

A California Perspective on Herbicide-Resistant Weeds

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The Weed School Session of this year's CWSS meeting focuses on the issues of herbicide-resistant weeds. I'll give a quick overview of the situation in California; Stanley Culpepper from the University of Georgia will share the situation in the Southeast and update us on the situation in the Midwest and South; finally, Albert Fischer will discuss mechanisms of herbicide resistance with a special focus on the unique management challenges conferred by nontarget site based resistance mechanisms. As we go through the meeting program, you'll also notice the issue of herbicide resistance cropping up in graduate student research, and in the various crop and non-crop concurrent sessions.

In California, like in other regions, our weed management practices impose selection pressure for species that are tolerant or resistant to the practice. Less diverse management practices impose greater selection pressure compared to more diverse weed management programs. While very effective for weed control, herbicides impose great selection pressure; especially in systems with physical or economic limitations on non-chemical weed control methods. Currently, there have been 26 cases of herbicide-resistant weed populations confirmed in California. However, these are not equally distributed among all situations and differ in some ways from herbicide resistance in other regions of the country. Herbicide resistance in the US is primarily a problem in agronomic crops and the majority of the resistance cases are in broadleaf weeds. Conversely, in California, we've got more issues with herbicide-resistant grasses and monocots and our problems are in specialty crops like rice, orchards, and vineyards, and non-crop areas like roadsides and rights-of-way. So far, our agronomic crops are less affected but this may change as tillage and irrigation practices evolve in the state.

There are few easy solutions to California's problems with herbicide-resistant weeds because non-chemical weed control options are limited in some cases by economic, environmental, or practical limitations. Additionally, there are simply relatively few herbicide modes of action registered in many of our specialty crops. Thus, changes to selection pressure are likely to be slow and measured rather than fast and widespread. An additional concern in in much of the US is multiple-resistance – that is resistance to more than one mode of action in the same weed population. We have this to some degree already, especially in flooded rice systems, and this could greatly impact other California cropping systems too. Non-target site based resistance imparts an additional challenge as these can be difficult to predict and may also impart tolerance to other biotic and abiotic stress conditions. Weed management always includes tradeoffs; herbicide resistance management will also require growers to consider long- and short-term benefits to mitigating resistance selection. Economics and grower perception of the problem with herbicide resistance will be the biggest challenges. Although herbicide-resistant weeds will remain a serious management challenge, the challenge will not be felt equally among all situations. Rice, roadsides, and agronomic crops will be probably have greater difficulty while high intensity fruit and vegetable crop or more complex systems like rangelands will likely have fewer problems with resistance. Our challenge in light of herbicide-resistant weeds is to go back to systemic and long-

term thinking about integrated weed management strategies for specific situations rather than simply relying on one-size-fits-all herbicide solutions.

Weed Resistance – National Perspective

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Herbicide-resistant weeds are certainly not new but the impact from these weedy pests during the last decade has changed agriculture forever. In the Southeast, glyphosate-resistant Palmer amaranth, horseweed, and common ragweed as well as annual ryegrass resistant to ALS/ACCase inhibiting herbicides are having the greatest impact in agronomic crop production. Growers are managing these weeds effectively but at a significant cost, especially when fields are infested with Palmer amaranth. Increased costs to manage these pests in soybean, peanut, wheat, and cotton are \$25-35, \$10-15, \$10-20, and \$30-60 per acre, respectively.

Resistant weeds with greatest impact in the Midsouth include glyphosate-resistant Palmer amaranth, horseweed, ryegrass, johnsongrass, and goosegrass as well as annual ryegrass resistant to ALS/ACCase inhibiting herbicides. Similar to the Southeast, Palmer amaranth is the greatest challenge but, overall, resistant weeds have increased costs in corn, soybean, and cotton \$15-30, \$35-45, and \$30-60 per acre, respectively. One difference when comparing the Midsouth with the Southeast is that growers in the Midsouth are still having significant yield losses occurring even after implementing additional management expenses.

Waterhemp resistant to glyphosate and at least four other classes of herbicide chemistry offer the greatest challenge for Midwest farmers. Glyphosate-resistant Palmer amaranth, horseweed, and giant ragweed are also extremely problematic in areas where they are present as are foxtails with resistance to ALS inhibiting herbicides. Midwest scientists suggest management increases of \$10-30 per acre are occurring on many soybean acres with increases of \$0-15 per acre noted in corn due to these problematic weeds.

In Texas, herbicide-resistant weeds influencing agronomic crop production include ALS-resistant *Amaranthus* species and nutsedge as well as recently confirmed infestations of glyphosate-resistant Palmer amaranth. Growers who have these infestations, primarily Palmer amaranth, are spending approximately \$20 per acre to manage them.

Scientists from each of these regions had similar suggestions to help growers prevent/manage resistant weeds. It is essential that growers understand the need for diversity in their management programs. For areas heavily infested with glyphosate-resistant Palmer amaranth, herbicides alone are simply not a sustainable option. Thus, growers must implement an integrated management approach including as many control tactics as economically feasible such as an effective herbicide program, cover crop residue, tillage, hand weeding, and/or crop rotation. For large scale agriculture the herbicide system remains the key component in most weed management systems and must be

protected. Therefore growers need to develop programs that 1) rotate herbicide modes of action within years and across years, 2) include residual herbicides and herbicides with postemergence control of problematic pests, and 3) apply appropriate herbicide rates. Ultimately the goal of the integrated management approach is to attack the seedbank thereby reducing weed populations, input costs, and pesticide use over time. In many areas, hand removal of Palmer amaranth prior to seed development has been extremely effective with lower seedbank populations noted within just a few years of initiating the practice. Growers should also employ sound equipment sanitation methods when purchasing equipment or when moving equipment from an area infested with a problematic weed to areas where the weed is not an issue.

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Mechanism of Propanil Resistance in *Cyperus difformis* L.

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Weed resistance to herbicides was first discovered nearly 30 years ago. To date, 396 different weed biotypes showing resistance to diverse herbicide chemical classes have so far been reported. Herbicide-resistance in *Cyperus difformis* L., a major weed of rice, is widespread worldwide but has thus far only been reported for acetolactase synthase-inhibiting herbicides. Faced with the ensuing reduced control options, rice growers in California have come to rely on the contact herbicide propanil (3,4-dichloropropionanilide) for control of ALS-resistant *C. difformis* populations. Nonetheless, growers have recently experienced poor control with any of the available propanil formulations, suggesting resistance to this photosystem II-inhibiting herbicide may have evolved in *C. difformis* populations. The objectives of this study were to (a) confirm resistance to propanil in *C. difformis* lines by means of whole-plant dose-response experiments and establish resistance levels, and to (b) examine whether or not mutations at the photosystem II thylakoid-membrane-bound D1 protein could be playing a role in the propanil-resistant plant's ability to survive a rather lethal dose of propanil. A *C. difformis* line derived from populations collected in rice fields of California's Sacramento Valley was confirmed resistant to propanil; its resistance level (R/S ratio) equaled 16.8. This is the first case of such resistance outside the *Poaceae* family and the first time *C. difformis* exhibits resistance to an herbicide mechanism of action other than ALS inhibition. Carbaryl - a known propanil synergist due to its role as substrate for the propanil-degrading enzyme aryl acylamidase - did not increase propanil toxicity in R plants but did synergize propanil against S plants, resulting in an R/S ratio of 38.9 when carbaryl was present. Such results indicate enhanced degradation of the herbicide molecule is not playing a role in *C. difformis* resistance to propanil. By means of whole-plant dose-response experiments, R plants were shown to resist greater levels of the PSII-inhibitors bromoxynil, diuron and metribuzin relative to S plants, but are as susceptible to atrazine as the latter. Following such results, we selectively amplified the herbicide-binding region of the chloroplast *psbA* gene of propanil-R and -S plants using PCR. Sequence analysis of the R plants exhibited a substitution from valine to isoleucine at position 219 of the D1 protein encoded by the *psbA* gene, thus suggesting a partial loss of affinity between propanil and its binding site could be playing a role in *C. difformis* resistance to propanil. Such mutation (Val219Ile) has been reported for metribuzin, diuron-resistant *Poa annua* populations. To our knowledge this is the first report of a higher plant exhibiting resistance to propanil due to a *psbA* mutation, for all previous cases were attributed to enhanced propanil degradation by aryl acylamidases. The loss of propanil to control this important weed of rice underscores the fragility of herbicide-based weed control in monoculture rice. Integrated weed management approaches to decrease herbicide selection pressure are needed to mitigate the evolution of multiple-herbicide resistance in *C. difformis* of California rice.

Management Strategies of Potential Herbicide Resistant Weeds in Cotton in the San Joaquin Valley

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Glyphosate-resistant (GR) weeds are changing the Roundup Ready (RR) cotton (*Gossypium hirsutum* L.) production system throughout the US cotton belt. This phenomenon has compelled cotton producers in the San Joaquin Valley (SJV) of California to search for options before the onset of this problem. One such option could be the combined use of pre-emergence (PRE) residual and postemergent (POST) herbicides. We hypothesized that PRE herbicide applications may reduce the density of weeds at initial application of glyphosate in RR cotton production systems. Further, this may also be an effective weed seedbank management strategy. Therefore, the objectives of this study was to compare the efficacy of some POST and PRE herbicides applied at 15 and 35 days prior to planting cotton (DPP) on weed control, and to assess their deleterious effects on the crop.

Once the crop established, crop injury and stand loss evaluations were taken in May and June. Monthly weed density evaluations were taken from May to September. In both years, the PRE treatments did not cause crop injury or stand loss. Final plant mapping was taken before defoliation. In both years, the crop was harvested in October. It is not determined if the PRE treatments incorporated did an excellent job of controlling weeds or weed pressure was just low. The data for both years showed that weed pressure was nonexistence. None of the treatments affected ($P>0.05$) weed densities, stand loss, crop injury, and final plant mapping. Although, the treatments applied at 35 DPP had no effect on lint yield, differences occurred between the treatments for lint yield when they were applied at 15 DPP.

Increasing Prevalence of Palmer amaranth in the San Joaquin Valley: Evaluating for Glyphosate Resistance

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Glyphosate has been a popular herbicide for weed management in annual, perennial cropping systems and non-crop areas for more than a decade. Heavy reliance on a single mode of action can increase the risk of weed species evolving resistance to the herbicide. Glyphosate-resistant (GR) populations of Palmer amaranth have been confirmed throughout the southeast United States since 2005. Since 2012, growers in California's San Joaquin Valley (SJV) have observed poor control of Palmer amaranth in glyphosate-tolerant corn (*Zea mays L.*) and cotton (*Gossypium hirsutum L.*). Palmer Amaranth (*Amaranthus palmeri*) is one of the most problematic weeds because of its competitive ability, C4 photosynthesis, high water use efficiency and drought tolerance, rapid growth rate, and prolific seed production. However, it is not known if these are cases of GR populations or application of glyphosate at more tolerant stages of the weed. Glyphosate screenings at rates ranging from 0 to 88 oz/ac were conducted on natural populations of Palmer amaranth at various growth stages in the field in 2013. However, all the plants were controlled with the labeled rate of glyphosate in these studies. Therefore, Palmer amaranth seeds from 23 annual and biannual cropping systems from different locations of the SJV were collected for evaluation of glyphosate resistance. To date, two SJV populations have been evaluated against a known GR and a glyphosate-susceptible (GS) population from New Mexico. The experimental design was a 4 by 9 factorial randomized complete block with four replications. The 4 populations and the 9 herbicide doses were the factors. Glyphosate treatments were administered at the 5- to 8- leaf stage at 0.5x, 1x, 1.5x, 2x, 2.5x, 3x, 3.5x, and 4x rates with a control, where 1x= 22 oz/ac (labeled rate). The study was repeated. Both the SJV populations had 100% mortality at the 22 oz/ac rate of glyphosate in both studies and therefore deemed to be GS. However there was a significant difference ($P < 0.05$) between the two studies in the biomass. When the light intensity and day length were increased in the chamber in the second study, some of the plants from one of the SJV population took a longer time to die and regrew at the 1.5x and 2.5x rate of glyphosate. Additional field studies are also being conducted to evaluate the effect of growth stage of the plants in tolerance to glyphosate. Collectively, these studies will provide information on whether the reported lack of control in the SJV Palmer amaranth populations are cases of GR populations or due to tolerance to glyphosate at later growth stages and environmental conditions during glyphosate application.

Responses of C₄ Waterhemp and C₃ Cotton to Ozone and Moisture Stress: Contribution to a Developing Weed Problem?

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Tropospheric ozone (O₃) is a major air pollutant and an important anthropogenic stressor in agricultural cropping systems of the Central Valley of California. Studies have reported that O₃ can have differential effects on crops and weeds and thereby alter crop-weed competition dynamics in some crops. Some weeds like black nightshade (*Solanum nigrum*), horseweed (*Conyza canadensis*), and yellow nutsedge (*Cyperus esculentus*) have been found to be tolerant to O₃ and in some cases more competitive with crops in elevated O₃ condition. Common waterhemp (*Amaranthus tuberculatus*) is a problematic weed in the Midwest soybean and corn production systems. Although it is not a widespread weed in California, it has been reported in some counties such as San Diego, Santa Barbara, and Sacramento. Preliminary studies showed that some populations of this weed species were tolerant to glyphosate at later growth stages (beyond 6" size). Due to its ability to spread rapidly and tolerance to glyphosate at later-stages, common waterhemp could be a potential weed in the Central Valley and other parts of California. Further, availability of water for irrigation is a challenge in the Central Valley and it has resulted in an increased interest in research on regulated deficit irrigation (RDI) in several cropping systems. However, it is not known how this weed species would adapt to elevated O₃ levels and reduced moisture conditions. Knowledge of the response of common waterhemp to these environmental conditions would help predict the invasive potential of this weed in the Central Valley. Therefore, a study was conducted to determine the effect of different O₃ levels and reduced irrigation on common waterhemp. The study was conducted in controlled O₃ environments in continuously stirred tank reactor (CSTR) chambers. The growth and stomatal conductance (day and night) of cotton (*Gossypium hirsutum*) and common waterhemp in these chambers were compared in a split-plot design with O₃ as main effect and irrigation as sub-effect. The main plots consisted of three different concentrations of 12 hour mean exposure to O₃ (15ppb: low O₃, 80ppb: medium O₃, and 150 ppb: high O₃) and the sub-plots consisted of two irrigation levels (control and reduced). The experiment was conducted twice (in early and late summer of 2013). Ozone and irrigation level had a significant (P<0.05) effect on the day and night time stomatal conductance of cotton but not on common waterhemp. Day time stomatal conductance decreased while night time stomatal conductance increased in cotton as O₃ concentration increased. Similarly, while increasing O₃ and reduced irrigation level significantly decreased the above- and below-ground biomass of cotton, these variables had no effect on common waterhemp. Our results suggest that common waterhemp can be more invasive and more competitive with crops under high O₃ and deficit irrigation conditions in the Central Valley. The problem can be more serious if this weed evolves resistance to glyphosate. Therefore, the spread of this weed needs to be monitored carefully so that it does not become a serious threat in the Central Valley as in other parts of the country.

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 a fairly new herbicide, saflufenacil (Treevix ®), on glyphosate-susceptible (GS), GR, and GPR biotypes of hairy fleabane when applied at different developmental stages. Potted hairy fleabane plants were grown in a greenhouse set at 25°C with ambient lighting. Plants were treated at the seedling stage (5-8 leaves), rosette stage (16-20 leaves), or initial bolting (extension of main stem). Treatments included saflufenacil applied at the rate of 0, 0.25x, 0.5x, 1x, and 2x (where x = 1 oz/ac of saflufenacil), 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 with growth stage as main-factor, biotype as sub-factor, and herbicide treatment as split-split-factor. The experiment was replicated five times and repeated.

Results showed plants were most susceptible at the seedling stage. The mix of saflufenacil and glyphosate provided the best result with 100% mortality of all 3 biotypes at the seedling stage. At the rosette stage, the 2x rate of saflufenacil resulted in only 70% mortality of the GS biotype and 50-60% of the GPR and GR biotypes respectfully. The mix of saflufenacil provided better control of the plants at the rosette stage with 80% mortality of the GPR biotype, 90% of the GR biotype, and 100% mortality in the GS biotype. At the initial bolting stage, the 2x rate of saflufenacil only provided 40-50% control of the GS and GR biotypes and no control of the GPR biotype. The mix of saflufenacil and glyphosate had only 50% control of the GS biotype, 30% control of the GR biotype, and no control of the GPR biotype at the initial bolting stage. Of the remaining treatments, glyphosate was only effective on the GR biotype at the seedling stage, although it controlled up to 60-80% of the GS biotype up to the initial bolting stage. Saflufenacil had some level of control at lower rates (0.25x, 0.5x and 1x), but once the plant reached the initial bolting developmental stage, these rates did not show any control. Therefore, it can be concluded that it is best to apply saflufenacil alone or as a tank-mix with glyphosate up to the 5- to 8-leaf stage. Any applications beyond this growth stage will result in inconsistent control or poor control

Herbicide Resistance Management – Human Dimensions to an Evolving Problem

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The evolution of an increasing number of herbicide-resistant weed species and populations has become a major concern across U.S. agriculture, particularly in those crop production systems that depend upon the widespread use of a limited number of weed management practices. The scientific community has expressed concern that the ability to manage weeds in production agriculture will decrease if an integrated system of best management practices (BMPs) is not developed and implemented. In May 2012, a number of organizations, with support from a USDA AFRI conference grant, sponsored a National Herbicide Resistance Summit which was hosted by the National Research Council in Washington, DC. The WSSA used this forum to promote a special report commissioned by USDA Animal and Plant Health Inspection Service (APHIS) on BMPs, their levels of adoption, impediments to adoption, and recommendations to optimize herbicide resistance management (Norsworthy et al. 2012). A summary of results from the Summit can be viewed at <http://nas-sites.org/hr-weeds-summit/>.

Rather than an end-point, the first Herbicide Resistance Management Summit was viewed as a starting point and call for action. Since the first Herbicide Resistance Management Summit, the WSSA has presented findings from the APHIS report to a number of organizations and has also published a comprehensive suite of herbicide resistant weed management training modules that have been widely disseminated (<http://wssa.net/>). The WSSA continues to be actively engaged with industry, grower organizations, state and federal agencies, and the science community on how to facilitate the adoption of herbicide resistant weed management practices. However, while some progress is being made as evidenced by increasing grower adoption of more diversified weed management programs, the level of adoption is still far below expectations and acreage infested with herbicide resistant weeds continues to grow at an increasing rate. It should be noted that the effectiveness of BMP adoption on a single farm is at least partly dependent on adoption by neighboring farms, as weeds have the capacity to travel across property lines. Thus, the effectiveness of BMPs is dependent on a wide range of adoption.

The myriad of factors driving the evolution of herbicide resistant weeds in crop production make its management incredibly complex. Weed management is ultimately the responsibility of farmers and farm managers. However, each farm household and farming enterprise are different, facing a variety of sociologic, economic and agronomic conditions. “One-size-fits-all” BMP recommendations cannot account for this variety and thus will have uneven success at best, and may prove costly and ineffective at worst. Moreover, dispersal of weed pollen and seeds, whether natural or human mediated, means that herbicide resistance can spread throughout the farm community. This “common pool” nature of the herbicide resistance problem makes the collective actions of neighboring farmers and the widespread adoption of BMPs necessary to ensure sustainable solutions.

The process of farm management innovation, including the development and dissemination of new technologies, strategies and tactics, has been studied by social scientists. The development and implementation of solutions to the myriad of problems in agriculture is part of a complex process that is influenced by factors such as farmer knowledge, values and objectives, size of operation, specific commodities produced, community social structure and other social networks, market influence, resource costs, governmental regulations and policies, and crop price signals.

What is now widely recognized is the need to engage all stakeholders in a dialog that results in the identification of the most important decision drivers that impact weed management across different crop production settings and ecosystems. The results of this dialog will be an understanding of how best to approach effective weed management planning from all who contribute to these decisions, including growers, land managers, retailers, applicators, agrichemical industry, university research and extension, crop advisors, state and federal agencies, and others.

How Plants Talk and Why We Should Listen

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Plants are able to exchange information regardless of the intent or fitness consequences for other plants. Mechanisms of information exchange often occur through the emission of volatile organic compounds which may be released in response to insect or disease infestation. The ability to exchange information may occur both above and below ground and result in enhanced fitness for the neighbouring plant population. In this presentation, we propose that exchange of information can occur through the detection of changes in light quality. The ability of crop plants to exchange information with neighbouring weeds is viewed as a primary mechanism of plant competition. This presentation will discuss the physiological and morphological changes that occur as a result of the ability of a weed to talk to a crop plant.

Management of Western Watermilfoil in the Friant-Kern Canal

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The Friant Water Authority (Authority) oversees the Operation and Maintenance 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 which encompass over 1,000,000 acres of highly productive land. Over a 14 year period invasive *Myriophyllum hippuroides*, or western watermilfoil, spread to entire earthen sections of the FKC causing numerous operational challenges in the FKC, Contractor's distribution systems, and end user's systems. In response, the Authority prepared the bold and ambitious FKC Western Watermilfoil Treatment Program (Program) in coordination with federal, state, and local stakeholders. During the winter of 2012, the Program utilized a pre-emergent drawdown application of Fluridone, trade name Sonar Genesis, and Imazamox, trade name Clearcast. The Authority reintroduced water into the FKC in early 2013 at which time evaluation of the Program's effectiveness began. Initial evaluation indicates the Program was successful in retarding or limiting the regrowth of western watermilfoil in areas of the FKC leaving the question as to the duration of control open for ongoing evaluation.

Weed Control in North Coast Vineyards

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Two studies were conducted in 2013 to evaluate weed control in vineyards in California's North Coast vineyards. The first study was conducted at the UC Oakville Station, Oakville, Napa Co, and compared three weed control methods over two years to determine differences in weed populations. This ongoing study compares mechanical cultivation, postemergence treatment with glyphosate herbicide and a combination of preemergence and postemergence herbicides on several weed species. Evaluations show that panicle willowherb (*Epilobium brachycarpum* C. Presl) is the dominant and spreading weed in the postemergence (glyphosate) only treatment. Grasses, 'Zorro' fescue and 'Blando' brome, that were moved into the undervine area of the vineyard from the middles are now dominant in the cultivated plots and may be acting as a mulch to compete with weeds.

