications are prohibited during rainfall (except under eaves), in standing water, to stormdrains and curbside gutters, and unprotected termiticide applications. More specific information can be found at the CDPR website (http://cdpr.ca.gov/docs/legbills/calcode/040501.htm). Although the new surface water regulations will reduce pyrethroid use, they will also prolong the life of these insecticides.

References

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California Weed Science Society
Custom Summary Report
July 1, 2012 through May 24, 2013

	Jul 1, '12 - May 24, 13
Ordinary Income/Expense	
Income	
4000 · Registration Income	107,503.00
4001 · Membership Income	490.00
4010 · Proceedings Income	1,361.92
4015 · Field Tour Income	1,900.00
4020 · Exhibit Income	17,750.00
4030 · Sponsor Income	10,500.00
4040 · CWSS Textbook Income	10,000.00
4065 · Orchid Fundraiser	400.00
4290 · Refunds	-2,108.00
Total Income	147,796.92
Expense	
4300 · Conference Accreditation	190.00
4310 · Conference Facility Fees	550.00
4315 · Conference Bus Tour	656.40
4320 · Conference Catering Expense	44,992.25
4330 · Conference Equipment Expense	3,818.20
4360 · Student Awards/Poster Expense	2,000.00
4361 · Awards-Board/Special Recog.	145.77
4370 · Scholarship Expense	11,500.00
4380 · Conference Supplies	1,824.02
6090 · Advertising	1,500.00
6110 · Chase Paymentech charge	886.30
6111 · Moolah Bankcard Online Charge	1,911.66
6112 · Gateway Online Service Charge	233.40
6115 · American Express service charge	501.48
6120 · Bank Service Charges	214.09
6130 · Board Meeting Expenses	988.54
6240 · Insurance - General	3,103.00
6270 · Legal & Accounting	3,323.50
6280 · Mail Box Rental Expense	76.00
6300 · Office Expense	306.43
6307 · Outside Services - PAPA	37,386.90
6340 · Postage/Shipping Expense	3,210.23
6345 · Printing Expense - Newsletter	2,900.17
6355 · Website Expense	1,200.00
6360 · Storage Rental Expense	264.00
6390 · CWSS Textbook	5,000.00

California Weed Science Society
Custom Summary Report
July 1, 2012 through May 24, 2013

	Jul 1, '12 - May 24, 13
6520 · Telephone/Internet Expense	749.21
6530 · Travel - Transport/Lodging	2,303.74
6540 · Travel - Meals/Entertainment	450.87
6545 · Student Travel - Transport/Lodg	2,326.30
6550 · Student Travel - Meals	124.43
6555 · Speaker Lodging/Travel Expense	2,265.25
Total Expense	136,902.14
Net Ordinary Income	10,894.78
Net Income	**10,894.78**

RBC Wealth Management Account

Balance as of 4/30/13

$273,140.74

24% Cash and money market

28% US equities

47% Taxable fixed income

1% Other assets

CWSS HONORARY MEMBERS LISTING

Harry Agamalian (1983)
Norman Akesson (1998)
Floyd Ashton (1990)
Alvin Baber (1995)
Walter Ball *
Dave Bayer (1986)
Carl E. Bell (2010)
Lester Berry
Tim Butler (2008)
Mick Canevari (2008)
Don Colbert (2002)
Floyd Colbert (1987)
Stephen Colbert (2012)
Alden Crafts *
Marcus Cravens *
Dave Cudney (1998)
Richard Dana
Boysie Day *
Nate Dechoretz (2003)
Jim Dewlen (1979)*
Paul Dresher *
Ken Dunster (1993)*
Matt Elhardt (2005)
Clyde Elmore (1994)
Bill Fischer *
Dick Fosse *
Tad Gantenbein (2004)
Rick Geddes (2006)
George Gowgani
Bill Harvey *
David Haskell (2009)
F. Dan Hess (2001)*
Floyd Holmes (1979)
Nelroy Jackson (1997)
Scott A. Johnson (2013)
Warren Johnson (1977)*
Bruce Kidd (2009)
Jim Koehler
Harold Kempen (1988)
Don Koehler (2003)
Butch Kreps (1987)
Edward Kurtz (1992)
Art Lange (1986)
Wayne T. Lanini (2011)
J. Robert C. Leavitt (2010)
Oliver Leonard *
Jim McHenry
Bob Meeks
Bob Mullen (1996)
Robert Norris (2002)
Ralph Offutt
Jack Orr (1999)
Ruben Pahl (1990)
Martin Pruett
Murray Pryor *
Richard Raynor
Howard Rhoads *
Jesse Richardson (2000)
Ed Rose (1991)
Conrad Schilling *
Jack Schlesselman (1999)
Vince Schweers (2003)
Deb Shatley (2009)
Conrad Skimina (2003)
Leslie Sonder *
Stan Strew
Huey Sykes (1989)
Tom Thomson (1999)
Robert Underhill
Lee VanDeren (1983) *
Ron Vargas (2001)
Stan Walton (1988) *
Bryant Washburn (1988)
Steve Wright (2007)

*Deceased

CWSS AWARD OF EXCELLENCE MEMBERS LISTING

1985	June McCaskell, Jack Schlesselman & Tom Yutani
1986	Harry Agamalian, Floyd Colbert & Ed Rose
1987	Bruce Ames, Pam Jones, & Steve Orloff
1988	Bill Clark & Linda Romander
1989	Earl Suber
1990	Ron Hanson & Phil Larson
1991	John Arvik & Elin Miller
1992	Don Colbert & Ron Kelley
1993	Ron Vargas
1994	Jim Cook & Robert Norris
1995	Mick Canevari & Rich Waegner
1996	Galen Hiett & Bill Tidwell
1997	David Haskell & Louis Hearn
1998	Jim Helmer & Jim Hill
1999	Joe DiTomaso
2000	Kurt Hembree
2001	Steven Fennimore, Wanda Graves & Scott Steinmaus
2002	Carl Bell & Harry Kline
2003	Dave Cudney & Clyde Elmore*
2004	Michelle LeStrange & Mark Mahady
2005	Scott Johnson & Richard Smith
2006	Bruce. Kidd, Judy Letterman & Celeste Elliott
2007	Barry Tickes & Cheryl Wilen
2008	Dan Bryant & Will Crites
2008	Ken Dunster* & Ron Vargas*
2009	Ellen Dean & Wayne T. Lanini
2010	Lars W.J. Anderson & Stephen F. Colbert
2011	Jennifer Malcolm & Hugo Ramirez
2012	Rob Wilson
2013	Rick Miller

*President's Award for Lifetime Achievement in Weed Science

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