The second study was conducted in American Canyon, Napa Co. compared 22 treatments for weed control, predominately panicle willowherb. This test was conducted under less than desirable conditions. The current California drought began in January 2013. This site received 10 inches of precipitation prior to application, a rain event of 0.23 inches occurred 13 days after application, but only a total of 2.17 inches of rain fell between application and the end of the growing season. This lack of precipitation caused a high degree of variability in the results. Matrix (rimsulfuron), Alion (indaziflam), Chateau (flumioxazin) (all combined with glyphosate) and combinations of these treatments provided very good season long control. Trellis (isoxaben) and Surflan (oryzalin) did not perform as well under these trial conditions for the control of willowherb.

Orchard Herbicide Symptomology Refresher

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Herbicides can provide an amazing level of weed control in many situations; however, they can also cause unexpected crop injury in some cases. Most of the margin of safety with the herbicides used in orchards is due to placement; we apply the herbicides below the tree or vine foliage and minimize the exposure to the deeper-rooted perennial crops. Foliar routes of exposure to orchard and vineyard crops can include drift (from outside or inside the orchard), vapor movement, and movement on soil dust. Damage from soil and root exposure most often happens in overdose situations or when unusual or unexpected soil or weather conditions move the herbicide deeper into the soil profile.

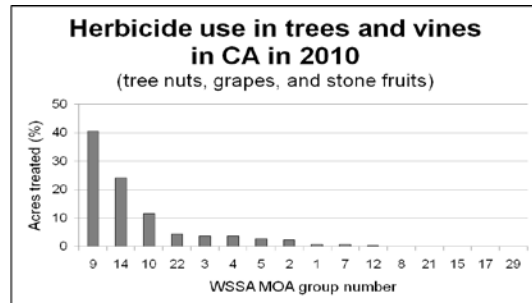
When trying to diagnose herbicide symptoms on any crop, it's important to think about how they work (mode of action), how they move in soil or plant tissue. This information can provide important clues as to expected symptoms, timeline, and duration of injury. Most of this presentation is a picture-based refresher on the symptoms that different classes of herbicides can cause to orchard crops and not very amenable to written descriptions. However, in troubleshooting suspected cases of herbicide injury, remember that symptoms can vary widely depending on the crop species, part exposed to the herbicide, the dose/rate of exposure, and the time since exposure. Additionally, many biotic and abiotic disorders can be confused with herbicide injury so it's important to avoid jumping to conclusions. When in the field, take good photos of the symptoms and include both overviews and close-ups. Describe the timeline of events and symptom development on crop and non-crop plants. Question the growers and advisors about herbicides and other practices used at the site in question as well as think about the weed control practices used in surrounding areas. Look for patterns in the field – these can be especially important in diagnosing application errors or soil issues and may reveal other cultural practices that can cause crop damage. Finally, symptomology can never be fully diagnostic of herbicide injury – when in doubt, collect leaf and tissue samples and freeze in case it becomes necessary to confirm herbicide exposure through laboratory analyses.

Resistance Management in Trees and Vines in California

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Tree and vine growers in California try to maintain fields in a relatively weed-free state were possible to facilitate irrigation, harvest, and other cultural operations, as well as to promote healthy, vigorous trees and vines. Although both pre- and postemergent herbicides are routinely used in orchards and vineyards, glyphosate is the most widely used herbicide (see figure) in these systems because of its ease of use and relatively cheap cost, compared to other herbicides. Currently in California, there are 19 herbicide-resistant weed biotypes resistant to herbicides in eight different chemical families, including the glycines (glyphosate). In recent years, glyphosate-resistant *Conyza bonariensis* (hairy fleabane) *C. canadensis* (horseweed), *Echinochloa crus-galli* (junglrice), and *Lolium multiflorum* (Italian ryegrass) have become especially problematic in tree and vine production systems in the southern San Joaquin Valley. Development of herbicide-resistant weed biotypes is usually associated with repeated use of a single herbicide mode-of-action (MOA), as is the case with those mentioned here.



To help combat glyphosate- and other herbicide-resistant weed populations and prevent additional outbreaks, growers must be proactive in their approach to weed management. This means growers need to consider multiple options and be willing to modify their programs as conditions warrant. The different weed control options available vary in effectiveness at

Control tactic	Potential impact
Herbicide – rotation (MOAs)	Excellent
Herbicide – mixtures (MOAs)	Excellent
Herbicide – timing	Excellent
Herbicide – rate	Poor to Fair
Herbicide – precision application	Poor
Tillage – primary	Good to Excellent
Tillage – general mechanical	Fair to Good
Cultural – crop selection/rotation	Fair to Good
Cultural – planting date	Poor to Fair
Cultural – seeding rate	Fair
Cultural – planting configuration	Good
Cultural – cover crops, mulching	Poor

impacting resistance (see chart).

At the forefront of combating herbicide resistance is preventing weedy plants from producing new seed (potential herbicide-resistant offspring). This means eradicating weeds within the treated field escaping chemical or physical control, as well as those along field edges, borders, ditches, and other near-by sites where weeds tend to proliferate. Preventing weed seed production in these areas will help reduce the risk of new weeds entering the field.

Herbicide labels have written sections referring to weed resistance management recommendations and strategies. It is important to follow these label guidelines, to help reduce the risk of developing herbicide resistance and to maintain that product’s effectiveness over time.

A third consideration should be given to the operation of the spray equipment used to treat weeds. If the proper dose of herbicide and carrier are not uniformly applied over the treated area, weed control will suffer and risk of resistance development increases. It is necessary to routinely monitor the spray operation, including items such as sprayer and spray tip performance, spray coverage, and environmental conditions. Employing an applicator with the right attitude and level of skill necessary to ensure the area is treated appropriately is critical for successful weed management. The applicator should be aware of the consequences of under- or over-dosing herbicides applied to the field to help minimize risk of resistance.

Applying herbicides at the appropriate timing, according to label recommendations, is also important to consider. Failure to treat when weeds are the most susceptible to the herbicide(s) usually leads to herbicide failure, requiring additional follow-up treatments. Often times, this leads to hardened-off plants which can still flower and produce seed. This is a common occurrence when hairy fleabane and horseweed are treated with glyphosate beyond their seedling stages of growth.

Because tree and vine growers in California rely on herbicides for economic weed control, it is important that consideration be given to use of herbicide MOAs for management of weed resistance. Over-reliance on a single herbicide MOA is a sure-fire way of encouraging resistance

development. Combining multiple herbicides with different MOAs in the spray tank and rotating different herbicide MOAs should be used where possible. Simply changing herbicide brand names or active ingredients may or may not mean one is using different herbicide MOAs. Therefore, one needs to recognize these differences when selecting products. Most herbicide labels list the herbicide MOA for that particular product and active ingredient. To aid recognition,

Herbicide active ingredients and mode-of-actions registered in almonds in California			
Preemergent herbicide active ingredient	Mode-of-Action (WSSA group)	Postemergent herbicide active ingredient	Mode-of-Action (WSSA group)
nimsulfuron	2	clthodim, fluazifop, sethoxydim	1
oryzalin, pendimethalin, trifluralin, thiazopyr	3	2,4-D	4
simazine	5	glyphosate	9
epic	8	glufosinate	10
norflurazon	12	carfentrazone, oxyfluorfen, pyraflufen, flumioxazin, Treevix	14
flumioxazin, oxyfluorfen	14	msma	17
isoxaben	21	paraquat	22
indaziflam	29		
penoxsulam + oxyfluorfen	2 + 14		

product labels often list the MOA by name and/or by group number or code. An example of herbicide active ingredients and their corresponding MOA group numbers for herbicides registered for almonds in California is shown in the table. As weed flora changes within a field over time, there will be a need to modify the herbicide program as needed.

Herbicide-resistant weeds are not new to California. Growers must take a proactive approach to weed management, particularly when it comes to herbicide selection and use, in order for them to be effective in their weed management efforts. Consideration must be given to weed seed production, label recommendations, spray operation, herbicide timing, and herbicide MOA selection in order to successfully combat and help prevent herbicide-resistant weed populations from developing.

Impacts of Harmful Algal Blooms on Humans and their Environment

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Algae encompass a diverse array of life, and thrive in a variety of habitats. Specifically, cyanobacteria are of special concern for freshwater resources *via* their production of toxins. Humans are exposed to algal toxins more than previously thought (tainted food, inhalation, and etc.), and have been reported to cause illness and death with cattle, pets, and people. There are multiple toxins produced by cyanobacteria (e.g. saxitoxins, anatoxins, hepatotoxins, and dermatotoxins), and new toxins and affects are discovered frequently. Despite these negative impacts attributed to algal toxins there are proactive and reactive solutions to mitigate these risks. Decisions to protect ourselves and our interests are dependent on human actions, and the longer one waits to resolve harmful algal blooms the worse a problem can grow.

Presenter Autobiography

Ben Willis is a scientist that received a B.S. in Environmental Science from Western Carolina University, NC where through is passion and love of water inspired concentrated focus on chemistry and water resource management. He additionally, received his M.S. at Clemson University, SC where he conducted and published research on the fate and effects of copper algaecides. Ben's passion for water and science continues through his work with SePRO Corporation where he discovers new solutions with his colleagues for resolving algae, water quality, and aquatic weed issues.

2013 Update on Hydrilla in California

Pat Akers, California Department of Food and Agriculture, pakers@cdfa.ca.gov

Hydrilla has been called the world's worst submerged aquatic weed. It proved its destructive potential in California in the Imperial Irrigation District infestation, where it reduced water deliveries in some canals by as much as 85%. Since hydrilla was first found in California in 1976, the Department of Food and Agriculture has worked hard to keep the weed from spreading in the state, with much success. Of over 30 distinct infestations, CDFa has eradicated all but about 5. Four infestations were declared eradicated between 2010 and 2012, and of the five active eradications, at least three have had no plants for six years or more. The major remaining infestations with plants are in Clear Lake and a small canal and associated ponds in the Sierra foothills about halfway between Marysville and Grass Valley. Even in these infestations, numbers of plants are now very low. CDFa has achieved these goals with persistent effort and employing a wide range of treatment options including burial, lining, herbivorous fish (sterile grass carp), dewatering combined with soil fumigation, manual removal, and dredging of root structures, as well as standard aquatic herbicides.

The New 2014 California NPDES Aquatic Pesticide Permit

Michael S. Blankinship

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Intentional introduction of pesticides into Waters of the US to control algae and weeds requires an NPDES permit, not just compliance with the label. Differences between the old permit (2004-2013, RIP) and new permit are significant. Compliance with the new permit requires that you know where your herbicide is, when it is there and what it is doing, or more importantly, not doing. Details, tools and examples will be presented to help you recognize if you need a permit and if you must have one, how to comply with it in a cost-effective manner.

Aminopyralid Research Summary for Aquatic Labeling

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Aminopyralid is a member of the pyridinecarboxylic acid family of herbicides and controls noxious and invasive broadleaf weeds in rangeland, permanent grass pastures, Conservation Reserve Program (CRP) acres, non-cropland areas including industrial sites, rights-of-way (such as roadsides, electric utility and communication transmission lines, pipelines, and railroads), non-irrigation ditch banks, natural areas (such as wildlife management areas, wildlife openings, wildlife habitats, recreation areas, campgrounds, trailheads and trails), and grazed areas in and around these sites. It is currently registered in products either alone (Milestone[®]) or with other active ingredients such as metsulfuron, clopyralid, triclopyr, or 2,4-D (for example, Opensight[®], Sendero[®], Capstone[®], or ForeFront[®] HL, respectively). The current labels state, “*It is permissible to treat non-irrigation ditch banks, seasonally dry wetlands (such as flood plains, deltas, marshes, swamps, or bogs) and transitional areas between upland and lowland sites. Milestone can be used to the water’s edge. Do not apply directly to water and take precautions to minimize spray drift onto water.*” The labels also state, “*Do not contaminate water intended for irrigation or domestic purposes. Do not treat inside banks or bottoms of irrigation ditches, either dry or containing water, or other channels that carry water that may be used for irrigation or domestic purposes.*” Aminopyralid degradation rate in water in sunlight (photolytic half-life of 0.6 days) is similar to triclopyr, an active ingredient registered for aquatic uses (half-life of 0.5 days).

Therefore, to expand the utility of aminopyralid containing products, research was conducted in 2010 to gather data for a submission to support the addition of aquatic uses to aminopyralid product labels. Research studies in ponds and in moving water generated residue data in order to establish tolerances for fish, shellfish and crustaceans and define the dissipation kinetics in water and sediment over time. Pond studies were conducted in Texas and Indiana and moving water studies in Oregon and Florida. Data were used in submissions to support aquatic uses for Milestone, GrazonNext[®] HL, ForeFront HL, Capstone, and PasturAll[®] HL. Following approval labels are expected to have no restrictions on recreational or livestock use of water after applications but use will not be permitted on the inside banks of irrigation ditches. Use precautions and restrictions on use of water treated with Milestone for irrigation will likely be included on the new label. Registration is anticipated for the use season in 2014.

[®][™] Trademark of The Dow Chemical Company (“Dow”) or an affiliated company of Dow

MONITORING DROPLET SIZE TO MINIMIZE DRIFT

Marty Wagner, TeeJet Technologies marty.wagner@teejet.com

Improperly sized spray tips have the real potential to create an application pattern that contains very small droplets which can result in excessive drift of active spray material away from the intended target and spray area.

Droplet size monitors provide real time operating pressure and corresponding droplet size category feedback for liquid applicators. In-cab mounted monitors will normally include a bright backlight adjustable touch screen. Graphics will include imaged based tip series and tip capacity settings that promote simple, one touch selection of correct spray tips. The tip capacity settings will normally utilize ISO color coding as well as text for easier tip identification and selection. In addition to visual displays, the monitors will also incorporate high and low pressure audible alarms to alert operators when system pressure deviates from an operator selected range or limit. Unit measurements can be designated as US (PSI) or metric (bar). More advanced monitors may also include pre-loaded performance criteria for user defined “favorite” tips.

Demonstrating Drift-Reducing Nozzles for Adoption in Foothill Vineyards

Lynn R. Wunderlich¹ and Kurt J. Hembree²

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²University of California Cooperative Extension-Fresno County.

Introduction and Background. Drift reducing nozzles for herbicide applications are one of the most exciting developments in spray technology today. These nozzles can reduce drift by increasing droplet size spectra and include “turbulence” nozzles, Turbo TeeJet (TT), turbo nozzles with split orifices, Turbo TwinJet (TTJ), air induction (A.I.) nozzles-also called “venturi” nozzles, and combinations, i.e. TeeJet’s air induction turbo twinjet (AITTJ). Although herbicide spray drift is not a large problem in Sierra foothill vineyards, grapes are extremely sensitive to off-site spray movement. Pesticide labels are beginning to indicate recommendations for larger nozzle droplet size ranges, pointing to the need for applicators to consider and implement drift management. Drift reducing nozzles are relatively inexpensive for growers to try, and present a very hands-on “teachable moment” for spray application extension. Furthermore, recent work (Hembree and Hanson, 2012) has shown that drift reducing nozzles can be as effective as standard flat fan nozzles for controlling weeds with contact materials.

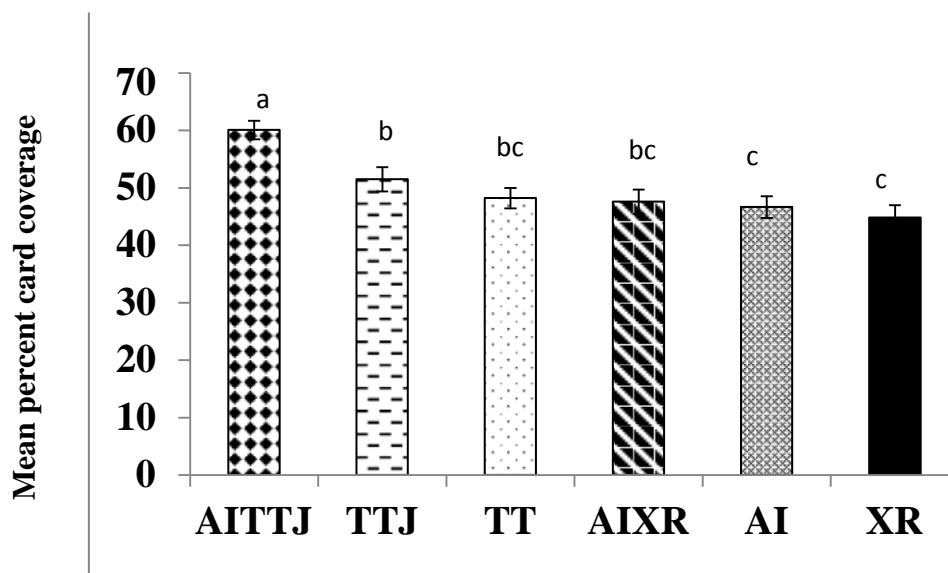
A pesticide nozzle typically produces a range or spectrum of spray droplet sizes, indicated by the volume mean diameter (VMD or Dv0.5), using microns (μm) as the unit of measure. Droplet size spectra is categorized, using standards developed by the British Crop Production Council (BCPC) and American Society of Biological and Agricultural Engineers (ASBAE) as “fine” ($<177 \mu\text{m}$), “medium” ($177\text{-}218 \mu\text{m}$), “coarse” ($218\text{-}349 \mu\text{m}$), or “very coarse” ($349\text{-}428 \mu\text{m}$). Manufacturers such as TeeJet color code nozzles based on droplet size categories for growers to easily pick out nozzle differences. The smaller the droplet size, the more likely the droplets are to drift. Yet the conundrum for applicators is that the smaller the droplet size, traditionally, the better the coverage. Thus, a standard XR TeeJet nozzle has a “fine” droplet spectra rated for “excellent” results with a contact product, while a TeeJet Turbo nozzle has a “coarse” droplet spectra rated for “very good” results with a contact product (www.teejet.com). However, work by Hembree and Hanson (2012) showed that Turbo and Turbo TwinJet nozzles provided similar weed control as an XR or standard flat fan nozzle, when applying contact herbicides. Their work also showed that air induction nozzles needed larger volumes for adequate control. We wished to repeat this work in a foothill vineyard demonstration trial and extend the results to growers.

We asked the questions 1.) Can we get adequate weed control (equal or better than with a standard XR nozzle) with drift reducing nozzles using contact materials? and 2.) How does spray coverage vary with the different nozzles, as compared to a standard XR nozzle?

Methods. We compared 5 drift reducing nozzles to a standard XR flat fan in a replicated trial and measured weed control by visual rating and spray card coverage using laboratory analysis. The nozzles were an air induction (AI), an extended range air induction (AIXR), a Turbo TeeJet (TT) a Turbo TwinJet (TTJ) and an air induction turbo twinjet (AITTJ), compared to a XR flat fan. The spray mixture consisted of 64 oz. Rely 280, 6 oz. Chateau and 4.25 lbs. ammonium sulfate per sprayed acre. Since this trial was conducted on-farm, in a commercial situation, the grower determined the spray mix rate. All nozzles were 11003, delivering 0.3 gal/min. at 40 psi and manually calibrated to confirm flow rate. Spray boom height was 18 inches and one nozzle was used, giving a 4 foot swath width in two passes. Tractor speed was 3 mph, and application volume was 26 gal./acre. A weed badger (unsprayed) treatment was also included for demonstration purposes. Each treatment was replicated four times in a RCB design. Treatment date was March 11, 2013. Main weed species present included red stemmed filaree, radish, yellow starthistle, clover, panicle willowherb and various grasses.

Weed control was visually rated at 7DAT and 23DAT. We used a rating scale of 0-10 where 0= no control, 5.5=55% control, 10=100% control etc. Water sensitive spray cards were placed in the center (vine row) and to the east and west of the vine row, within the spray swath, of each replicate, and analyzed in the laboratory for percent coverage.

Fig. 1. Comparison of Mean Percent Card Coverage For Drift- Reducing vs. Standard Nozzles

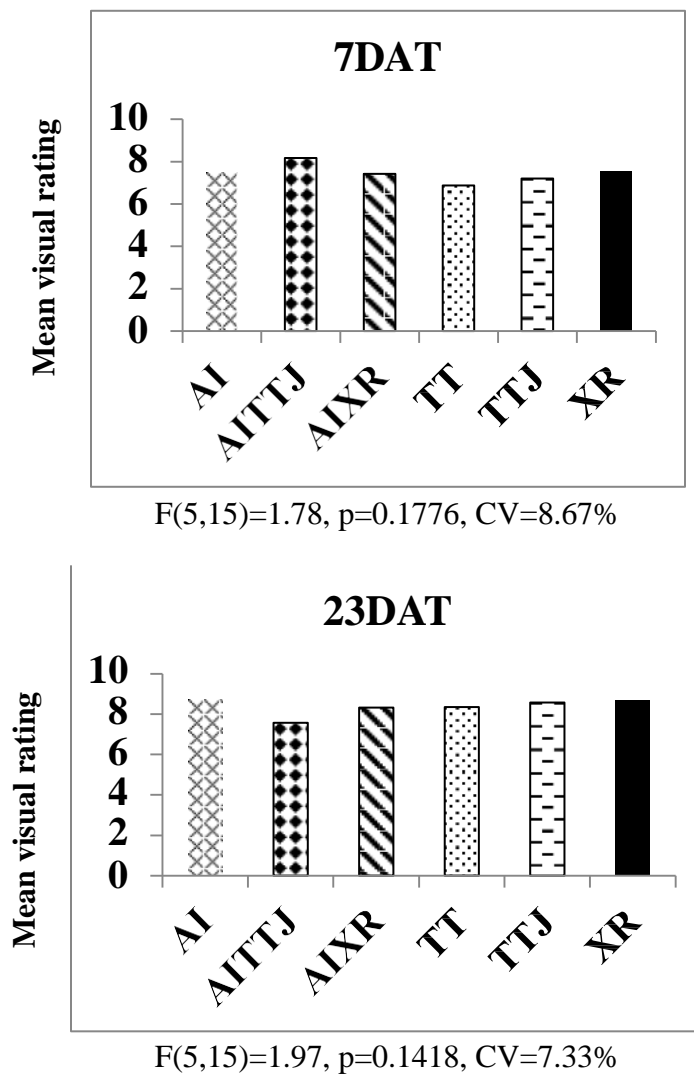


$F(5,15) = 13.09, p=0.0001; LSD= 4.650$ at $\alpha=0.05$

Results. Spray card coverage analysis found that all nozzles had equal or better than the standard XR nozzle. The AITTJ nozzle provided the greatest coverage, 60.07%, as compared to the other nozzles. The TTJ, TT, and AIXR nozzles all gave similar and next highest percent coverage but only the TTJ was different than the AI or XR nozzles. The AI and XR nozzles gave similar percent coverage and had the lowest coverage of the nozzles overall.

The visual ratings at 7 and 23 days after treatment showed no differences in observable weed control between the nozzles (Fig. 2). We held a successful field day to demonstrate the nozzles to growers with 25 attendees. 100% of post-survey respondents said they would try drift reducing nozzles.

Fig. 2. Mean visual ratings of weed control comparing drift reducing nozzles to a standard XR nozzle at 7 and 23 DAT. Scale 0-10: 0=no control, 10= 100% control.



Acknowledgments. We thank Brad Hanson and his lab for assisting with spray card analysis and our grower cooperators Naylor Farms.

References:

Hembree, K. and B. Hanson. 2012. Effects of Spray Coverage and Nozzle Selection on Weed Control. 2012 Proceedings of the California Weed Science Society Meeting. Vol. 64:92.

Individual Nozzle Control Combined with Variable Rate and GPS For Boom Spraying

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Bio info:

BS & MS at University of Minnesota – Agricultural Sciences/Animal Science

Over fifteen years of professional career as *International and OEM Sales Manager* at Hypro/Pentair. Pentair (formerly Hypro) manufactures sprayer components for the spraying industry.

Founded *Frost Services Inc* in 2009 to bring new and specialized technologies to the spraying market.

Member of *American Society of Agricultural and Biological Engineers*

Expanded presentation description:

Individual spray nozzle control is now possible using can-bus communication between the controller and nozzles. The *Seletron* system, developed by ARAG, includes multiple nozzles at every position to add variable speed range while keeping spray pressure in an optimal zone. GPS guidance using WAAS and DGPS creates a high accuracy system where spray over-lap is virtually eliminated. Shape files generated with GIS software can be up-loaded for controlled spray applications and spray job files can be exported easily for records management. Faster, more accurate spray applications are achieved along with chemical savings.

INJECTION RIG TECHNOLOGY UPDATE

Dick DuBey, Spraytec, Walnut Creek, CA, rdubey@sbcglobal.net

Industrial weed control and right-of-way spray application equipment that employs direct chemical technology is becoming more sophisticated and user friendly in recent years. In-cab controllers now have the capacity to monitor and control up to six injection pumps and both multiple product and variable application rates, using preprogrammed prescription files. Utilizing GPS guidance, spray controllers can produce detailed application maps and site specific job reports that include acres (or miles) sprayed, applied active ingredient totals and other job specific requirements such as multi line or shape files of the actual application, weather and equipment used.

This versatility has been matched by an evolution of spraying application devices and booms. With the systems' ability to react to rapid swath width changes and/or changes in spread as experienced in roadside and ditch bank spraying, the use of "boomless" spray nozzles and spraying devices has become more readily acceptable and very necessary.

Boomless heads that include the capacity to increase and decrease swath widths using individual control of nozzle "clusters" are in great demand for right of way, ditch bank and flood control channel maintenance. These clusters might create patterns as narrow as twelve inches or broad multiple swaths or swaths as great as twenty or thirty feet. Unlike the "Off Center" single boom nozzles, multiple nozzle boomless spray heads utilize "zero" degree spray tips in multiple nozzle clusters or groups to cover individual segments of the sprayed pattern. Individual pin streams are set up to fill a narrow portion of a sprayed swath.

"Zero" degree spray tips are noted for the coarse droplets created in the pin shaped stream. However, there is still the potential for drift off target as the projected stream completes its' trajectory from the tip to the target. Smaller droplet sizes and drift off target are not suitable for most roadside applications due to drift off target into sensitive vegetation areas that might border a right of way.

Air induction is a fairly recent breakthrough in nozzle design and has created an excellent tool for use in boomless heads. Based on an internal venture incorporated into the nozzle design, the introduction and mixing of ambient air into the sprayed stream as it passes through the nozzle has created the capacity to increase droplet average median diameter size by as much as 400%. The resulting pin streams contain significantly larger droplets, demonstrate better wetting characteristics and produce a more clearly defined swath width with readily discerned reduction of drift particles and overspray.

MONITORING NOZZLE FLOWS TO AVOID STREAKS AND SKIPS

Marty Wagner, TeeJet Technologies, marty.wagner@teejet.com

Plugged or partially blocked spray tips can have a significant impact on the quality of a sprayed application. Streaks in the field caused by misapplication can result in yield reductions, increased weed pressure and the need to re-apply – all of which can be costly.

In-cab mounted Tip Flow monitors individually monitor flow performance from every spray tip on a boom array. The technology is simple, - a compact flow meter mounted in each spray tip nozzle body. The flow meter detects flow variation caused by clogs, nozzle damage or loss of upstream flow due to restrictions. The in-cab central controller has the capacity to monitor many tips, in some cases as many as seventy five. The monitors are usually back lit with easy to understand graphic displays. A tip error is indicated by an audible alarm, monitor display notification and, in some cases, an illuminated Light Emitting Diode (LED) at the affected nozzle.

Effects of Regulations on Vegetation Management in the Santa Clara Valley

*Mark E. Wander, Vegetation Field Operations Unit Manager, Santa Clara Valley Water District,
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The Santa Clara Valley Water District is responsible for the management of an integrated water resources system that includes the supply of clean, reliable water, ensuring flood protection and maintaining healthy creeks and ecosystems on behalf of Santa Clara County's 1.8 million residents and businesses.

A key component of the District's successful management of water resources, assets and infrastructure is vegetation management. The Vegetation Field Operations Unit is responsible for the District's vegetation management program, which includes the following activities:

- Weed abatement and vegetative pruning for fire code compliance and maintenance access
- Control of in stream vegetation for flood control and water conveyance
- Algae and pondweed control on Groundwater Recharge Ponds
- Control of vegetation on Levees and Dams to maintain the structural integrity of the asset
- Management of mitigation
- Formal landscape maintenance
- All pesticide related activities and compliance

Work performed by the Unit exceeds 4,000 acres annually on:

- 10 Dams and Reservoirs
- 3 Water Treatment Plants
- More than 400 acres of Groundwater Recharge Ponds
- 140 miles of Pipeline Right of Way
- 3 Pump Stations
- Over 275 mile of streams

The author started his career in the vegetation program at the District in 1986, or about 70 pounds ago. Back in those days you came in, did your work and went home. A regulator was a car part that you hoped didn't leave you stranded on the side of the road. Seriously, we had permits and agreements from agencies (formerly known as) the California Department of Fish and Game, and the Soil Conservation Service, and dealt with the Army Corps of engineers on

some projects, but for the most part, those were pretty much “slam dunks” as we went about our day to day business.

Things began to change in the late 1990’s. In 1997, the California Red Legged Frog (CRLF) was listed as an endangered species. The entire vegetation management program was suspended for the summer construction season, meaning a deferral of all work until such time as permits could be negotiated with the US Fish and Wildlife Service.

This was the beginning of a series of species listings that would affect how and if we did maintenance work.

Today, the District deals with nine different agencies to acquire the various permits to do vegetation management and other activities in meeting the goals of its flood control and asset management programs:

- California Department of Fish and Wildlife
- United States Fish and Wildlife Service
- United States Environmental Protection Agency
- United States Army Corps of Engineers
- National Marine Fisheries Service
- Central Coast (Region 3) Regional Water Quality Control Board
- San Francisco Bay (Region 2) Regional Water Quality Control Board
- Santa Clara County Department of Agriculture
- Merced County Department of Agriculture

Once permits are issued by these agencies, work can still not proceed without “Pre-Construction Surveys” to determine the presence (or absence) of endangered, threatened, listed, or “soon to be listed” species of plants and animals. In the Santa Clara Valley, there are 18 such species on the current list, with an additional 148 species which could be listed at any time in the future.

Pre-Construction Surveys are performed relative to the time of year, the potential for species presence, and even the type of terrain such as soil or vegetation type. Each survey is only good for a specific time frame, which varies by species, season and surrounding habitat. The following are a few examples of survey windows and durations:

- Ground Nesting Birds: Surveys necessary between January 15th and August 31st. Duration of surveys is 14 days before re-survey is required.
- California Red Legged Frog: Surveys required year around. Duration of surveys is 7 days before re-survey is required
- California Tiger Salamander: Surveys are necessary year around. Duration of surveys is 7 days between August 1st and October 31st, and 3 days between November 1st and July 31st before re-survey is required.

Program Limits

As part of the permitting process, the District set up program limits. By definition, program limits “Define the maximum amount of work by activity that will be performed during the life of the permit.

Program limits relative to vegetation management consist of “Acres of Work Performed” and “Quantity of Herbicides Used”. In the case of the current permit the program limits define the total limits for the 10 year program as well as the annual limit in any one year of the permit. For example, the annual limit may be 20% of the program limit, but the program limit may not be exceeded.

I would caution anyone setting up a similar program that you may want to carefully consider whether or not to use a staff person with only 3 years left in their career to establish the 10 year program limits. On one hand they have no real ownership in the end results of the ten year program. On the other hand, you have someone to blame if things do go wrong. Check their work carefully!

Reporting

As part of the permit requirements, the District is required to prepare and submit two documents each year defining the work proposed and the work performed.

- The Notice of Proposed Work, or NPW defines the location, amount of work and activity type **proposed**. The NPW is due to the agencies April 1st of each year.
- The Annual Post Construction Report, or PCR describes the location, amount of work and activity type actually **performed**. The PCR is also used to calculate and track the work limits total for the year.

Summary

To say that things have changed dramatically in how work can be performed on Santa Clara Valley Water District projects since 1986 would be an understatement. The cost of doing work has risen significantly with the added costs of permits, surveys, mitigation of impacts and reporting of work performed. It costs more to do less. The level of service is reduced, as a larger portion of the budgeted funding for projects is spent on these added costs, and in effort to minimize impacts and provide associated mitigation.

The public taxpayer expects the same level of service as they are accustomed to, which can only be achieved through increased costs. Priorities for work types have to be established. Having to find different ways to approach the work to accomplish the desired outcomes becomes a way of life.

Educating the public and “re-tooling” their expectations is critical to the success of any program. The modern vegetation manager who can accomplish this will have a successful program.

Challenges to Vegetation Management in the Bay Area

Bill Nantt, CalTrans, Stockton, CA

My name is William Nantt and I serve as a Caltrans Landscape Specialist in District 4 which covers the San Francisco Bay Area. There are three Landscape Specialists in District 4. I cover Alameda and Contra Costa Counties. We are all licensed Pest Control Advisors. Each part of the Bay Area presents its own vegetation management challenges and today I'll mainly cover the ones I face on a regular basis.

Imagine facing the daily challenge of engaging people who don't respect you. People who feel you're out of touch. Emotional people who consider you clueless and an obstacle to getting anything done. Well I'm not talking about people in the Bay Area, I'm speaking of living in a house with two junior high aged teens with smartphones. With that juxtaposition in mind, working in the Bay Area seems completely manageable.

I usually get sympathetic looks when I tell people where I work. The perception is that you can't get anything done in the Bay Area. Most people think everyone you encounter is an activist with an agenda of some sort and write the entire area off as a place unfriendly to business. While there is truth to these perceptions you'd be ill served to take such a simplified view. I'll cover my experience with these matters in today's presentation.

Bay Area folks have a well-deserved reputation of being against vegetation removal and often even vegetation management of any sort. Many feel all vegetation including invasive weeds should remain in a "natural" state. We of course know that there is nothing natural about the vegetation in this mainly urban environment and these opposing views are the front lines of an ongoing battle.

This vegetation mentality is not without merit. Imagine growing up in a world where creeks and rivers are mainly channeled concrete with dense civilization butted up against it. Imagine driving down freeways of endless soundwalls and mega concrete structures. Just getting from point A to point B involves sitting in stop and go traffic with a seemingly unchanging view. In Lodi where I grew up and still live there are open spaces and a nice river. Even the irrigation canals are more inviting than the waterways of the Bay Area.

Due to an excellent climate, job availability, higher than average pay and lenient attitudes, the Bay Area is a popular place to live. Most of the Bay Area is much too expensive to migrate to and for that reason the East Bay is one of the fastest growing locations in California. With rapid population growth on top of already dense population conditions you get corresponding issues that need to be solved.

If you looked at a satellite view of the Bay Area at night you would see there is actually a fair amount of open space and might wonder why that is. Basically, the flatland areas of the Bay Area have been developed. In addition, areas near the bay have been modified for commerce and foothill areas claimed for more expensive housing. There has been an anti-sprawl desire in most of the Bay Area for decades. Hundreds of thousands of acres adjacent to these areas are in a state of preservation and will never be developed. This preservation desire separates the Bay Area from what has happened in the Los Angeles basin.

I'll cover just a few of the problems associated with the aforementioned geographical realities and vegetation preservation mentalities. The first one is the federal Water Board system and the associated NPDES permit. Another satellite view shows how most of the developed areas surrounding the bay go right up to the water. When we used to have rain events in California there wasn't much preventing all the fluids and debris from washing directly into the bay. Consequently the Boards that govern the Bay Area take a strict view of what happens around the bay involving water. As you might imagine with all the Caltrans managed freeways close to the bay they take a keen interest in Caltrans maintenance activities. They do challenge certain spray activities and their perception appears to be that our herbicides are washing directly into the bay. I have seen no evidence of that however and will change our BMPs if faced with evidence. They don't seem to respect label language in my experience and we have discussed these sorts of issues. The people I've spoken to didn't even know the difference between a pre and post emergent herbicide application. Fortunately for our spray program the Boards are currently going after the litter issue in earnest. Litter is a much less abstract concept than herbicide use and easily spotted. It is, however, warm and fuzzy compared to "chemicals".

Wildfire danger is ever-present in California and the Bay Area is no exception. A variety of factors make the Bay Area even more susceptible to wildfire than many other parts of the state. One of them is my previous mention of the regional reluctance to allow vegetation removal. Another is the number of vegetated, non-irrigated areas located in close proximity to dense population centers. Ignition sources also contribute to the danger. In addition to the obvious vehicle sources are the large number of homeless who live in vegetated areas near to developed areas but hidden from view.

The Oakland Hills fire of 1991 opened a lot of eyes to wildfire potential. That October saw an apparently quenched fire rekindle and permanently change the lives of thousands of people. In all, 1525 acres were burned, 25 deaths reported, 3,354 homes destroyed and 437 apartment units lost. The monetary damage exceeded 1.5 billion dollars. Many building codes changed and fire awareness increased but with each passing year the passion subsides. If you visit the area today you'll see mature Eucalyptus trees and broom covering the hillsides. The homeowners who

sustained losses from the fire are adamant about removing fuel, and the people who have moved in since are just as adamant about keeping vegetation.

The Bay Area is a popular spot for launching federal injunctions. The entire state is bound by the Red Legged Frog Injunction but the Bay Area counties are constantly threatened with additional ones. The so-called Gobi 11 is one example. These injunctions never seem to get resolved so you just end up moving on.

Some of Caltrans' problems are self-inflicted. Many of our designs are not practical from a maintenance standpoint and resources are seldom sufficient for the need. I've said many times that "maintenance is not sexy" and the money flows to concrete and steel instead.

As an optimistic person I wouldn't conclude this presentation without offering some solutions to the problems I've highlighted. The first step while working in a complicated place like the Bay Area is to define success in advance. This isn't like working in Pixley. You can think of it as guiding a load of barges loaded with toxic waste down a river with a million people watching from the shoreline. My first advice is don't make any sudden movements. Make considerate movements and always keep your eyes up looking for danger.

There are a lot of passionate people in the region. Make that work for you. Not all passion is misguided. Engage small groups of people with the goal of mutual respect. You have more in common with these people than you might think. Explain what your goals are and entertain suggestions. It's an opportunity to show people the complexity of some of the challenges you face.

Collective solutions are a great way to tackle problems. Partnering with other agencies with common goals really works. Every bureaucracy has strengths and weaknesses. Utilize the expertise of more than one agency to fill in the gaps. One such partnership is between Caltrans, East Bay Regional Parks and Dow Agro. Together we have been restoring endangered species habitat at the Hayward Regional Shoreline over the last three years. The results have been spectacular with huge numbers gains for the California Least Tern. In addition Caltrans is involved in an invasive weed abatement project with the City of Richmond, Contra Costa County and the Chevron Corporation. I anticipate more such partnerships in the future.

A valuable tool for Caltrans is IVM. Many people scoff at IVM but you can't perform weed management in the Bay Area without it. Proper IVM starts with good design. With minimal maintenance resources available, design with vegetation management in mind is paramount. Good design takes into consideration major issues such as water use, herbicide use reduction, homeless pressure, green waste reduction, aesthetics and of course worker safety.

Some of the IVM practices we employ are guardrail treatments, grazing animals, mulch, mowing and use of herbicides. Caltrans has achieved nearly 80% reduction in herbicide use over the last 22 years. This would not be possible without IVM.

Training is a critical element to a successful vegetation management program. There is a big turnover in personnel annually in Caltrans maintenance. People promote and jockey to find jobs closer to home to avoid driving great distances in the heavy traffic. Local knowledge is often not passed down so regular training is essential. Mandated training is not enough to be honest. The mandated annual pesticide handler training is obsolete in my opinion. Additional training has to be provided. It's difficult to believe calibration training is not mandated for spray personnel.

Having the proper equipment for the job is essential. With worker safety in mind Caltrans uses large spray trucks to mitigate the danger of being struck by passing vehicles. The next generation vehicles are just now coming on the line. The workhouse spray rig is a 1000 gallon capacity vehicle equipped with the new Midtech Legacy computer injection system. The rig has GPS capability and daily spray reports can be downloaded from the computer in the truck and transferred to a laptop or desktop and then used to generate spray reports and records. Another vehicle being delivered is a 2500 gallon capacity spray tanker. It is also equipped with the Legacy system and can spray 50 acres of roadside firestrip without refilling. That equals 100 miles at 50 gallons per acre.

Excellent recordkeeping is critical in the Bay Area. Of course recordkeeping is mandated by law but you will be well served to take it to another level. When you are being challenged by outside groups and other entities on their perceived notion of how you are managing vegetation, it helps to have the facts handy. Of course facts don't always carry much weight with emotional people, but they do in court.

A couple of things I've learned about dealing with agitated groups of people: do not appear at a meeting of angry people on their home turf. You can meet with representatives of these groups but do so at a neutral site. Remember to take names and use them. Remember mutual respect will serve you well. Another good policy is to have in your records canned responses to typical complaints. Don't try to reinvent the wheel every time someone calls to complain that you are poisoning the earth.

Finally I want to briefly mention the future. Who knows what the future holds for transportation in the Bay Area. I only know that the future comes faster there. You have to be flexible and no matter how creative the solutions, the weeds will be there stronger than ever.

Weed Resistance Update in Non-crop Areas

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Evolved resistance to herbicides in several important weed species is a global phenomenon and a matter of great concern as there are a limited number of herbicide modes-of-action (MOA) and very few new herbicide active ingredients in the pipeline. Globally, there are 416 biotypes of weeds that are deemed to be resistant to one or more herbicides. These herbicide-resistant weeds have been observed in agricultural and non-agricultural systems. There are 20 different weed species reported to have herbicide-resistant biotypes in California. Although some of these species have been reported from non-crop areas such as roadsides, much of the local and national attention has focused on herbicide resistance in agricultural weeds.

Weeds growing on roadsides, and near water ways and canal banks can also travel with water and invade crop fields. A recent example of such invasion seems to be sprangletop in orchards and vineyards. A similar example of such invasions in the past few years is that of horseweed and hairy fleabane. Glyphosate-resistant (GR) biotypes of these weed species were first documented from non-crop areas adjacent to irrigation canals and ditchbanks. It is not known if the selection pressure of glyphosate in these non-crop areas led to GR biotypes which moved to crop areas or if occurrence of GR horseweed and hairy fleabane in crop and non-crop areas were independent events. Therefore, integrated weed management and planning for herbicide-resistance management may require a landscape approach where weeds in cropped and non-cropped areas are considered integral parts of the landscape.

Although most reported cases of herbicide resistance have been from cropped areas, several of these weed species also occur in non-crop areas such as roadsides, railway tracks, right-of-way areas, fallow areas, and canal banks. In recent years, escapes of species such pigweeds (primarily Palmer amaranth, spiny pigweed), Russian thistle, prickly lettuce, shortpod mustard, and common sunflower are becoming prominent in the Central Valley and in some cases, in the Central Coast. It is not known, if alternate MOAs being used in these areas are causing a species shift to these weeds or herbicide-resistant biotypes of these weed species are evolving. However, herbicide resistance should not be confused with herbicide failure as environmental (e.g. temperature, humidity, soil moisture etc.) conditions and growth stage of the weed during herbicide application, water quality etc. can all cause herbicide failures. Therefore, it is important to follow label directions during herbicide applications.

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Understanding the Utility Vegetation Management Business

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Utility vegetation management activities surrounds our state in many ways. Utility vegetation management begins at the powerhouse then moves to substations where transmission and distribution lines move electricity to our communities. There are additional utility vegetation management done for gas transmission lines and access roads to all facilities. Knowing why the utilities conduct utility vegetation management can help property owners and agencies accept many of the practices.

The utilities do have rights for their facilities and maintenance. Rights are in the form of easements, franchise, prescriptive, permit and special use. Each document has different descriptions and responsibilities for the utility. While the utilities have the right to do reasonable maintenance, there is always room to negotiate for a win-win for the utility and property owner.

Utilities are required by specific laws to maintain their facilities. Electric utilities must meet the requirements of GO 95 Rule 35, Public Resource Code 4292 and Public Resource Code 4293. GO 95 Rule 35 requires utilities to have a minimum of 18 inches clearance from trees in cities. PRC 4293 requires a minimum of four feet clearance on distribution lines in wildland fire areas, additional clearances for transmission line and specific requirements related to hazard trees. PRC 4292 requires a bareground circle around specific poles that have equipment that can drop hot burning material to the ground as a result of operation. Some critical transmission lines are also regulated by NERC FAC-003 which require the utility to have no outages from vegetation clearances and hazard trees from any vegetation within the right of way.

The utilities have industry standards and best management practices. ANSI A300 part 1, Utility Tree pruning best management practices which provides clear direction on how to prune trees under and adjacent to powerlines. Vegetation management within transmission right of ways has standard ANSI A300 part 7, Best Management Practices for Integrated Vegetation Management.

There is an important first step in ANSI A300 Part 7 Best Management Practices that describes the internal and external communications and this is where most utilities have problems. A utility vegetation manager can be more successful by building partnerships with internal and external stakeholders. Partnerships are developed through communication and applying the first three steps of the BMP's, 1) Set Objectives 2) Evaluate Site, and 3) Define thresholds. This is where a utility can look for ways meet adjacent landowner needs while still meeting compliance and reliability requirements.

The other three steps are 4) Evaluate and select control methods, 5) Implement IVM and Monitor treatments and 6) Quality Assurance. Control methods include manual, mechanical, biological, cultural and chemical. Utilities that do not include all control methods are not practicing Integrated Pest Management. Herbicides and their application methods can help develop sustainable vegetation types that require less environmental disturbance.

Partnerships with landowners and agencies can help reduce conflicts. For example, an agency may have some noxious weeds within the right of way and a utility can offer to include some treatment options as part of their herbicide applications. Utilities can look for environmental organizations like Pollenator Partnership to help build community and agency relations while developing their IVM project.

Utilities have the responsibility to provide safe and reliable power. There are many options to the practice of complete clear cutting of right of way vegetation that adjacent landowners and agencies can negotiate with the Utility.

Weeds and Stormwater Management

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Many commercial and municipal landscapes now include areas designed to intercept and filter stormwater and other runoff from impervious surfaces like roofs and pavement. These areas require weed management since weeds are usually among the best adapted plant on these parts of landscapes, just like rest of the landscapes. This presentation describes some of the terminology and concepts that managers of “stormwater” landscapes may have to understand when communicating with property managers and local regulators about weed control.

Weed control in these “runoff bio filtration” areas may have different management expectations since these “stormwater” landscape areas are technically regulated as part of the EPA’s Clean Water Act and have a National Pollution Discharge Elimination System (NPDES) permit regulating their construction and management. The goal of the Clearwater Act was to restore all "Waters of the United States" to their "fishable" and "swimmable" conditions, and the NPDES permit is the regulatory mechanism to achieve this. Unfortunately, most “Waters of the United States” remain classified as “impaired” in spite of greatly reducing industrial and sewage discharges. Much of the “impairment” is due to polluted runoff from streets, roofs and other impervious surfaces. Also, “impairment” is a moving target since lower and lower concentrations of chemicals can be now be measured, and there is much more concern about substances active in very low concentrations such as pesticides that can perhaps be endocrine disruptors. Plant nutrients like nitrogen and phosphorous are common in the urban or built environment and these are considered potential pollutants. The purpose of bioswales, detention basins etc. is to remove much of the pollution and nutrients in the runoff before it goes into the stormwater drain system and into "Waters of the United States".

These NPDES permits go through a political process that incorporates many interests and sustainability values. Consequently, the stormwater regulations include very hard to define terms like natural, native, safe, and non-toxic. There are also scientifically dubious statements like “fostering a healthy environment in which plants have the strength to out-compete weeds”. In fact these stormwater landscapes often have weed seeds from pavement washed into them along with sediment and plant nutrients. And they can be moist for long periods. This can be an ideal weed growing environment and often a poor root environment for the desirable landscape plants.

In California the NPDES permitting agency is the State Water Resources Control Boards. These permits include many programs managed by cities, counties, regional agencies and self-perpetuating joint powers authorities (JPA) like StopWaste.org. StopWaste.org claims “85–95% weed suppression without herbicides”. The permit compliance is enforced by local ordinances and encouraged by grants. Most California counties operate under Municipal Regional Stormwater Permits (MRP) that requires water treatment by using the landscape to filter runoff through vegetation, soils and organic matter, and biodegrade pollutants by the soil-food-web. Some of the runoff is “captured” by infiltration, groundwater recharge, evapotranspiration, and rainwater

harvesting. The concept of the regulations is to have landscape areas mimic “natural” hydrologic functions using vegetated swales, bioretention systems and permeable pavements. These landscape features also assist with water conservation.

Pesticides

For regulators in California and most states a *pesticide* is something that kills pests – weeds, insects, fungi, mice – any pest. Unfortunately, for most of the public, and most public agency people a pesticide is synonymous with insecticide – a pesticide is something that kills insects. Stormwater regulations have a history with insecticides, but use the term pesticide. First chlorinated hydrocarbons like DDT, then organophosphates like Diazinon and now neonicotinoids have been found in aquatic systems from storm water. When Clean Water legislation was written the term *least toxic pesticide* basically referred to “not-an-organophosphate”. Organophosphates are much more toxic to people than most other insecticides. Local regulations to manage stormwater runoff often copy the term “least toxic” but not the definition or history. General use of the term “least toxic” does not inform a weed control professional which herbicide can legally be used to control weeds in a biofiltration landscape. For example, the following is from a Municipal Regional Stormwater NPDES Permit:

...urban development can create new pollution sources and increase levels of existing sources such as car emissions, car maintenance wastes, municipal sewage, **pesticides**, household hazardous wastes, pet wastes, trash, etc. As rain becomes runoff, it collects pollutants while passing over impervious surfaces. The runoff typically enters a storm drain system that rapidly conveys it, untreated, to a lake, creek, river, bay, or ocean.

It is not clear if **pesticides** refers to improper use of household insecticides or proper use of Roundup (glyphosate). All the other pollution sources mentioned are clearly pollution. In practice this means landscape maintenance managers may have to define the terms pesticide and herbicide for the property manager, or more likely their sustainability consultant.

Here is another example from a Municipal Regional Stormwater NPDES Permit:

... Avoiding pesticides ... is particularly important when maintaining stormwater treatment measures to protect water quality. IPM encourages the use of many strategies for first preventing, and then controlling, but not eliminating, pests. It places a priority on fostering a healthy environment in which plants have the strength to resist diseases and insect infestations, and out-compete weeds. Using IPM requires an understanding of the life cycles of pests and beneficial organisms, as well as regular monitoring of their populations. When pest problems are identified, IPM considers all viable solutions and uses a combination of strategies to control pests, rather than relying on pesticides alone. The least toxic pesticides are used only as a last resort.

This kind of regulation terminology makes weed control management difficult. First the regulation says “avoid pesticides”. Which most people would interpret as, don’t use pesticides. Then it says “fostering a healthy environment in which plants have the strength to out-compete weeds.” Healthy environment is never defined, and like a “healthy lifestyle” is very hard to define even if the regulations tried to. Very few landscape plants in urban landscapes can out-compete weeds. And lastly the undefined term “least toxic pesticide” is used.

What is the biological definition of weeds? A weed is often a plant that is adapted to disturbed habitats, and the reason weeds are often the best adapted plant on the landscape. People have been disturbing plants and the soil for a long time. When developing a commercial landscape there is a lot of soil disturbance. The existing vegetation is removed and the soil is reshaped, compacted and consolidated to remain stable, and for California, to remain stable during an earthquake. This disturbance usually continues as the site development goes through all the phases required to go from the initial state, through temporary roads, utility installation, constructing buildings and to the final landscape. Weeds are not only adapted to disturbance, they usually can maintain their abundance in repeatedly disturbed landscapes. This often creates the situation where a large seed bank is created over the course of site development. These seeds can be viable for many years and will germinate for many years, especially when soil is re-disturbed in a bioswale by digging up weeds or removing sediment. An important part of landscape weed control is not disturbing the soil once the landscape is installed.

Many weeds adapted to grazing and Mediterranean climates are hard to control. The roots and other underground parts usually need to be controlled. Short of extensive digging, soil pasteurization or soil fumigation, the only way to do this is with systemic herbicides. There are no “alternative” or “least-toxic” systemic herbicides.

Biofiltration

Many stormwater regulations are built on the assumption that post-development runoff will be no more than pre-development run-off. This assumes that there is a lot of undeveloped pervious land for runoff to be directed onto. This may be true in parts of the east where a lot of the stormwater regulations were developed, but is not typically true in California. The Municipal Regional Stormwater Permits requires stormwater treatment requirements to be met by using evapotranspiration, infiltration, rainwater harvesting and reuse. Where this is infeasible, landscape-based biotreatment is allowed. As discussed above, part of site development in California is stabilizing the soil by compaction. The result is no free draining pores (high bulk-density) and low infiltration or percolation rate. This limits the amount of stormwater that can be expected to soak into the ground. Consequently most stormwater is filtered by landscape biotreatment and released to stormwater drains. Plants and soil life can absorb nutrients and many soluble materials. However, pavement collects a lot of fine material from wear and tear of pavement and vehicles. Plants constantly shed parts and produce a lot of fine material. All filters, including biofilters require maintenance as the pores in the filter clog up. For many landscape biofilters this means cultivation to break up the layer of accumulating fine particles. Also accumulating sediment has to be cleaned out to maintain a grade that water flows down. These soil disturbances are favorable for weeds. It is important to recognize that standing water in which mosquitoes can breed is typically not allowed. The water has to flow. Some stormwater designs have water detention and retention ponds. These often require aquatic weed control as well as mosquito control. “Alternative” aquatic weed controls are usually not very effective.

Weed control is required on many landscape areas devoted to stormwater. Hopefully this introduction to stormwater management will help you manage any weed control challenge in spite of regulations that can seem designed to hamper the use of systemic and preemergent herbicides. My conclusion from reading NPDES Permits is that, if your weed control program is compliant with

County Agricultural Commissioners and California Department of Pesticide Regulations, you will be compliant on stormwater landscaping. Hand weeding may always be an option, but the soil disturbance often makes this option less desirable.

Cultural Practices for Managing Herbicide Resistant Weeds in California Rice Systems

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California rice systems have more herbicide resistant weeds than any other cropping system in the world. The reasons for this are first, that most rice systems are continuous rice systems (not rotated with other crops) due to the nature of the soils. Second, the herbicides used have similar modes of action or detoxification mechanisms. Of the weeds with resistance the big problem weeds are watergrass and the sedges. Cultural practices, along with good herbicide management, are needed to effectively control these weeds and ensure the sustainability of rice systems.

Research experiments were set up at the Rice Experiment Station to examine how alternating establishment systems (between wet and drill seeding) and the use of stale seed beds affect population dynamics of important rice weeds. Stale seedbed refers to the practice of preparing the seedbed as normal and then flushing with water to recruit or germinate weed seeds. From this point on there is no further disturbance of the soil. Once weeds have germinated they are killed with a broad spectrum herbicide and the field is planted either by water or drill seeding methods.

The way rice was established had a large effect on weed populations. Water seeded rice was dominated by aquatic weeds, such as the sedges and ducksalad. In contrast, drill seeded rice was dominated by grass weeds such as barnyardgrass and sprangletop. Thus by drill seeding rice it was much easier to control the aquatic weeds and vice versa. One problem with this study was that watergrass was not present at the site. Watergrass germinates and grows effectively under both wet (anaerobic) and drill seeded (aerobic) systems and thus switching from one establishment practice to another is not likely to control it.

With the use of stale seed beds however, watergrass can be controlled. In wet seeded systems, the stale seedbed practice effectively controlled grasses and to a limited degree the sedges. In drill seeded systems the stale seedbed was not effective in controlling grass weeds primarily because drill seeding disturbs the soil surface and brings more weed seeds to the surface. With proper herbicide and N fertilizer management it is possible to achieve the same rice yields with stale seedbeds as conventionally managed rice

Based on these findings and from experience with growers who have used the stale seedbed the following observations/recommendations can be made.

1. The stale-seedbed is an option growers use as a last resort when other options have failed.
2. Only attempt stale-seedbeds with water seeded rice as is not effective in drill seeded systems.

3. When using stale seedbeds do not attempt to go after the sedges. Sedges take longer to germinate and will delay planting. Some sedges will germinate but plan to take care of late emerging sedges with appropriate herbicides.
4. Research has shown that weeds germinate fastest when the soil is kept very moist near saturated conditions. However, this is not practical to achieve at a field level. Rather the field should be flooded and the water allowed to slowly subside. This generally keeps the field flooded or wet long enough to germinate the grass weed seeds.
5. This practice is difficult to manage on large fields due to difficulty of maintaining soil/field water conditions uniform across a field. Therefore, growers should try to become familiar and learn the practice on small fields first.
6. The stale-seedbed delays planting due to the time required to germinate weed seeds. Therefore, short duration varieties (such as M105) should be used.
7. Nitrogen will need to be applied to the surface (urea is usually recommended) after the field has been sprayed with a broad spectrum herbicide and before flooding to plant. The N rate will need to be increased by about 30 lb N/ac compared to the comparable aqua-N rate.

A Learning Cycle in Global Weed Management

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Weed management has taken major strides in history from hand-pulling of weeds to the discovery of modern synthetic herbicides. Additionally, the development of crops with herbicide-tolerant traits has further simplified weed management in several annual cropping systems. The herbicide industry in recent years has exceeded \$20 billion and it is projected that there will be further growth in this industry as developing countries start using herbicides. The need for the use of herbicides in several developing countries has been triggered by shortages in labor as the labor-force has shifted to industries with higher wages than agriculture. While all these projections and scenarios may pose a rosy picture to the pesticide industry in terms of herbicide sales and profit, it is important to realize that despite all the weed control efforts and an arsenal of herbicides, weeds are still present in agricultural cropping systems of the countries which began using herbicides decades ago. In fact, there are now 416 known cases of herbicide-resistant weed biotypes and weed management in developed countries is becoming a challenge due to these resistant weeds to the extent that growers in several cropping systems have been forced to resort to hand weeding. Thus, as herbicide use is beginning to gain popularity in developing countries, have the developed countries completed a learning cycle on weed management? Is herbicide technology failing in developed countries or have people forgotten the basics of weed science?

It is time to revisit the information on the biology and ecology of weed species, consider economically viable non-chemical methods of weed control, and to use herbicides judiciously. It must also not be forgotten that there are a limited number of herbicides belonging to about 26 different sites of action that have been developed so far. Further, there has been almost no development of herbicides with new modes of action. Also, not all of these herbicide groups are labeled for use in every crop or situation. Therefore, we may have to rely on the existing herbicide modes for several years to come while the known cases of herbicide-resistant weeds continue to increase.

As developing countries start using herbicides, it is important to realize that these countries may have access to only a limited number of herbicides, people using these herbicides may not have the level of education and training as those in developed countries, these countries may have a lack of weed scientists, and herbicide users may not be aware of environmental and human health issues surrounding herbicide use. For example in some areas, growers may only have access to glyphosate and paraquat, however they may not know the difference in terms of human safety or weed management. Success of certain herbicides in these countries may prompt them to use the same mode of action repeatedly and thus select for herbicide-resistant weeds. With the current scenarios of global trade and global villages, it may not take too long to spread the seeds of these resistant weed species worldwide and to cause unintended irreversible environmental impacts that may have adverse consequences globally. Therefore, given the predicted rise in herbicide use globally, it becomes important to take proactive

measures on herbicide resistance management and environmental stewardship not only locally but also globally. Weed scientists and the herbicide industry, therefore, may have to face the challenge of herbicide resistance and environmental adversities on a much bigger scale in the very near future. As part of training agronomists and weed scientists one should consider also the significance of the plants (is it a toxic weed, competitive, or an important medicinal plant or highly nutritious for human consumption). When drought takes place often people depend on certain plants for survival. It may be advisable for weed scientists in developed countries to take proactive measures on weed management on a global scale as agriculture is faced the challenge to feed the increasing population under scenarios of diminishing crop acreages and limited water availability.

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New Developments in Alfalfa Weed Management

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It is critical to effectively control weeds in alfalfa because most markets expect nearly weed-free alfalfa or the price is significantly discounted. Weed control practices in alfalfa are continually evolving to develop more effective weed management systems.

Roundup Ready Alfalfa

The most significant recent advancement in alfalfa weed control has been the development of Roundup Ready (RR) alfalfa, its initial commercial release in the fall of 2005, and its reintroduction in 2011. It is debatable whether this should be considered a “recent” development. While definitive data are not available, anecdotal evidence suggests that the popularity of RR alfalfa continues to increase. A survey of RR alfalfa growers conducted in 2011 indicated that 85% of the growers who had tried it were either very pleased or felt it had exceeded their expectations and 72% indicated that they would plant it again. The primary advantages cited are the improvement in weed control and the simplicity of weed management.

Roundup is very effective for the control of some problematic weeds in alfalfa like dodder, Bermudagrass, dandelion, and quackgrass. Roundup also controls larger weeds than are typically controlled with most post-emergence herbicides. However, growers are still encouraged to treat when the weeds are relatively small (typically when the alfalfa has 3-5 trifoliate leaves). While larger weeds can be controlled, early season competition with alfalfa seedlings can have a lasting effect.

The most significant risk with RR technology is the possibility of weed shifts and worse yet, the evolution of herbicide resistant weeds. Growers are encouraged to treat early while the more tolerant weeds are still small. Common weeds encountered in alfalfa fields that are somewhat tolerant to Roundup include burning nettle, ryegrass, malva or cheeseweed, filaree, knotweed, black mustard and others. Treating early may help control the more susceptible of these weeds but the oftentimes a tank mix with a complementary herbicide is necessary.

The evolution of weeds with resistance to glyphosate is a serious concern in RR crops including alfalfa. Hopefully, alfalfa growers will recognize this threat and will use sound weed management practices to reduce the likelihood of weed resistance. The principle method to avoid weed resistance is to reduce selection pressure. This is accomplished through crop rotation, rotating to herbicides with another mode of action and herbicide tank mixes. Fortunately, there are numerous other herbicides registered for use in alfalfa and they all have a different mode of action than glyphosate. The key is not to rely solely on Roundup

over the life of the alfalfa stand and to include other herbicides or weed management practices in an integrated weed management program.

Lack of New Herbicide Active Ingredient Registrations

It is interesting to examine the registration timeline for herbicides in alfalfa in California. The precise registration date was not recorded prior to 1970 so most herbicides registered before then are just noted as pre 1970. Several herbicides were registered in the late 70's to early 80's. Then there was an 8 year gap without new herbicide registrations except for a new formulation of 2,4-DB. From 1992 to late 2003 there were ten new herbicide or herbicide formulation registrations culminating with the registration of the herbicide Chateau in 1993 and Prowl H₂O in 2004. The recent drought in new herbicide registrations, nearing 10 years, has been the longest time period without a new registration since registration dates were recorded. The lack of new registrations is likely due to the escalating costs for herbicide registrations coupled with manufacturers perceiving reduced potential market share with the increased acreage of RR alfalfa.

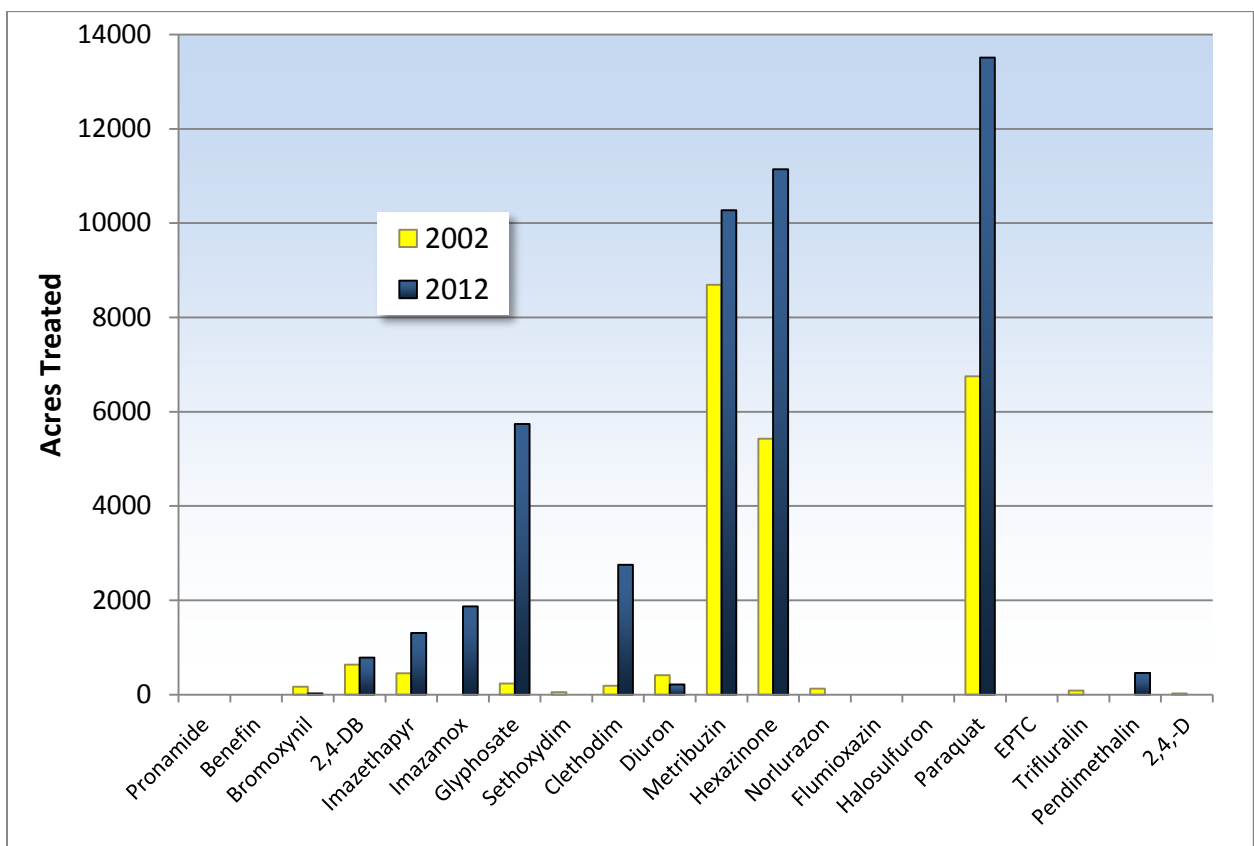
Trade Name	Common Name	Date First Alfalfa Registration Date
Treflan	Trifluralin	6/17/1966
Eptam	EPTC	Pre 1970
Butyrac	2,4-DB, dimethylamine salt	Pre 1970
Gramoxone	Paraquat dichloride	Pre 1970
Sencor	Metribuzen	Pre 1970
Karmex	Diuron	Pre 1970
Kerb	Pronamide	Pre 1970
Roundup	Glyphosate, Isopropylamine salt	Pre 1970
Balan	Benefin	4/11/1977
Buctril	Bromoxynil octanoate	12/28/1978
Butyrac	2,4-DB, butoxyethanol ester	3/4/1980
Velpar	Hexazinone	8/11/1982
Poast	Sethoxydim	5/20/1983
Treflan TR-10	Trifluralin	5/30/1984
Butyrac	4(2,4-DB), isooctyl ester	3/18/1987
Prowl	Pendimethalin	1/30/1992
Pursuit	Imazethapyr	8/17/1993
Pursuit	Imazethapyr, ammonium salt	8/17/1993
Select Max	Clethodim	10/31/1994
Solicam	Norflurazon	10/29/1996
Butyrac	2,4-DB	5/20/1997
Sandea	Halosulfuron methyl	9/26/2000
Raptor	Imazamox	7/10/2002
Chateau	Flumioxazin	10/16/2003
Prowl H2O	Pendimethalin	8/17/2004

Data provided by
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Specialist, DPR

Shift in Herbicide Uses

To evaluate how alfalfa herbicide use has changed over the last decade, data was collected for Siskiyou County (representative of the Intermountain Region) and Tulare County (representative of the Central Valley). The most recent data available was for 2012 so it was compared with 2002 data (a decade earlier). In the Intermountain area, Raptor (imazamox) has now become the primary herbicide used for weed control in conventional seedling alfalfa. Paraquat (Gramoxone) was applied to more acres than any other herbicide. Metribuzin (Sencor) and hexazinone (Velpar) were also dominant herbicides used on established alfalfa. Glyphosate (Roundup) was only used for stand removal in 2002 but has already become the fourth most widely used herbicide on alfalfa in 2012.

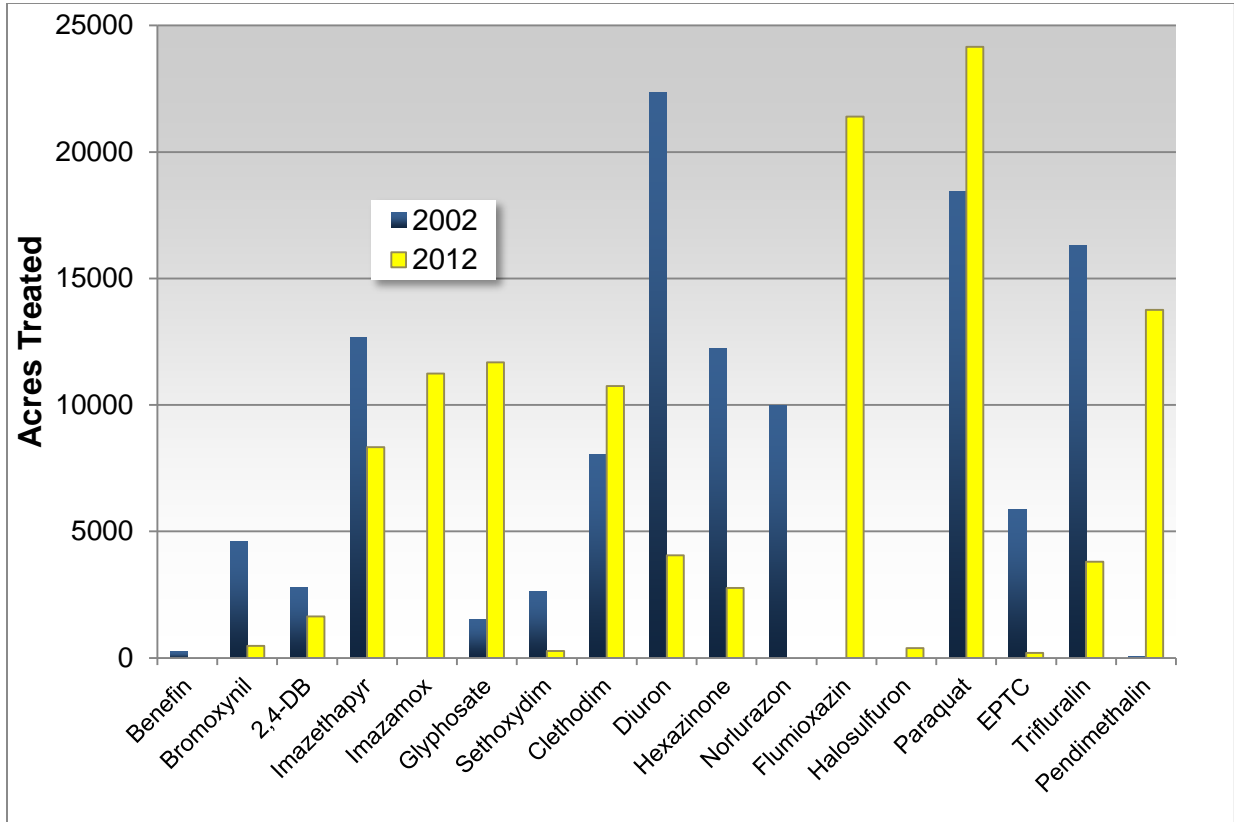
Figure 1. Herbicide use in Siskiyou County in 2002 vs. 2012.



Herbicide use patterns have changed more dramatically in Tulare County. In 2002 bromoxynil (Buctril), 2,4-DB and imazethapyr (Pursuit) were the dominant herbicides used on seedling alfalfa and now that has switched to Pursuit and imazamox (Raptor). Sethoxydim (Poast) usage has dropped way off and Clethodim (Select) has become the primary post-emergence grass herbicide. Trifluralin (Treflan TR-10) was widely used in 2002 but has now been largely replaced by Prowl H₂O. Diuron (Karmex), Velpar, and norflurazon (Zorial) were dominant herbicides in 2002 but their use has dropped off dramatically in 2012. Flumioxazin (Chateau) has become the second most widely used herbicide on alfalfa, largely replacing the other soil residual herbicides for winter annual weed control. As in Siskiyou County, paraquat is used on more acres than any other

herbicide. Roundup use has also increased dramatically, and is now used for weed control in RR alfalfa in addition to its previous use for stand removal.

Figure 2. Herbicide use in Tulare County in 2002 vs. 2012.



Potential New Herbicide

As noted above, Gramoxone is now the most widely used herbicide in these two California counties. This underscores the need for post-emergence broad spectrum herbicides for use in established alfalfa to complement the soil residual herbicides currently used and for use in RR alfalfa production systems to rotate with glyphosate. The new herbicide saflufenacil (Sharpen) is currently being evaluated in established alfalfa. It shows considerable promise for controlling a broad spectrum of broadleaf weeds but it does not adequately control grasses. It is a contact herbicide providing rapid burn down of the foliage it contacts. Plant tissue necrosis is more extensive and longer lasting than what is observed with paraquat. Research is currently underway to quantify the appropriate application timing to avoid crop injury that could result in a yield loss. One of the most promising attributes of Sharpen is its excellent control of common groundsel, a troublesome toxic weed in alfalfa that has been difficult to control with currently available herbicides. When Sharpen might receive registration in California is unknown, but it may be the next herbicide registration potentially ending the drought in new active ingredient registrations in California for alfalfa.

Managing Weeds in Conservation Tillage and Conventional Corn

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Introduction

In California, approximately 650, 000 acres of corn are grown in 2011, two-thirds of it planted for silage. The majority of the corn was planted in the Central Valley. No single weed control regime is effective for all growing conditions. An integrated weed management program utilizes a combination of cultural, mechanical, and chemical methods for consistent, effective weed control. It also helps prevent the development of weed resistance to herbicides and the emergence of a few dominant weeds. Some of the major weeds include pigweeds, tall and annual morningglory, common and horse purslane, barnyardgrass, and purple and yellow nutsedge. The major grass weeds include barnyardgrass, sprangletop, Johnsongrass, and volunteer wheat. Purple and yellow nutsedge are controlled using halosulfuron or glyphosate in combination with sweep type cultivators. Accent gives excellent control on Johnsongrass and small barnyardgrass when applied to up to 20 inch tall corn, then after that using drop nozzles to 36 inches.

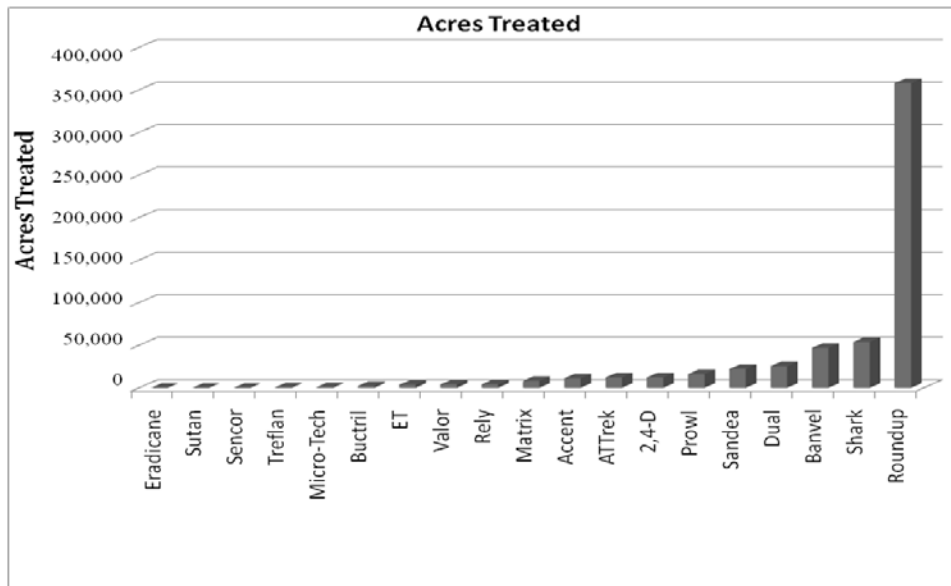
Cultural practices play an important role in corn weed management. In California, a well-managed corn crop is extremely competitive with most weeds. Good cultural practices, including timely cultivations, often control weeds sufficiently to maximize yields and profit.

Growing corn under no-till or reduced tillage may reduce weeds because the soil is not disturbed, thus reducing the number of seeds that germinate. Preirrigation prior to planting and controlling volunteer cereals and emerged weeds will get the crop off to a good start, although this practice delays planting. For weeds that do emerge, postemergent herbicides can be applied. In practice though much of the reduced tillage corn has uncomposted manure spread on the fields, fields are irrigated up, and often a single mode of action (glyphosate) is used, leaving fields very weedy by the end of the growing season.

Preplant, preemergent, or postemergent herbicides are available that will selectively control most species of weeds in corn. Select an herbicide based on costs, weeds present, stage of corn growth, soil type, succeeding rotation crop, and adjacent crops.

Transgenic Corn. Herbicide-tolerant varieties represent approximately 60% of corn grown in California and provide additional options for weed control. The Roundup Ready technology has provided growers with an excellent tool for managing many annual and perennial grasses. Glyphosate can be applied post emergence so growers can wait and see the weeds present. There are no plant back restrictions nor is it listed as a restricted material like several other corn herbicides. There is substantial fuel savings, as tillage operations are reduced.

Fig. 1. 2010 Herbicide Usage in California Corn



The following herbicides are used in corn:

Pre-Plant: Atrazine, Aatrex, Eradicane, Sutan, Roundup, Dual Magnum, Outlook, Gramoxone Inteon, Micro-Tech

At Planting: Micro-Tech, Aatrex, Atrazine, Dual Magnum, Roundup, Gramoxone Inteon, Eradicane

After Planting: Accent, Prowl, glyphosate, 2,4-D, Banvel, Clarity, Distinct, Buctril, Gramoxone Inteon, Sencor, Aatrex, Atrazine, Sandea, Shark, Yukon, Option, Outlook, Laudis, Matrix, Standis

Weeds not controlled by a pre-plant incorporated herbicide or by cultivation can often be controlled with a postemergent herbicide application, depending on the weed species present and its growth stage. Postemergent herbicides are most effective when applied to weed seedlings.

An over-the-top application can be used, but some products or tank mixes require a directed spray on corn larger than 8 to 12 inches in height to keep the herbicide out of the whorl and to minimize the risk of corn injury. Postemergent herbicides commonly used in corn include 2,4-D, bromoxynil (Buctril), carfentrazone (Shark), dicamba (Clarity), dicamba/halsulfuron (Yukon), diflufenzopyr (Distinct), halosulfuron (Sandea), metribuzin (Sencor), nicosulfuron (Accent), and foramsulfuron (Option). It is important, however, to pay close attention to application guidelines on the labels to avoid phytotoxicity to the crop, especially with carfentrazone (Shark). Fig. 1 demonstrates the acreage of various herbicides used in California. Even though there are many herbicide options to use in corn, the chart demonstrates the dominance of a one mode of action approach. Research conducted in 2011- 2013 with Matrix (rimsulfuron) as a post plant but either preemergent or postemergent to the weed demonstrated excellent weed control. Laudis and Standis add to the options available for corn growers.

Summary

Weed management in corn should incorporate resistance management strategies that include crop rotation, herbicide rotation, and control of weed escapes by tillage or hand. In Roundup Ready crop systems in other states, weed shifts and weed resistance occurs. Weed shifts occurred when an herbicide program was used repeatedly, resulting in the survival of only weeds that are tolerant of the herbicide. Weed shifts were associated with reduced tillage systems and not rotating herbicides nor including tillage even when that was the most appropriate weed control tool.

A major concern is the development of resistance to glyphosate (Roundup) in lambsquarter, pigweed species, horseweed, fleabane, and junglerice in California. Rotating glyphosate-resistant corn with another glyphosate-resistant crop such as cotton or alfalfa will only increase this problem. To help prevent the development of herbicide-resistant weeds and prevent weed shifts from occurring, it is important to incorporate tillage into your weed management practices, as well as alternating herbicides that have a different chemical mode of action. Manage field edges as many of these weed seeds can blow into neighboring fields.

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Benefits and Concerns with Future Herbicide Tolerant Traits

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Technology with tolerance to glyphosate, glufosinate, and 2,4-d or dicamba will offer cotton growers more effective weed management programs with potentially greater long-term sustainability. However, adoption of these technologies and respective herbicide programs will be determined by the ability of growers to manage off-target movement; primarily for the auxin herbicides 2,4-D or dicamba. In response to the development of auxin technologies, tremendous advancements in reducing off-target movement have occurred. For example, researchers now have the ability to quantify the percentage of driftable fine spray droplets while actually spraying an herbicide mixture just as if it were applied in the field. This approach allows researchers to determine the most effective spray tip to use with any given herbicide mixture in an effort to reduce drift while still maintaining weed control. Developing auxin-tolerant crops has also led to vast improvements in reducing off-target movement through formulation advancement with both 2,4-D and dicamba. New formulations for both of these herbicides are nearing commercialization and have been shown to be less volatile and/or less prone to drift than current formulations. Improved methods for cleaning herbicide residues from spray tanks are also being realized. One process currently being studied (process developed over 100 years ago) includes a deactivation agent that can be added into a “dirty” tank and within 30 minutes the tank and lines (with proper mixing) be free of numerous herbicides including dicamba and 2,4-D. Progress in managing pesticide movement has been monumental over the past few years and these efforts will undoubtedly continue with auxin technology commercialization. Further advancement in managing off-target movement will be needed to negate the large foot-print 2,4-D and dicamba have on many high-value sensitive broadleaf specialty crops.

Controlling Broadleaf Weeds in Irrigated Pasture

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In 2011 and 2012 we evaluated herbicide methods for controlling broadleaf weeds in Northern Sacramento Valley irrigated pastures. Our intent was to find methods of controlling broadleaf weeds with minimal impact on desirable pasture vegetation. We applied differing rates of the following broadleaf-selective herbicides and combinations: bromoxynil (0.5 lb a.e./acre, 2011), dicamba/diflufenzopyr (0.125/0.05 and 0.25/.1 a.e./acre, 2011), dicamba/2,4-D (0.25/0.72 lb a.e./acre, 2011), 2,4-D/triclopyr (2.0/1 lb a.e./acre, 2011), MCPA (0.23, 0.46, and 0.93 lb a.e./acre, 2012) carfentrazone (0.014 and 0.03 lb a.e./acre, 2012), 2,4-D/triclopyr (0.5/0.25, 1.0/0.5, 2.0/1 lb a.e./acre, 2012), 2,4-D (0.95 and 1.9 lb a.e./acre, 2011&12), and triclopyr (1.0 lb a.e./acre, 2011&12). As target species we evaluated their control of slender aster (*Aster subulatus* var. *ligulatus*), buckhorn plantain (*Plantago lanceolata*), and field bindweed (*Convolvulus arvensis*). In 2011 all treatments controlled slender aster except for the combination herbicide dicamba/diflufenzopyr. In 2012 carfentrazone and the lowest rate of MCPA (0.23 lb a.e./acre) were not successful in controlling slender aster. All treatments controlled plantain. Treatments of 2,4-D looked the most promising for bindweed control. Unfortunately, all treatments decreased the cover of birdsfoot trefoil (*Lotus corniculatus*). However, 2,4-D (0.95 lb a.e./acre or less), bromoxynil, and carfentrazone did not adversely impact the cover of white clover (*Trifolium repens*), usually a very desirable component of irrigated pasture. The application of 2,4-D at 0.95 lb a.e. /acre looks very promising for broad spectrum broadleaf weed control without negatively impacting most of the desirable pasture species. No treatments significantly affected any of the grass species present.

Aminopyralid Prevents Seed Production in Ventenata and Medusahead

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Medusahead (*Taeniatherum caput-medusae* (L.) Nevski) is an invasive annual grass negatively impacting rangelands throughout the western U.S. Amino acid synthesis inhibitor and photosynthesis inhibitor herbicides are sometimes used to control medusahead. Conversely, growth regulator herbicides are generally considered ineffective against invasive annual grasses. However, in a recent study of pre-emergence herbicide applications, the growth regulator aminopyralid appreciably reduced medusahead cover, primarily by killing emerging medusahead plants. Additionally, in recent studies of post-emergence herbicide applications, we found the growth regulators aminopyralid, dicamba and picloram drastically reduced seed production of downy brome and Japanese brome, two other invasive annual grasses. In these post-emergence studies, growth regulators sterilized the plants without otherwise greatly affecting them. The purpose of this greenhouse study was to extend our growth regulator/plant sterility research from downy brome and Japanese brome to medusahead and ventenata. Each tested aminopyralid rate and application growth stage (late seedling, internode elongation, heading) reduced medusahead seed production to nearly zero. Picloram also reduced medusahead seed production, but not quite as consistently as aminopyralid. With ventenata, aminopyralid applied at the seedling stage reduced seed production ~95-99%. Beyond the seedling stage, however, ventenata responses to aminopyralid were highly variable. Picloram had low activity against ventenata seed production. These results contribute to a growing body of evidence suggesting it may be possible to use growth regulators to control invasive annual grasses by depleting their short-lived seedbanks.

Tulare County WMA Leading Edge Cost-Share Yellow Starthistle Control Program

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Few noxious weeds have caught the general public's attention as has Yellow starthistle (*Centaurea solstitialis*). Yellow starthistle (YST) proliferation is a serious threat to the biodiversity and the productive potential of California's rangelands and natural areas. YST has continued to colonize susceptible habitats including an estimated 20,000 acres of Tulare County foothill range. UC Cooperative Extension Tulare County (UCCE) office conducted various research trials from 1997-2008 to determine effective control strategies for yellow starthistle. The Tulare County Weed Management Area (TCWMA) was established, in 2000. The TCWMA acquired a California Department of Food and Agriculture (CDFA) grant in 2001, which funded an YST cost-share spray control program. Between 2002 and 2013 the WMA conducted 10 years of treatment programs for a total of 411 sites totaling 2929 acres of YST controlled with Transline® (clopyralid) and/or Milestone VM® (aminopyralid). In 2013, the cost-share program experienced the highest level of participation, with 64 participants. The cost-share program has significantly reduced infestations within rangelands and provides small landowners an affordable method of control. Landowners contribute a cost-share of \$50 up to three acres and \$15 per acre for greater than three acres. In 2009, based on increasing invasive threats to the National Park and Forest lands, CDFA and USFS ARRA funds were acquired to enhance the cost-share program, hire a program coordinator, and to develop a "Leading Edge" program effort. Funding to support a part time program coordinator significantly increased the program's impact through various community outreach efforts, improved surveying and monitoring strategies; as well as improved use of GIS for monitoring and data analysis. Funding has been increased through joint funding partnerships, and increasing the scope of the WMA strategic plan to include weed source and transportation issues. Cooperators now include aggregate and construction material producers and the County Roads Department.

Role of Seed Treatments in Plant Competition

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Thiamethoxam, is a broad-spectrum neonicotinoid insecticide which when applied to seed, has been observed to enhance seedling vigour under environmental stress conditions. No previous work has explored the effect of thiamethoxam as a seed treatment on the physiological response of maize seedlings growing in the presence of weeds. Thiamethoxam was found to enhance seedling vigour and to overcome the expression of typical shade avoidance characteristics in the presence of neighbouring weeds. The enzymatic and physiological responses that occurred within the maize seedlings will be presented. These results suggest that seed treatments may provide an opportunity to enhance crop competitiveness with weeds.

Robotic Weed Control

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In their 2008 comprehensive review of autonomous robotic weed control systems, Slaughter et al. (2008) reported that systems for plant detection and their classification (crop vs weed) presented the greatest technical challenge for development of a successful weeding robot. Methods for precision weed control also needed further development. Although the few fully autonomous robotic weeding systems that had been developed at the time showed promise for reducing hand labor and/or pesticide requirements, none had been successfully commercialized. Since then, technology has advanced and several automated weeding machines are commercially available. This paper describes some of these devices and provides an update on the current state of robotic weeding.

Commercial robotic weeding machines utilize one of several means to kill weeds including mechanical, flame or herbicidal spray. Robotically controlled devices are used to eliminate weeds in the seed line between the crop plants (intra-row) while weeds between the seed lines (inter-row) are controlled with conventional cultivation techniques. All systems use a camera-based machine vision system to detect plants. Due to proprietary reasons, the specifics of how these machines' computer algorithms work is not known, but based on observation and a review of product literature; it is assumed they do not classify plants as being either crop or weed, but rather selectively identify crop plants. Classifying plants as either crop or weeds is difficult with system accuracies of around only 85%, even under ideal conditions. There are many ways to identify crop plants in digital images, but typically this is done by first analyzing a captured image and classifying each pixel in the image as being either a plant or a non-plant part using some type of green thresholding technique. Once the image has been "segmented", adjacent pixels are analyzed. Regions with high levels of contrast between plant and non-plant parts indicate potential leaf edge boundaries and contour lines are traced around the borders of these areas. These "objects" are then further analyzed based on size, location relative to each other, position relative to the seed row, shape and color. Objects that do not meet the user defined criteria as being characteristic of a crop plant are removed from the segmented image. Once crop plant objects have been located, commands are sent to a microcontroller which controls the intra-row weeding device. An example of the image processing technique described is depicted in figure 1. In this example, the machine vision system is used to identify plants for the purpose of selective

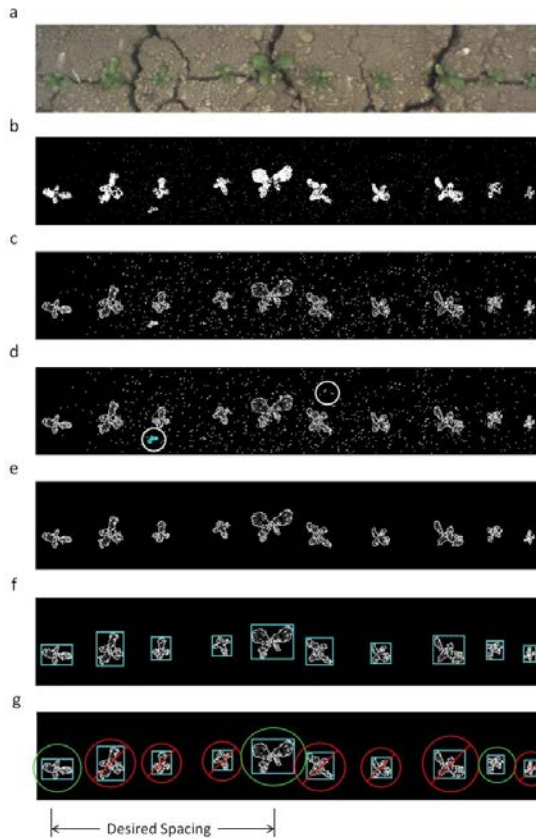


Fig. 1. Illustration of the image processing steps used by a robotic thinning machine: a) raw image captured, b) image segmented image based on color thresholding (green), c) contours traced around regions of high contrast, d) objects contained within contour boundaries are further analyzed for color, size and shape, e) objects that do not meet criteria for crop plant color, size and/or shape are filtered, f) bounding boxes placed around plant objects identified, g) plants to be “saved” or selectively thinned are chosen based on plant location and desired final plant spacing.

(Harringvleit, Netherlands), has been in commercial production for only two years. The technology was developed in partnership with Wageningen University Research (Wageningen, Netherlands). The robotic weeding machine utilizes cameras, one for each crop row to identify crop plants based on color, size and spacing. To ensure that images of consistent quality are obtained, the cameras are enclosed in a hood and artificial lighting is

thinning. Plants to be “saved” are selected based on the desired final plant spacing.

The first commercially available robotic weeding machine was probably a device called the Robocrop. The technology was developed by Tillet and Hague Technology Ltd. (Silsoe, United Kingdom) and commercialized by Garford Farm Machinery Ltd. (Peterborough, England). The device utilizes a forward looking camera to detect crop plants and sets of rotating disc blades attached to an off center shaft to cultivate around crop plants and within the crop row. Fennimore et al. (2013) compared the device with hand weeding in direct seeded and transplanted Bok Choy, celery, lettuce and radicchio. They concluded that the machine provided acceptable performance in transplanted crops, but was not suitable for use in directed seeded crops. An explanation for this is that in addition to color, the machine’s plant detection algorithm utilizes plant spacing and size as selection criteria. In direct seeded crops where crop plants are irregularly spaced and of similar size to weeds, the system has difficulty reliably differentiating between crop and weed plants.

The IC-Cultivator, manufactured by Machinefabriek Steketee BV

provided by LEDs. As the machine travels through the field, a pneumatic cylinder is actuated to open and close a set of cultivating knives around the crop plants. The machine was released in Europe in 2013 and several units will be available in North America in 2014 via Northern Equipment Solutions (Wasage Beach, Ontario, Canada). According to product literature, the unit is modular in design providing for working widths of ranging from roughly 5-20 feet. Hoeing capacity is 3-4 plants per second. With plant spacing at 11 inches, this translates to an operating speed of 1.9-2.5 mph. The price for a six row unit is \$80,000 or about \$13,000 per row. No information about the performance of the machine could be found.

F. Poulsen Engineering Aps. (Hvalsø, Denmark) manufactures a similarly styled mechanical hoeing robot. The unit utilizes cameras positioned over each crop row and detects crop plants based plant color, size and spacing. Intra-row weeds are controlled by knife blades that are opened and closed around crop plants as the machine travels through the field. Although the cameras are not enclosed in a hood, artificial lighting is provided so that images of consistent quality can be obtained. Depending on soil and plant conditions, product literature states that the machine is capable of operating at speeds of up to 2.5 mph and available in modular 3-6 row units. Multiple modules can be mounted on a toolbar to provide wider working widths. The cost of the system is about \$125,000 for a five row unit (about \$25,000 per row) and there is no known U.S. distributor. No information about the performance of the system could be found.

F. Poulsen Engineering Aps. (Hvalsø, Denmark) also manufactures an intra-row weeding robot that uses flame to kill weeds. The machine uses the Robovator vision system to identify crop plants. A series of plasma jets oriented towards the crop row are cycled on and off to kill weeds between crop plants. Multiple jets are used for each crop row so that a sufficient amount of heat is applied to kill the weeds. The company's website states that the patented system can be operated at speeds of 0.6-3.75 mph. Again, no information about the performance or cost of the system could be found.

Automated lettuce thinning machines can be thought of as intra-row weeding robots since they are used to remove undesired plants in the seed row. Since 2011, four automated thinners have been commercialized in the U.S. These include units from Ramsay Highlander Inc. (Gonzales, Calif.), Agmechtronix LLC, (Silver City, N.M.), Blue River Technologies Inc. (Mountain View, Calif.), and Vision Robotics Corp. (San Diego, Calif.). All systems use a machine vision system to locate lettuce plants for selective thinning and herbicidal spray solutions to kill unwanted plants. These machines are capable of thinning crops planted as close as 1.5 inches apart as speeds of 2-3 mph.

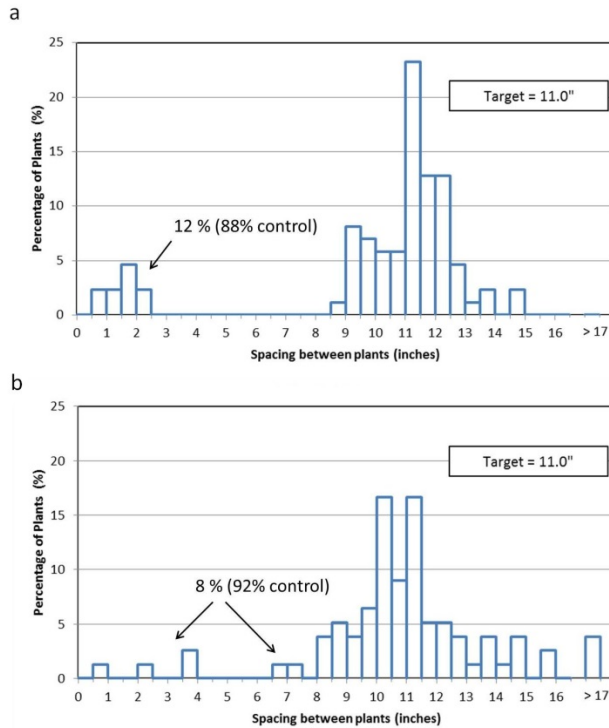


Fig. 2. Plant spacing distribution after thinning lettuce seedlings nominally spaced 2 inches apart with a) an automated thinner and b) by hand.

should be expected today since technology has advanced since the time of the study. To utilize automated thinning technologies as robotic weeding machines, theoretically all that is needed to have the user be able to adjust the size of the "objects" the system considers to be a crop plant. This can easily be accomplished programmatically. The unit would also need to be equipped with banding nozzles to spray and control inter-row weeds. It is not known how well such a system would control intra-row weeds, especially those close to the crop plant and further research is needed. We have initiated studies to address this issue.

In summary, over the last several years, several technologies for robotic weeding have become commercially available. To date, there is little information about their performance or their viability for use in California production systems. Research is needed to address this issue. Automated thinner technologies show good promise for use as robotic weeding machines, but further study is also needed. As technologies continue to advance, robotic weeding machines will become more precise, have expanded capabilities and be more affordable. It is reasonable to expect that these types of devices will play an increased role in production agriculture in the future.

Prices for a tractor pulled four bed (2 wide beds) machines are roughly \$150,000 while self-propelled, two bed (1 wide bed) units cost \$250,000. The technologies utilized by these devices could easily be adapted for robotic weeding purposes since crop plants are identified by color, size and location. The technique shows promise. Siemens et al. (2012) evaluated a prototype automated lettuce thinner and found that the system was able to control 88% of the unwanted lettuce plants within 8 inches of the saved crop plant (Fig. 2). This was comparable to hand thinning where 92% of the unwanted lettuce seedlings were controlled. Better performance

Links to some of the videos shown during presentation are provided below.

Robocrop (Garford Farm Machinery Ltd., Peterborough, England):

<http://www.thtechnology.co.uk/Movies%20and%20thumbs/Robocrop%20in-crow%20weeder.wmv>

IC-Cultivator (Machinefabriek Steketee BV, Haringvleit, Netherlands):

http://www.youtube.com/watch?feature=player_embedded&v=NrozkdH4VxQ

Robovator (F. Poulsen Engineering Aps., Hvalsø, Denmark):

<http://www.youtube.com/watch?v=qeYyWiLfiYw>

Thermal Hoeing Robot (F. Poulsen Engineering Aps., Hvalsø, Denmark):

<http://www.visionweeding.com/Videos/flame-normal-speed.wmv>

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Heat Treatment of Soil for Weed Control

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Our research program has been evaluating physical weed control tools such as heat for soil disinfection. These methods use heat to kill weed seed in the soil seedbank, i.e., soil disinfection. Heat kills soil pests like weed seeds by heating the soil to lethal temperatures for a critical length of time, i.e., dwell time, sufficient to kill soil pests. Decades of steam use in greenhouse soils have found that a dwell time of 20 minutes at 158°F is sufficient to kill weed seed in the soil. Reported here are two methods we have tested recently, dry heat in the case of the Culticlean from The Netherlands and steam for soil disinfection.

Culticlean. The Culticlean, a commercial soil pasteurizing device from the Netherlands, helps manage weeds by heating the planting bed with a propane flame as it rototills the top 2 inches of a finished seedbed prior to planting. Our goal was to test this claim, and also to see if the system would also control the soil borne lettuce drop pathogen, *Sclerotinia minor*. Eighty inch beds were prepared and planted with 5 seed lines per bed of romaine lettuce, ‘Sunbelt’ at the Spence USDA Farm at Salinas, CA. Plots were 80 inch wide beds by 20 foot long replicated plots with 4 treatments; each replicated 4 times, in a randomized, complete block design. Mustard seed meal at 3,000 lb/A was included because we have found in other studies that mustard seed meal and steam are complimentary (Fennimore et al. 2013).

Perennial ryegrass and pigweed seed were seeded into the finished beds, The Culticlean device was next run over all treated beds on 5/28/13, rototilling the top 2 inches of soil, and the heating element (which heated the tilled soil briefly to 400°F) was engaged in half the treatments. Lettuce was seeded 5/29/13 and first irrigation was 5/30/13, followed by 3 per week irrigations until established, then 2 per week until harvest.

Weed control was modest with some reduction in ryegrass, but little improvement in pigweed or groundsel control (Table 1). Apparently the dwell time was not sufficient to kill weed seed. The Culticlean either needs to go slower, or be better insulated so that soil temperatures remain above the critical temperature for sufficient dwell time to kill weed seed. Results are somewhat promising, but the treatment as performed here needs improvement.

Table 1 Impact of Culticlean treatment on weed densities

	Ryegrass density #/ft ²	Pigweed density #/20ft ²	Groundsel #/10ft ²
	6/18/13	6/18/13	6/24/13
non-treated	87.25 a	20.25 a	17.25 a
MSM @ 1.5 t/a	53.75 b	18.75 a	9.75 a
Culticlean	60.50 b	42.50 a	7.75 a
Culticlean+MSM @ 1.5 t/a	38.75 b	4.00 a	1.00 b
treatment probability (P)	.0066	.0711	.0028

Steam.Field tests were conducted to evaluate a prototype steam applicator designed to deliver steam to raised strawberry beds. In previous work we concluded that existing designs from European manufacturers were impractical, requiring development of a new design for California strawberry. With funding from the Propane Education and Research Council (PERC) in October 2011 we built an automatic steam applicator. The objective of this research was to compare preplant soil disinfestation of raised strawberry beds with our custom designed steam applicator to standard soil fumigation in strawberry.

Materials and methods

Equipment description.The initial prototype consisted of a tractor-towed wagon with a propane fueled Clayton 100 HP steam generator (Clayton Industries, City of Industry, CA) capable of steaming one 52 inch wide raised bed per field pass. Steam was injected and mixed into the soil through a bed shaper equipped with a rototiller, multiple steam injection shanks in front and behind the tiller, and steam injection nozzles above the tiller. Water was supplied to the steam generator through a 1,200 long hose reel.

Field tests. Four tests total were done during 2011 to 2013. Two tests were done in October 2011, one at Salinas, CA and the second at Watsonville, CA. Soil at both Salinas and Watsonville sites were a sandy loam soil. Two tests were done in September 2012, both near Watsonville, CA. Soil at both sites were a Salinas clay loam. Soil temperatures were measured with Hobo temperature loggers (Onset Computer Corp. Pocasset, MA). Weed seed bags were installed in the strawberry beds as soon as the steam applicator passed. Weed seed were removed 1 week after treatment and tested for viability with tetrazolium. The trials were arranged in a randomized complete block design with 4 reps. In 2011 Pic-Clor 60 EC was included as a fumigant standard at 350 and 250 lbs/A in Watsonville and Salinas, respectively. In 2012 mustard seed meal at 3,000 lbs per acre (Farm Fuels, Watsonville, CA) as applied to one set of the steam treated beds prior to steam application. Weed densities were measured periodically and weeding times were recorded as described in Samtani et al. 2012. Fruit harvest was measured by a commercial harvest crew once or twice weekly as needed during the April to September 2012 and 2013 harvest intervals.

Results and discussion

At all locations the soil temperature at 2, 6 and 10 inches from the bed surface reached $>158^{\circ}\text{F}$ for $>20\text{min}$. The 10 inch probe marks the lower end of heat penetration into the bed and temperatures were cooler at the bottom of the bed. Fuel consumption was measured at 1,561 gallons/A propane, which means that 163 MJ m^{-3} of energy were applied which is comparable to that listed in Baker and Roistacher (1957). Estimated machine, fuel and labor costs are \$5,727/A based on the single bed prototype and the field application rate was 19 hours/A. We estimate the cost of a two bed unit would be about \$3,700 /A based on our current design and an application rate of 8 hours/A. The comparable 2013 price of methyl bromide plus chloropicrin broadcast fumigation in California was \$4,000 /A.

Viability of chickweed, knotweed and yellow nutsedge were reduced by steam and Pic-Clor 60 fumigant compared to the control (Table 2). Only steam killed the bluegrass seed. Measurements

of weed fresh weights and weed densities, indicate that steam and Pic-Clor 60 performed similarly (Table 3).

Table 2. Weed seed viability at Watsonville steam test in 2011-12.

Treatment	Bluegrass	Chickweed	Knotweed Control (%) ^a	Mallow	Nutsedge
Steam	1 b	2 b	6 b	72 b	0 b
Pic Clor 60	86 a	4 b	0 b	63 b	0 b
Control	66 a	69 a	96 a	95 a	45 a

^a Means with the same letter within columns are not significantly different according to Fisher's LSD at P = 0.05

Table 3 Cumulative weed biomass and weed densities at four sites over two seasons. The MBA, TCR and SJR sites are all near Watsonville, CA and the Spence site is near Salinas, CA.

Units: trial : treatments	Weed biomass ^{a,b}				Weed density			
	2011-2012		2012-2013		2011-2012		2012-2013	
	MBA	Spence	TCR	SJR	MBA	Spence	TCR	SJR
non-treated	102	386 a	80 a	1	18 a	80 a	223 a	2
steam	6	15 b	1 b	1	3 b	16 b	5 b	1
steam + MSM	--	--	11 b	2	--	--	13 b	1
Pic-Clor 60	5	138 b	--	--	2 b	37 b	--	--
<i>P</i> =	.0999	.0127	.0141	.6329	.0016	.0027	.0015	.2586

^aBiomass data for 2011-2012 sites was taken fresh; for 2012-2013 sites after oven drying.

^bMean separations by Duncan's multiple range test, $P \leq .05$. Values based upon 4 (MBA, TCR, SJR) or 5 (Spence) replications

Summary. What these data indicate is that dry heat as delivered by the Culticlean is marginal. Steam is more dependable than dry heat, but slower and more expensive. Additional engineering work is needed to improve the efficiencies of both of these technologies.

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Field Bindweed Management in Processing Tomatoes

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Subsurface drip irrigation in processing tomatoes (*Solanum lycopersicum*) has been rapidly adopted in California over the past decade, and is now used on approximately 90% of the production area. The economic necessity of maintaining the beds and replanting with only minimal tillage for multiple seasons has created a system where field bindweed (*Convolvulus arvensis*) has become more prevalent. Field bindweed is extremely difficult to manage because established plants have extensive root systems and are less susceptible to control measures. Currently, UC IPM guidelines are limited with respect to their management options for established bindweed: glyphosate and repeated cultivation. Clearly, additional management information is needed. Therefore, beginning in 2011, field studies were conducted at University of California Davis campus to evaluate the efficacy of registered herbicide combinations in controlling established field bindweed in processing tomatoes; parallel studies were conducted at the UC West Side Research and Extension Center in 2012 – 13 using drip irrigation. The treatment design was a randomized block split-plot with four replications. Main plots consisted of pre-emergent (PRE) and pre-plant incorporated (PPI) applications of Prowl H₂O (pendimethalin, 3 pints/A; 1600 g a.i. ha⁻¹), Treflan (trifluralin, 2 pints/A; 1120 g a.i. ha⁻¹), Zeus (sulfentrazone, 4.5 fl oz/A; 112 g a.i. ha⁻¹), and Matrix (rimsulfuron, 2 oz/A; 35 g a.i. ha⁻¹), which were applied prior to transplanting and either mechanically or water incorporated, according to label recommendations. Split plot treatments were post-emergent (POST) applications of Matrix (2 oz/A; 35 g a.i. ha⁻¹) or Shark (carfentrazone, 2 fl oz/A; 35 g a.i. ha⁻¹) applied one week after transplanting to emerged bindweed. Concurrently, additional herbicide treatment combinations were tested with a randomized block design, and included sequential POST applications of Matrix (2 oz + 2 oz/A), Shark (2 oz + 2 oz/A), Shark + Roundup (2 fl oz/A + 2% glyphosate; 96 g ai ha⁻¹), Treflan applied PPI and again at lay-by (2 pts + 2 pts/A), Zeus + Dual Magnum (4.5 oz + 1.5 pints/A S-metolachlor, 1600 g a.i. ha⁻¹) PPI, and a Treflan + Dual + Matrix combination that is commonly used in tomatoes, as well as untreated and hand weeded controls. Post-emergence applications of Shark were applied using a shielded sprayer as to minimize contact with the tomato crop; Matrix was applied over the top with a non-ionic surfactant at 0.25% v/v. The second post application for select plots was done about 21 days after transplanting. Weed-free check plots were maintained by manually removing all weeds at bi-weekly intervals during the growing season. Weed and crop ratings were made at 14, 28, 54 days after treatment by estimating the percentage of the plot area covered with bindweed; the analysis of variance was performed on arc-sin transformed data and means separation using Fisher's protected LSD at $p = 0.05$. These transformed data were then used to calculate bindweed control estimates as a percentage of the untreated control plot. In 2013, the UC Davis trial was changed to include transplanting date and pre-plant glyphosate treatments along with several of

the PPI herbicides described above; Treflan was a component of all herbicide programs in this study.

Combining results from all years, Treflan was the most effective pre-emergence treatment for suppressing established field bindweed. As compared to the untreated control, PPI Treflan ranged from about 20 to 75% control of bindweed, with an average of 39%. Suppression faded as the season progressed; as a result, Treflan did not significantly differ from the other treatments or the untreated control by the last evaluation date. In contrast, the application of Matrix or Shark as a POST treatment usually provided significant suppression of bindweed as compared to the untreated plots on all evaluation dates. Post-emergent applications of Matrix and Shark were statistically similar in improving bindweed control (about 20% averaged across all treatments) although Matrix provided significantly better total weed control and improved crop safety as compared to Shark (Table 1). Thus, the combination of Treflan PPI + Matrix POST gave the best overall bindweed control (Figure 1, results are for WSREC only and weed pressure ratings, not bindweed control; UCD was similar). The PPI x POST herbicide interaction was not significant for any evaluation date.

Bindweed growth was significantly reduced by some of the additional herbicide treatments included in the studies, including Treflan applied pre-plant and again at layby. In 2012, a double POST application of Matrix gave good bindweed suppression; in 2013, Shark + Roundup applied POST, sequentially, also worked well. While only evaluated for one season and location, the 2013 trial at Davis had very good suppression, > 70%, when a pre-plant application of Roundup was included in a herbicide program with Treflan PPI and Matrix or Shark POST. The use of Dual Magnum and Zeus (PPI) Matrix (PRE), in combination with Treflan also helped to reduce field bindweed density in late planted tomatoes. Pre-plant applications of glyphosate to emerged bindweed (late planted tomatoes) reduced weed cover by more than half in herbicide treated plots, supporting a common IPM recommendation that all growers should strive to plant into clean fields.

The combination of Treflan PPI and either Matrix or Shark applied post-emergence, or applying Treflan both PRE and at layby, have been the best treatments for suppressing established field bindweed in both furrow and drip irrigated processing tomatoes. Pre-plant Roundup also improved control about 15% when applied to late planted tomatoes. Yields were significantly higher in the herbicide treatments as compared to the untreated check plots at both locations (data not shown); however, concerns about this herbicide program remain for its potential crop phytotoxicity and plant-back restrictions to crops other than tomatoes.

Table 1. Field bindweed control for the various treatments as compared to the untreated control at WSREC and UC Davis, 2011 - 2013.

Treatment PPI	POST	WSREC Aug 2012 control (4)			WSREC July 2013 control			UCD FBW control			FBW
		FBW(1)	other BL(2)	grass(3)	FBW	other BL	grass	Aug-11	Aug-12	Jul-13	Average
1. UTC	a. UTC	0	---	---	0.0%	0.0%	0.0%	0%	0.0%	0%	0.0
	b. Matrix	3.4%	29.6%	28.6%	40.9%	17.6%	59.1%	---	42.0%	---	29%
	c. Shark	-3.4%	-3.7%	42.9%	31.8%	2.9%	22.7%	---	44.0%	---	24%
2. Prowl	a. UTC	10.3%	92.6%	85.7%	4.5%	35.3%	90.9%	5%	22.0%	---	10%
	b. Matrix	37.9%	77.8%	85.7%	13.6%	58.8%	95.5%	61%	35.0%	---	37%
	c. Shark	37.9%	85.2%	85.7%	22.7%	44.1%	100.0%	---	38.0%	---	33%
3. Matrix	a. UTC	6.9%	59.3%	0.0%	4.5%	17.6%	59.1%	6%	42.0%	---	15%
	b. Matrix	37.9%	59.3%	57.1%	22.7%	44.1%	86.4%	63%	40.0%	---	41%
	c. Shark	27.6%	51.9%	28.6%	9.1%	14.7%	68.2%	---	22.0%	---	20%
4. Treflan	a. UTC	24.1%	96.3%	100.0%	31.8%	38.2%	100.0%	75%	26.0%	---	39%
	b. Matrix	48.3%	96.3%	100.0%	36.4%	73.5%	100.0%	87%	42.0%	45%	52%
	c. Shark	48.3%	96.3%	100.0%	40.9%	47.1%	95.5%	---	35.0%	33%	39%
5. Zeus	a. UTC	6.9%	66.7%	85.7%	18.2%	20.6%	31.8%	31%	21.0%	---	19%
	b. Matrix	13.8%	66.7%	57.1%	31.8%	52.9%	59.1%	58%	22.0%	---	31%
	c. Shark	10.3%	59.3%	28.6%	13.6%	41.2%	-27.3%	---	35.0%	---	20%
OTHER											
	Matrix 2x	51.7%	37.0%	100.0%	4.5%	55.9%	95.5%	---	38.0%	---	31%
	Shark 2x	27.6%	14.8%	-71.4%	---	---	---	---	51.0%	---	39%
	Shark + RU	---	---	---	50.0%	-2.9%	27.3%	---	---	---	50%
	Matrix+Sandea	44.8%	55.6%	100.0%	---	---	---	---	30.0%	---	37%
Zeus + Dual		---	---	---	4.5%	76.5%	95.5%	---	---	---	5%
Treflan	Treflan	48.3%	92.6%	100.0%	31.8%	73.5%	100.0%	92%	35.0%	---	52%
Treflan+Dual		0.0%	88.9%	100.0%	---	---	---	---	40.0%	---	20%
Treflan+Dual	Matrix	---	---	---	22.7%	79.4%	100.0%	---	---	53%	38%
	Hand	82.8%	96.3%	71.4%	81.8%	100.0%	100.0%	---	71.0%	---	79%

- 1) FBW = field bindweed.
- 2) BL = broadleaf weeds other than field bindweed. Mainly puncture vine, pigweed, lambsquarters, purslane, and nightshades.
- 3) Grass = grassy weeds, dominated by Jungle Rice and Barnyard Grass.
- 4) Control = Rating(Treatment mean - UTC)/Rating(UTC) x 100

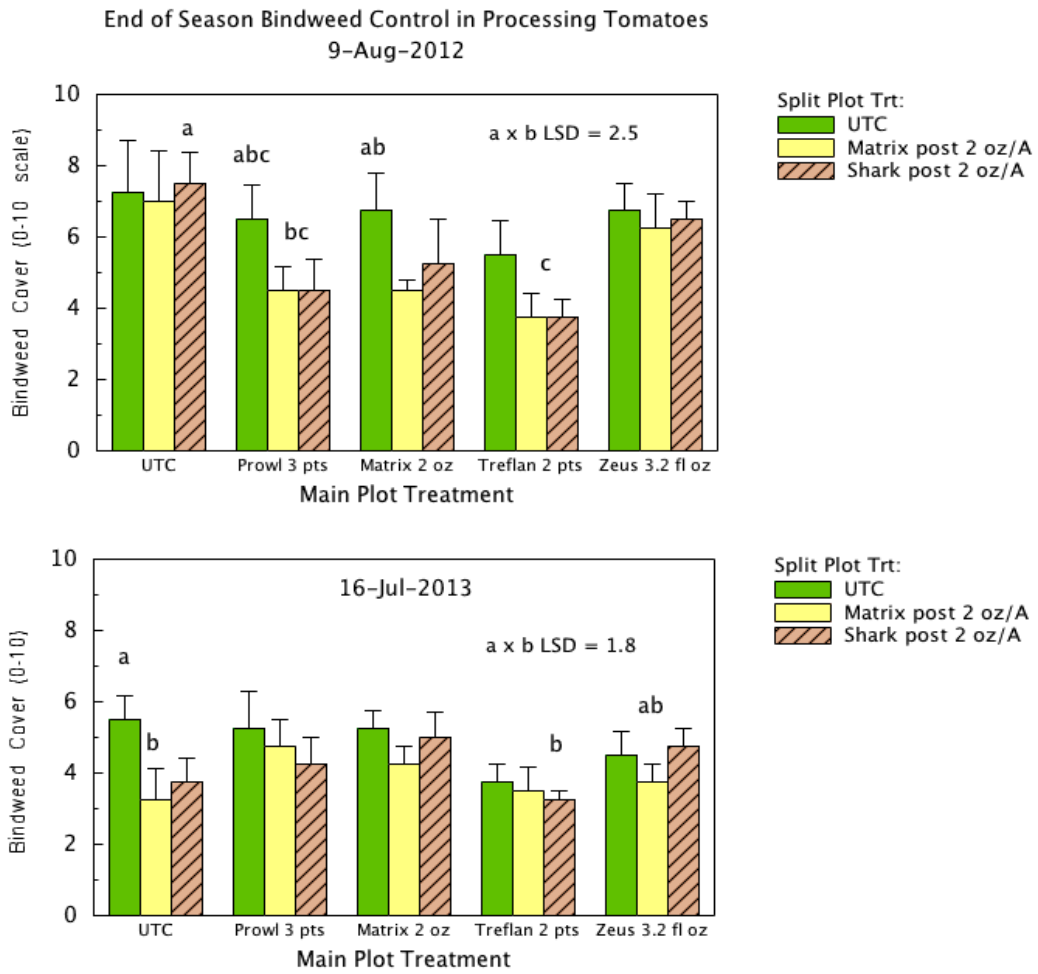


Figure 1. Field Bindweed cover in processing tomatoes at the last evaluation date in 2012 (top) and 2013 (bottom) as affected by herbicide treatment at the UC WSREC location.

Weed Control in Carrots at Bolthouse Farms

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Bolthouse Farms is the largest carrot (*Daucus carota*) producer in North America, cultivating carrots in California, Arizona, Washington, Georgia and Ontario, Canada. Headquartered in Bakersfield, carrots are grown primarily in Kern County. Outside of Kern County, production areas include field locations within the Salinas Valley, the Greenfield-Atwater areas, Avenal and Coalinga, Cuyama, Lancaster and Palmdale, and south to the Imperial Valley, Holtville region.

With approximately 30,000 acres in production and a wide range of environmental conditions in the growing areas, carrot cultivation can take place year round. Harvesting can be conducted on a daily basis, as planting dates and growing seasons in the various areas provide conditions to allow for a continuum of carrots, to be run through the Bakersfield, processing plant.

A range of carrot based products are produced, derived from conventional and certified organic fields. From an agronomic perspective, the carrot production could be split into three main categories:

- 1) Cello production- carrots that are sold as intact taproots;
- 2) Short-cut or cut and peel production—taproots that will be cut into segments to ultimately be marketed as “baby carrots”;
- 3) Bunching—carrots that are sold in bunches with both leaf and taproot intact.

Cultivation of carrots

Carrots are grown from seed on raised beds with approximately 40 inch (1 metre) between bed centers. This provides a usable bed surface of about 25-28 inches across. There may be anywhere from four to seven seed lines on each half of the bed. Cultivars are selected based on the suitability to the growing region, from information on soil conditions, temperature, and typical climatic conditions, to ensure they are grown in areas where they will be the most productive and competitive. Crops are may be irrigated by pivot, solid set, flood, and subsurface drip irrigation.

Density of planting/seeding rate differs depending upon the ultimate taproot shape required. Cello carrots are grown at lower densities than short cut carrots, which are grown in close proximity to one another, to constrain growth to the specific diameter range required. Short-cut carrots are cut into segments, which will eventually be used in the production of baby carrots. These carrots are cultivated to grow straight with a uniform diameter for much of the length. Cello carrots are generally spaced to a greater extent, and have a wide shoulder (root crown) and a more pronounced taper to the root tip relative to cello carrots.

Principles of Carrot Weed Management

The basic principles of carrot cultivation and carrot weed management are summarized in the following quote from Luther Tucker in an 1861 article in *The Cultivator*, entitled "A Carrotty Exhortation":

"Carrots should be well cultivated--- because they are carrots and carrots will not grow where weeds are more plenty than carrots; therefore keep the ground mellow and the weeds clean from among the carrots"

From this brief quote, it is suggested the ground should be weed free, but also alludes to the fact that even 150 years ago, carrots were recognized as being poor competitors with other plants, especially in cases where weeds establish before the carrot is seeded.

In the early stages of growth, carrots are poor competitors relative to the broad spectrum of potential weeds that may be found in a carrot field. Carrots are slow growing, leaf expansion can be slow, the young seedlings have a very low leaf areas index, and the thin feather-like leaves, do not provide shade capable of suppressing other weeds, until much later in the growing season.

After germination of the seed, the hypocotyl slowly increases in length to develop into the taproot usually about 10 days after germination under ideal conditions (See Figure 1). In the initial 30 days of growth, the tap root increases in length, appearing as a long and thin easily damaged thread. This period of growth is critical for the development of the taproot, as the final length of the taproot length for the entire growing season is largely determined at this stage of growth. In the case of shortcut carrots, a decrease in desired length will reduce the number of potential segments from each taproot that will ultimately be marketed as baby carrots.

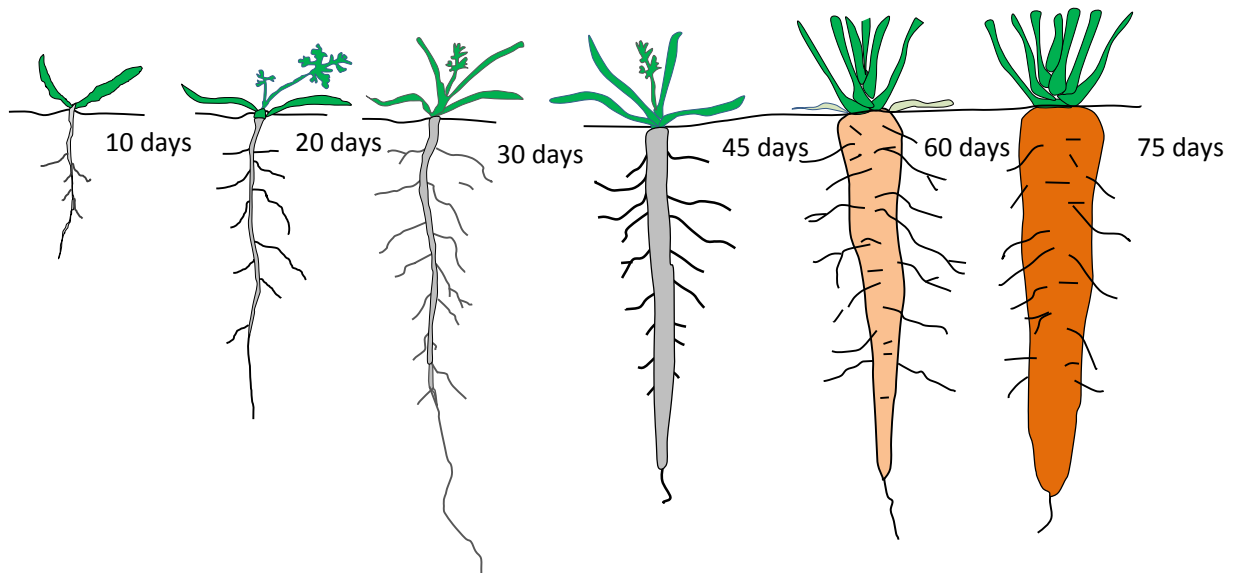


Figure 1: Typical development of the carrot tap root over time. Days to development will vary with environmental conditions, cultivar, and other cultivation practices.

Table 1 shows the importance of early season weed infestations on the development of the carrot. Even though the majority of the season was free of weed competition. The effect of early season weed infestations resulted in significant reductions in taproot mass and diameter that were not recovered.

Table 1: Influence of competition duration after planting and infestation level on the reduction in root fresh weight and root diameter, immediately after weed removal (Spring) and at harvest. All values are significant at the $p=0.01$ level (modified from Shadbolt, C.A. and Holm L.G. 1956)

Length of Competition (days)	Weed Stand (%)	% Reduction in Root fresh Weight		% Reduction in Root Diameter	
		Spring	Harvest	Spring	Harvest
31	15	43.6	30.1	12.6	10.7
31	30	81.2	30.6	25.3	10.0
31	50	92.9	44.5	30.1	17.8
38	15	77.7	38.7	50.1	14
38	30	87.4	47.4	58.1	23.9
38	50	90.9	61.9	62.2	32.5

Reduction in Harvest Efficiency

Carrots are harvested through the use of equipment that initially loosens the soil, and utilizes the strength of the leaves, to pull the carrots from the ground where they are dropped into trailers for shipping back to the processing plant in Bakersfield. If a carrot bed has a high infestation of weeds, these can be pulled into the carrot harvester. At some point the harvester will have to stop, in order to prevent damage to equipment. This can lengthen the period of time needed to harvest a field.



Figure 2: Nutsedge (*Cyperus* spp.) root damage to carrot tap-roots. Damage to the taproot may also result in decay of tissues.

Weeds can cause direct damage to the carrot tap root. While this is not a common problem, nutsedge roots can actually penetrate carrot tissue (See Figure 2)

Mechanical cultivation practices for weed management in carrots during the growing season can be difficult to employ and have been used on a limited basis. To remove weeds in a carrot planting, at times that herbicides are unable to be used, hand weeding is required both in conventional and organic carrot cultivation. While necessary, hand weeding in a carrot crop can be difficult due to the close proximity of the carrots to each other,

and the difficulty of removing weeds without removing and injuring carrots. Weeds that typically are problems in carrots can be found in Table 2.

Carrot Weed Management Plan

Crop Rotation

Crop rotations are planned years in advance when possible, though there may be restrictions on lands that are rented, and will not be under the control of Bolthouse Farms, prior to carrot planting.

Herbicide Management

Generally there are few options for weed management in carrots, this poses a number of challenges. Typically, the approach is to apply a post pre-plant product, followed with a post crop emergent product. When permitted by the label, applications are conducted by

Pre-Plant

Prior to planting, fields are pre-irrigated anywhere from 4-5 weeks before seeding to germinate weed seeds. This is followed by shallow cultivation, to avoid bringing any seeds or propagules to the soil surface.

In fields with nematode and soilborne plant pathogens, based on soil sampling and field history, a degree of weed control is derived from fumigation with a metam potassium or metam

sodium product 2-3 weeks before planting. Depending upon plant back restrictions on the land be cultivated, trifluralin for grass and broadleaf control may be applied.

Pre-emergence-Post Plant

At this stage in planting, there are generally four herbicide options:

- Trifluralin; for grass and broadleaf control (depending on plant back restrictions)
- Linuron; for broadleaves and grasses
- S-metolachlor; chiefly for yellow nutsedge (*Cyperus*), thought this has lessened other species pressure
- Pendimethalin; barnyard grass, pigweeds, london rocket

After the Crop Emerges

There are relatively few products that can be applied in season to carrots, generally linuron is used with the most frequency due to broad spectrum of weeds, that can be managed.

- Fluazifop-p-butyl, sethoxydim: grasses
- Linuron: broadleaf weeds, small grasses, suppression of yellow nutsedge
- Metribuzin: broadleaves

Summary

Carrots are generally poor crop competitors, and weed management is required early in the season in order to have the best chance of maximizing yields. Cultural practices within the seeded areas of the bed are limited to manual removal of weeds. Herbicides registered for use on carrots are available, but in season uses are limited.

Table 2: Weeds that have been of concern in carrots fields, in California.

Common name	Latin name
Yellow nutsedge	<i>Cyperus esculentus</i> L.
Purple nutsedge	<i>Cyperus rotundus</i> L.
Barnyard grass	<i>Echinochloa crus-galli</i> (L.) P. Beauv.
Field Bindweed	<i>Convolvulus arvensis</i> L.
Common Purslane	<i>Portulaca oleracea</i> L.
Shepherd's Purse	<i>Capsella bursa-patoris</i> (L.) Medik.
Russian Thistle	<i>Salsola tragus</i> L.
Pigweeds (prostrate,tumble)	<i>Amaranthus spp.</i>
Cheeseweed/Mallow	<i>Malva spp.</i>
Wild Mustard	<i>Sinapsis arvensis</i> L.
London Rocket	<i>Sisymbrium irio</i> L.
Lambsquarters	<i>Chenopodium album</i> L.
Nightshades	<i>Solanum spp.</i>

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DPR New Research Authorization Requirements

Don Antonowich, Senior Environmental Scientist (Specialist), C DPR, Sacramento, CA

Today's (RA) presentation covers general definitions and need for Research Authorizations (RA) in California. It explains recent changes to the application forms, information required, fumigant Notice of Intent's (NOI), and violation penalties for the 2014 test year and beyond. These changes coincide with the Department of Pesticide Regulation's redesign of its RA database, necessitated by the State mandate to migrate databases to a secure off-site server.

New Forms

- DPR recently redesigned its RA database.
- Several new data elements about the proposed research are required to be submitted on new RA application and use reporting forms.

Experimental pesticides needing to be tested

- New formulations of existing products
- New products containing old active ingredients
- Applications to any crop or site not on the California-registered label (or no label exists)
- Use of any spray adjuvant not registered in California
- Use in conflict with the California registered label

RA Test Methodology

- U.S. EPA Product Performance Test Guidelines (OCSPP Series 810.3000)
- Good scientific practices
- Testing under "California-like" conditions

Research Credibility

- Proper experimental design
- Criteria used for assessing efficacy
- Pre-treatment and post-treatment counts
- Randomized & replicated treatments
- Untreated control & positive control
- Rate-response relationship to verify that selected label rates are appropriate
- Statistical analysis

United States Environmental Protection Agency (U.S. EPA) and DPR Guidelines

- Data must
 - address all proposed uses
 - demonstrate efficacy
 - address phytotoxicity, and
 - demonstrate mode of action

- Product must be tested at different rates, including the lowest rate listed on the label

Personal protective equipment requirements:

- Use the pesticide label for personal protective equipment requirements
- In absence of a registered label, use the MSDS or SDS for personal protective equipment requirements

Fumigant applications restrictions

- Check with the Agricultural Commissioner for special County restrictions.
- At least 72 hours prior to fumigant application, the researcher must provide DPR with a copy of the notice of intent submitted to the County Agricultural Commissioner. The copy may be submitted by e-mail to **RA_NOI@cdpr.ca.gov** or by fax to 916.324.5872. **Note:** Some new AIs are subject to the same 72 hr NOI notification if there are special human or environmental concerns.

AREAS WHERE RA's ARE NOT ISSUED BY CDPR

Any University of California (UC) campus and field stations

- Any other land or treated site (including livestock) when used in experimental pesticide research field trials and demonstration operations that are activities of the UC
- Any land owned, controlled, or maintained by the UC to such an extent that a reasonable presumption can be made that the experimentally treated commodities will not be harvested or removed from the premises without authorization of the supervisor

Agricultural Research and Extension Centers

Registrants that are operators of the property where research is conducted and continue to be operators until the treated commodity is destroyed or harvested

Greenhouses or Laboratories

- Except where treated transplants will be planted
- DPR does have authority over nursery and lath houses

Federal or tribal lands

- Use on such lands requires Federal or tribal authorization
 - Bureau of Indian Affairs/Tribal lands
 - Bureau of Land Management
 - Bureau of Reclamation
 - Department of Defense (includes Army Corps of Engineers lakes)
 - Fish and Wildlife Service/Wilderness
 - Forest Service
 - National Park Service

TIMEFRAME – DATABASES & FORMS

Old database and forms

- Experimental field trials concluded by **December 31, 2013**
 - PR-REG-027 (Rev. 2/12)
 - PR-REG-028 (Rev. 1/01)
- Outstanding/Overdue Experimental Pesticide Use Reports
 - PR-REG-028 (Rev. 1/01)

New database and forms

- Experimental field trials beginning **January 1, 2014**
 - PR-REG-027a (Est. 12/12)
 - PR-REG-027b (Est. 12/12) for additional pesticides
- Experimental field trials concluded after **January 1, 2014** (*submit within two weeks*)
 - PR-REG-028a (Est. 12/12)
 - PR-REG-028b (Est. 12/12) for additional trial information

VIOLATION PENALTIES

Failure to comply with any of the conditions of an RA could result in its revocation and an administrative fine up to \$5,000 for each time a condition is violated.

RA Application & Report Forms

The instructions and forms presented at today's session are available on the CDPR website <http://www.cdpr.ca.gov/docs/registration/regforms/ra/ramenu.htm>

QUESTIONS

Questions regarding the RA process can be directed to:

Mr. Don Antonowich, dantonowich@cdpr.ca.gov or 916-445-3686.

Questions about the new forms should be sent to: RAs@cdpr.ca.gov

Answers to frequently asked questions about the new forms can be found at the DPR website <http://www.cdpr.ca.gov/docs/registration/regforms/ra/ramenu.htm> (beginning February 2014)

Effects of Destabilized Lignocellulosic Compost and Solarization on Weed Seed Mortality and Soil Biology

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Overview

Both soil solarization and knowledge-based application of organic materials (e.g., “ASD”; “BSD”) can be useful as pre-plant treatments to eliminate weed propagative structures in soil, without using fumigants or herbicides. With the goal of making both approaches more effective, predictable and flexible, we tested mortality of *Brassica nigra* (black mustard) seeds in field soil amended with mature green waste compost, and destabilized with wheat bran, as compared to non-amended field soil. The soils were solarized in the field at Parlier, CA for 22 days or 15 days. Mortality of seeds buried in compost-amended soil was significantly higher than non-amended soil both years. Additional laboratory and field studies showed that amended and destabilized soil initially was phytotoxic to lettuce seedlings. However, phytotoxicity was eliminated by subsequent solarization treatment. Amended soil resulted in temperatures 2-4 °C higher than in soil alone, and ~85% of total organic carbon in amended soil was exhausted within 22 days of heating. Bacterial community structure in solarized soil was measured by 16s rDNA sequencing. Community structure changed based on soil amendment and solarization. Also, bacterial communities varied with soil depth, indicating possible enrichment of thermophiles and other niche-specific taxa.

Table 1. Research Products for Additional Information

Dahlquist, R.M., Prather, T.S., and Stapleton, J.J. 2007. Time and temperature requirements for weed seed thermal death. <i>Weed Science</i> 55:619-625.
Gamliel, A., and Stapleton, J.J. 2012. Combining organic amendments and solarization for soil disinfestation. Pp. 109-120 in: <i>Soil Solarization: Theory and Practice</i> . APS Press, St. Paul, MN.
Marshall, M.N., Rumsey, T.R., Stapleton, J.J., and VanderGheynst, J.S. 2013. A predictive model for soil temperature during solarization and its validation at two California field sites. <i>Transactions of the American Society of Agricultural and Biological Engineers</i> 56:117-133.
Simmons, C.W., et al. 2013. Managing compost stability and amendment to soil to enhance soil heating during solarization. <i>Waste Management</i> 33:1090-1096.
Simmons, C.W., et al. 2014. Characterization of bacterial communities in solarized soil amended with lignocellulosic organic matter. <i>Applied Soil Ecology</i> 73:97-104.

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Dynamics of Weed Emergence in Alternative Rice Irrigation Systems in California

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The development of resistance in major weed species of rice in California, including *Cyperus difformis* L. (smallflower umbrellasedge) and *Echinochloa phyllopogon* (Stapf) Koss (late watergrass), has necessitated the search for management options that utilize cultural controls such as alternative tillage and irrigation methods. In order to effectively apply these controls, weed germination and emergence under a variety of tillage and irrigation methods needs to be understood. Recently developed laboratory models of germination and emergence for *C. difformis* and *E. phyllopogon* have accurately predicted timing of germination and emergence using soil moisture and temperature (hydro- and thermal-time models) in controlled environments. The long-term goal is to be able to utilize these models to predict weed emergence in the field, and thus, assessments were begun in 2013 to determine the models' validity under field conditions. Two locations known to have large seedbanks with susceptible populations of each species were selected. Beginning from the initial flood or flush, daily counts of emerged *C. difformis* and *E. phyllopogon* seedlings were conducted under two irrigation treatments: continuously flooded (water maintained at approximately 10 cm above the soil), and flushed (flush irrigated when the top layer of soil became dry). Plants were counted until no more plants emerged (45 days for smallflower umbrellasedge, and 40 days for late watergrass). Volumetric water content (m³/m³) and air and soil temperature (°C) were recorded continuously for the duration of the counts. In order to compare the field data to the laboratory-generated data, percent daily emergence was calculated per growing degree-day (GDD), using laboratory-determined averaged base temperature (T_b) for two biotypes of susceptible California smallflower umbrellasedge (18.39°C), and laboratory-determined base temperature for the susceptible biotype HR for late watergrass (9.03 °C). When expressed in growing degree-days (GDD), smallflower umbrellasedge initiated emergence from the flushed treatment at between 103 (±6) (GDD ± S.E.) and 113 (±6) GDD, whereas under the continuously flooded irrigation, emergence was initiated much earlier, between 63 (±2) and 73 (±2) GDD (both p = 0.0037). The average total number of plants that emerged under a continuous flood was 315 (±36) (average total number of plants ± S.E.), which was greater (p = 0.0014) than the average total number of plants that emerged from the flushed treatments (25±3). Late watergrass initiated emergence between 96 (±3) and 109 (±3) GDD in the flushed treatments. Timing of emergence in the continuously flooded treatments was between 104 (±2) and 117 (±2) GDD (no different from the flushed treatments, p = 0.1069 and p = 0.1134, respectively). The average total number of plants that emerged under flush irrigation was 24 (±3), which was no different (p = 0.3549) from the average total number that emerged from the continuously flooded treatment (36±10). When compared to the predicted emergence curves generated using the thermal time model with laboratory-generated parameters, $G = [\log t_g - (\log \theta_{T(50)} - \log (T - T_b))] / \sigma_{\theta T}$, there are differences between the predicted data

generated in the laboratory and observed emergence in the field. Reasons for the differences remain to be further evaluated.

Yellow Nutsedge Control in Nut Tree Crops

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Yellow nutsedge (*Cyperus esculentus* L.) is perennial weed from the Cyperaceae family and is commonly found in tree and vine crops of California. This fast growing plant propagates mostly by tubers and to a lesser extent from seed, and is a particular problem in young orchards and sandy soils. These tubers have several buds that able to sprout after tillage or herbicide applications contributing to yellow nutsedge resilience. The objective of this study was to evaluate control of yellow nutsedge with herbicide treatments and assess treatment effects tuber production and viability. A field experiment was conducted in a four-year old almond orchard in Merced County, CA where yellow nutsedge was the most common weed present (4 to 6 plants per sq ft). The experiment was initiated in March 2013, and sequential treatments applied four weeks later. Herbicides registered in almond were tested alone, in combinations, or sequential applications. Final control assessments were made eight weeks after treatment (WAT) when above ground biomass and weed density were recorded in a 0.25 m² area with the experimental plot. At that time, yellow nutsedge tubers were collected from two soil samples in each plot using a soil auger. Number of tubers, fresh weight, and viability were evaluated. Four WAT, all treatments provided more than 70% control of yellow nutsedge, except paraquat (Gramoxone SL – 3 pt/A) which provided less than 50% control. At 8 WAT, all sequential applications outperformed tank mix treatments in yellow nutsedge control, aboveground biomass, and ground cover ratings. Glyphosate tank mixed with rimsulfuron or flumioxazin controlled yellow nutsedge better than glyphosate tank mixed with oxyfluorfen, carfentrazone, or glufosinate. No treatments significantly reduced yellow nutsedge tuber weight or density at 8 WAT. Average tuber density 35 tuber per liter of soil and an average weight of 0.045 oz per tuber. All treatments significantly reduced the viability of tubers (<14% viable) compared to untreated control (26% viable). Sequential applications of herbicides reduced tuber viability (< 3.5% sprouted) than tank mixes of the same herbicides (> 5.8% sprouted).

Herbicide Strategies for Weed Control in Onions in Northeast California

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Weeds in processing onions can decrease yields, reduced onion stands, and obstruct harvest equipment. Hand-weeding and herbicides are the two main methods used for weed control in Northeast California. Weed control in onions can be particularly difficult due to the early emergence of weeds and the slow emergence and growth of onions after planting. Preemergence herbicides applied shortly after planting often provide the best weed control in onions because they control fast-growing weeds before they compete with the crop. On the flip side, early herbicide applications elevate injury risk as small onions are sensitive to herbicide injury. A weed control study was conducted at the Intermountain Research and Extension Center (IREC) in 2013 to evaluate at what rates DCPA (Dacthal) alone and combined with pendamethalin (Prowl H20) at loop stage can effectively control kochia populations in onions grown on silty clay soil with high organic matter. Sulfentrazone (Zeus) was tested at various rates as a preemergence and post emergence herbicide on the same soil type. Prowl H20 applied immediately after planting and at loop stage and in combination with Zeus were also tested. Onions were planted on April 22, 2013 on 28 inch beds with four seed rows per bed. Plot size was 12ft x 25ft arranged in a randomized complete block design with five replications. Weed densities were evaluated by counting kochia plants in each plot. All plots were hand-weeded at the five-leaf stage in order to prevent excessive weed competition. Onion stand density, visual injury, and crop yield were measured to determine early season herbicide injury and treatments influence on onion yield.

Results showed that Dacthal in combination with Prowl H20 at loop stage worked significantly better than Dacthal alone for controlling kochia on silty clay loam soil with high organic matter. Prowl H20 applied immediately after planting provided higher kochia control than Prowl applied at loop stage. Zeus (unregistered herbicide) applied at the 3fl oz/A rate immediately after planting or after the 3 leaf stage was safe on onions and provided over 88% control of kochia. Zeus applied at 4fl oz/A immediately after planting and at 2 fl oz/A at the loop stage caused unacceptable onion stand loss or yield reduction. Tulelake growers have long believed Dacthal was not effective on Tulelake soils due to their fine soil texture and high organic matter. This research contrasts this previously held belief showing Dacthal applied after planting can be effective at affordable rates when combined with Prowl H20. ¹

Melon Tolerance and Weed Control with New Herbicides

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According to the most recent statistics, the United States is the world's sixth largest producer of melons, with the majority of the country's production occurring in California, who leads the nation in both volume and value; the 2011 crop of cantaloupes and melons in California was worth an estimated \$227 million. Weed control in melons is necessary to maximize yields, but can be difficult because of the limited availability of registered herbicides. The objective of this current study was to evaluate the effects of pre-emergence (PRE) herbicides, along with a layby herbicide, on melon safety and season-long weed control.

The 2013 research trial was seeded on 6 June at a research farm on the University of California–Davis campus. Soil at the site is a fine, silty loam (Yolo series). Both cantaloupe ('Oro Rico' and 'Yosemite') and honeydew ('Saturno') melons were evaluated in the study. Each main plot consisted of three sets of two-row sub-plots (one set for each type of melon) that were 30 feet in length and were on a 60 inch spacing. Every other bed was planted, allowing for 120 inches between seed lines. Herbicides in the trial included: ethalfluralin (Curbit at 4 pt/A), clomazone (Command at 0.55 pt/A), ethalfluralin plus clomazone (Strategy at 4 pt/A), halosulfuron (Sanda at 0.75 oz/A), metolachlor (Dual Magnum at 1.33 pt/A), sulfentrazone (Zeus at 3.2 oz/A) and trifluralin (Treflan at 1.5 pt/A). Except for the Treflan, which was applied at layby, herbicide applications were made after planting (using a backpack sprayer calibrated to 20 GPA), but prior to crop emergence, and incorporated with sprinkler irrigation. Crop size and weed cover and density were evaluated weekly to bi-weekly for the first 6-8 weeks of the experiment. Fruit were harvested from each plot at maturity

The lowest levels of weed control occurred in the Command plots and the untreated check (8-87% cover 3-6 weeks after crop emergence). All other herbicide programs provided good to excellent control of weeds (0-11% cover) for up to 6 weeks after crop emergence. The greatest amount of crop injury (plant sizes were sometimes reduced by >50%) was observed in the Zeus plots, which also provided the best weed control. Herbicide injury was still evident in the Zeus plots at 5 weeks after crop emergence. Control plots, at 5 weeks after emergence, showed reduced plant growth as the result of significant weed competition. Crop yields (total fruit numbers and weights per plot) were the lowest in the check and Command plots (86 fruit/plot, 312 lbs/plot), where weed cover was the greatest. Despite significant early season injury, Zeus-treated plots (109 fruit/plot, 380 lbs/plot) yielded better than the control treatment and as well as the Curbit (101 fruit/plot, 370 lbs/plot) standard. Strategy, Sandea and Dual Magnum performed as well as the Curbit standard.

Evaluation of Pendimethalin Application Timing in Seeded and Transplanted Romaine Lettuce

Katie Neylan, Steve Fennimore, and John Rachuy, University of California, Davis

Experiments were conducted to evaluate several application timings of pendimethalin for crop tolerance and weed control in seeded and transplanted romaine lettuce. Two pendimethalin evaluations were conducted concurrently on romaine lettuce in Salinas, CA. The first trial was performed on seeded lettuce, the second on transplanted lettuce.

In the seeded lettuce trial, pendimethalin at 2.1 pt/A was applied to 1, 2, 3 and 4-leaf romaine lettuce; and compared to pronamide at 2.5 pt/A, applied pre-emergence and to 3 leaf lettuce. In transplanted lettuce, pendimethalin at 2.1 and 4.2 pt/A were each applied 1 day pre-transplant and 1 day post-transplant; and compared to pronamide at 2.5 pt/A, applied at the same application timing. Post-application evaluations for weed density, and crop injury, stand, and yield were conducted during each trial.

In seeded lettuce, pendimethalin applied at 4-leaf or later was safe on romaine lettuce. Pendimethalin applied to 1 to 3 leaf lettuce significantly reduced both lettuce stand and yield compared to pendimethalin applied at the 4-leaf stage or compared to pronamide. Herbicide treatments in the seeded lettuce trial did not reduce weed densities compared to the control. The reduction of shepherd's-purse by pendimethalin, applied to 1 leaf lettuce, was equal to that of the pre-emergence application of Pronamide. In transplant lettuce, both rates of pendimethalin applied pre- and post-transplant were safe on romaine lettuce. When applied post-transplant, pendimethalin at 2.1 and 4.2 pt/A showed significant reduction in crop stand compared to pronamide at 2.5 pt/A. Both rates of pendimethalin, at pre- and post-transplant application timings, did not reduce yield, compared to pronamide. Pendimethalin applied pre- and post-transplant provided good control of sow thistle and total weeds compared to similar applications of pronamide. Pre- and post-transplant pendimethalin applications resulted in similar weed control.

Pendimethalin was not safe for post-emergence use on seeded romaine lettuce prior to the 4th-leaf stage. Pendimethalin applied to 4 leaf lettuce at 2.1 pt/A provided overall weed control and produced crop stand and yields equal to the grower standard (pronamide at 2.5 pt/A) applied at both pre-emergence and 4th-leaf. In transplant lettuce, pendimethalin at 2.1 and 4.2 pt/A were safe when applied to either pre- or post-transplant romaine lettuce. The post-transplant applications of pendimethalin significantly reduced crop stand below that of the pronamide treatment. Pre- and post-transplant applications of pendimethalin at 2.1 and 4.2 pt/A resulted in yields equal to that of pronamide. When applied at either pre- or post-transplant, the two rates of pendimethalin provided significantly greater sow thistle and overall weed control than pronamide.

Spent Oyster Mushroom (*Pleurotus ostreatus*) Substrate as a Pre-emergent Bio-herbicide

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Weed management in organic cropping systems has often been cited as a major problem. Weed control in these systems generally rely on mechanical or physical methods because of the lack of reliable, organically accepted herbicides. In recent years, some organic herbicides have been accepted and registered for use in these certified organic systems. However, all of them are non-selective post-emergent materials that have the potential to injure the crop. Therefore, development of an organically-acceptable bioherbicide that prevents weed seed germination and seedling emergence can be of benefit to organic producers.

Isolated cases of allelopathic properties of spent oyster mushroom (*Pleurotus ostreatus*) substrate on weeds and crops have been reported in literature. The spent substrate is readily available locally and the material at present is being disposed as waste material by the mushroom industry. Therefore, the costs of developing this product as a bioherbicide may be very low. The range of weed seeds that are susceptible to extracts of this substrate is, however, unknown. Similarly, the phytotoxicity of the material to transplanted crops is also unknown. Therefore, the objective of this study was to examine the potential of extracts of spent oyster mushroom substrate as a pre-emergent bio-herbicide.

Spent oyster mushroom substrate was obtained from a local mushroom farm in Sanger . The volume of 3 kg of the substrate was measured and a volume of deionized water equivalent to half that of the substrate was added (1:0.5, v/v i.e. 3 kg of substrate and 3.22 l of water). The substrate and water was thoroughly mixed and allowed to soak for 24 hours. The extracted solution was filtered and collected in a conical flask. Twenty five seeds each of common weeds such as common purslane (*Portulaca oleraceae*), field bindweed (*Convolvulus arvensis*), hairy fleabane (*Conyza bonariensis*), horseweed (*C. canadensis*), and Palmer amaranth (*Amaranthus palmerii*) were placed in a 9.5 cm diameter petri dish containing Whatman#2 filter paper. Five ml of the solution was pipetted into each petri dish. An additional set of seeds was put into petri dishes and 5 ml of deionized water was added. The petri dishes were immediately sealed with parafilm and placed in a growth chamber at a constant temperature of 20°C with a 12 hour day light. Each treatment was replicated five times and the experiment was arranged as a completely randomized design. The seeds were checked for germination every third day for two weeks. A seed with a 1 mm radicle and plumule emergence was considered as germinated. Data for total seed germination was recorded. The experiment was repeated.

None of the seeds of the weed species tested germinated in the solution containing the oyster mushroom substrate extract whereas, the seeds of all the species germinated in the petri dish containing deionized water. Therefore, this study showed that the oyster mushroom substrate extract contained some allelochemical(s). A low molecular weight phenolic composition test is being conducted to determine the potential allelochemical(s) in the extract. The study will be expanded to larger greenhouse and small plot studies to examine the potential of this substrate as a pre- and post-emergence bioherbicide.

Nitrogen Uptake of Glyphosate-Susceptible and Glyphosate Resistant Horseweed and Hairy Fleabane Seedlings

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Horseweed (*Conyza canadensis*) and hairy fleabane (*C. bonariensis*) are troublesome pests in orchards, vineyards, and non-crop areas of the Central Valley. The exclusive use of glyphosate in these areas led to the evolution of glyphosate resistant (GR) biotypes of both these species in the Central Valley. Recent studies reported that the GR biotypes have increased vigor and growth compared to the glyphosate-susceptible (GS) counterparts. However, it is not known if this is due to better nitrogen use efficiency (NUE) in the GR than in the GS plants. Nitrogen (N) is well known as an important nutrient for plant growth and vitality. Plants that have a greater ability to access and assimilate N have a competitive advantage over other plants as they generally have increased biomass and vigor. Therefore, the objectives of this project were to a) determine the rate of N accumulation, and b) to determine total N uptake in the GR and GS biotypes of horseweed and hairy fleabane.

For objective 1, an ion exchange study was conducted using solutions of 0.2mM CaSO₄ and 1.0mM KNO₃. Plants were suspended above solution so only roots were exposed to the solution. The solutions were changed every 12 hours, 4 times and the pH and nitrate (NO₃⁻) concentration of the solution was measured each time. After 48 hours, the plants were removed, separated into roots and shoots, and their dry weights were recorded. For objective 2, GR and GS horseweed and hairy fleabane seedlings were planted in 2" pots containing sterile potting medium, fertilized weekly with a measured amount of N fertilizer, and grown for 60 days. Above- and below-ground biomass was recorded and plants were analyzed for N content. Data were analyzed using analysis of variance (ANOVA) procedures at $\alpha = 0.05$.

Results showed that the pH of the KNO₃ solution increased in a similar manner for both species and their biotypes. This means that NO₃⁻ uptake, especially in the first 12 hours, was greater than the K⁺ uptake and the horseweed and hairy fleabane plants and their biotypes had similar NO₃⁻ uptake patterns. However, NO₃⁻ concentrations remaining in the solutions showed that hairy fleabane was more efficient than horseweed in NO₃⁻ uptake. The GR and GS hairy fleabane had similar NO₃⁻ uptake levels; however, the GS horseweed was more efficient than the GR horseweed in NO₃⁻ uptake. Hairy fleabane accumulated more root biomass than horseweed but the shoot biomass was similar. The GS hairy fleabane had more root biomass than the GR hairy fleabane but the shoot biomass was similar. In contrast, the shoot biomass of the GS horseweed was greater than the GR horseweed.

Some of these findings are contrary to other studies that have shown more aboveground biomass in the GR than in the GS biotypes. However, the other experiments were conducted for longer durations. The second objective of our study may provide more information on N dynamics. These results may have important implications for management of these weed species and their biotypes.

Glyphosate-Resistant Italian ryegrass (*Lolium multiflorum*) in Sonoma and Lake Counties

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In recent years, resistance to glyphosate has become widespread in Italian ryegrass (*Lolium multiflorum*) in areas of northern California and resistance to glufosinate is suspected to be present in some populations. The objectives of this study were to determine the occurrence and geographic distribution of glyphosate and glufosinate resistance in Italian ryegrass within orchards and vineyards of Sonoma and Lake Counties. In 2013, seeds were sampled from 18 ryegrass populations, planted in the greenhouse, and individual plants are currently being cloned and treated with field rates of glyphosate (490 g ae ha⁻¹) and glufosinate (1290 g ae ha⁻¹) to test for resistance. The ryegrass populations screened for resistance to date have shown varying responses to both glyphosate and to glufosinate with the percentage of surviving plants ranging from 8 to 72% for glyphosate and 5 to 26% for glufosinate but many more populations remain to be tested.

Weed Management in Fresh Market Spinach (*Spinacia oleracea*) with Phenmedipham and Cycloate

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Fresh market spinach has a limited number of herbicides and the weed management in this crop depends upon hand weeding. Phenmedipham is a post emergence herbicide registered in California for use on processing and seed spinach (at rates ranging between 550 to 1100 g ai ha⁻¹), but not fresh market spinach. This study evaluates the potential for use of phenmedipham for weed control in fresh spinach in combination with cycloate. Greenhouse and field studies were conducted in 2013 using high and low phenmedipham tolerance spinach varieties. The greenhouse studies showed that phenmedipham at rates of 270 g and 550 g ai ha⁻¹ was safe to spinach when applied at the four leaf stage for the low and high tolerance varieties, respectively. Phenmedipham was evaluated in four field experiments applied to four leaf spinach. It was applied alone at 550 g ai ha⁻¹, and then as a sequential application following cycloate (pre emergence, 1700 g ai ha⁻¹) at rates ranging from 90 to 270 g ha⁻¹. When applied as a single application, phenmedipham was safe to spinach but the weed control was no better than cycloate alone. When applied as a sequential treatment following cycloate, all phenmedipham rates were safe and significantly reduced the weed biomass compared to cycloate alone. Cycloate Fb phenmedipham at 270 g ha⁻¹ provided 87% weed control relative to cycloate alone. This level of weed control was similar to the cycloate plus hand weeding treatment which provided 98% control. Results here show that of cycloate Fb phenmedipham improves weed control compared to cycloate alone, and has the potential to reduce need for hand weeding in fresh spinach.