Overview of Management Options for Controlling Aquatic Weeds. John Madsen, USDA-ARS Exotic and Invasive Weed Research Unit, Davis, CA

While managing aquatic weeds has many techniques in common with terrestrial weed management, there are important differences in the selection and application of these techniques. Aquatic weed management techniques can be divided into four categories of approaches: Biological, chemical, mechanical and physical. Biological control methods include the use of insect herbivores, vertebrate generalist herbivores, and pathogens. Chemical control techniques involve the use of US EPA-approved aquatic herbicides to control weeds that are either submersed or emergent, applying herbicides as foliar sprays or injected into the water. Some common US EPA-approved active ingredients include bispyribac sodium, carfentrazone ethyl, complexed or chelated copper formulations, diquat, endothall, flumioxazin, fluridone, glyphosate, peroxides, imazamox, imazapyr, penoxsulam, topramezone, triclopyr, and 2,4-D. Mechanical approaches include cutting, harvesting, hand removal, diver-operated suction harvesting, and rotovating. Physical control techniques include benthic barrier, drawdown, dredging, nutrient inactivation, and shading. Aquatic plant management must be species-specific to be effective. These methods should be used in the context of an integrated plant management approach, seeking to minimize both the economic and environmental cost of management while maximizing long-term effectiveness. Species-selective control is often desirable, managing the target species while encouraging the growth or regrowth of desirable native plants.

A Comparison of Automated Thinners with Hand Thinning of Lettuce in the Salinas Valley. Elizabeth Mosqueda*[1], Richard Smith[2], and Anil Shrestha[1]; [1]California State University, Fresno, Fresno, CA, [2]University of California Cooperative Extension, Monterey County, CA. *Corresponding author: Elizabeth_mosqueda@ymail.com

Recent labor shortages in the agriculture industry have impacted growers yield and income, especially in high volume producing areas such as California. Furthermore, it has also created a shortage in supply of crops, especially vegetables, which are a highly labor-intensive commodity. In 2012, lettuce growers in the Salinas Valley, which is California's largest producer of fresh market lettuce, began to implement the use of automated lettuce thinners to compensate for these labor shortages. These implements were meant to replace the standard lettuce hand thinning crew which goes through the fields to remove closely spaced lettuce plants and weeds. This provides adequate spacing for optimum crop growth. As these implements are relatively new to many growers, assessments on their efficiency to thin lettuce are imperative for grower's knowledge and livelihoods. Therefore, a study was performed in the summer of 2014 in order to analyze various aspects of the automated lettuce thinners compared to hand thinning. The primary objective of the study was to compare the efficiency of these implements with the hand thinning crew on weed control. The study was conducted at seven different locations. The experimental design was a randomized complete block with each location being a block. At each location, the field was split into two plots with one side being mechanically thinned and the other side being manually thinned. In each treatment, six to ten sub-plots consisting of one 40-inch bed measuring 30 ft. in length were randomly chosen as sampling sites. One to two days prior to thinning, lettuce stand counts and weed counts were taken in each sub-plot. Counts were taken within each seedline, as it is the area where weeds are of primary concern as they can inhibit crop growth if left uncontrolled. The time taken to thin each treatment plot was recorded at each location. Immediately following the thinning process, stand and weed counts were taken again in the designated sub-plots. Doubles, or two closely-spaced plants, were also counted for each treatment and measurements were taken to determine the average plant spacing. Seven to fourteen days prior to the thinning process, a hand crew removed any doubles and weeds at each site. Again, time taken for this process was recorded. It was observed that the automated system was more efficient than the manual system in lettuce thinning ($P<0.05$), as the average thinning time for the two systems was 0.91 hours per acre and 6.56 hours per acre, respectively. Although the automated system left more ($P<0.10$) number of doubles, the time taken to remove the doubles were similar between the two systems. Spacing of plants, which is targeted to be 10 in., was more accurate ($P<0.05$) in the automated system as 71% of plants were between 9 and 11 in. compared to 57% in the manual system. However, the manual system resulted in higher ($P<0.05$) weed removal (73 vs. 68%, respectively) than the automated system. These results suggest that automated thinning holds great potential to aid lettuce growers in the Salinas Valley in various ways. The study will be repeated in the summer of 2015.

Dose Response of Transplanted Tomatoes to Pre-plant Herbicides. Jorge Angeles[1], Anil Shrestha[1], and Kurt Hembree[2]; [1]Department of Plant Science, California State University, Fresno, CA [2]University of California Cooperative Extension, Fresno, CA

In the San Joaquin Valley (SJV), tomato planting has transitioned from direct-seeding, surface-irrigation, and deep tillage to the use of transplants, buried drip irrigation, and shallow tillage. Since drip tape can last at least three years when buried 10-12" deep in semi-permanent beds, tomatoes can be planted several years in a row or rotated with other crops that use similar practices. For several years, the use of pre-plant herbicides in tomato production has had no negative effects on tomato health, until the last few years. In 2009, stunted plants with reduced root growth were discovered in processing tomato fields that had been previously treated with pre-plant herbicides under this growing culture. The plant symptoms and field pattern were linked with the herbicide injury symptoms caused by dinitroaniline herbicides. Compared to the current growing practices in processing tomatoes, the old practices aided the breakdown of pre-plant herbicides that were routinely applied. With the conversion to sub-surface drip irrigation and shallow tillage, the potential of reduced herbicide degradation and increased residue carryover and the potential for negative effects on tomato production are of concern. The objective of this study was to determine the growth response of transplanted tomato plants to incremental doses of soil-applied herbicides at planting. A greenhouse pot study was conducted in summer 2014 to evaluate the effect of incremental doses of three common pre-plant herbicides used in processing tomato production in the SJV. These included trifluralin (Treflan), *s*-metolachlor (Dual Magnum), and pendimethalin (Prowl H2O). The experimental design was a two factor (herbicide type and dose) randomized complete block with four replications. The herbicides were mixed in field-collected native soil at doses of 0, 0.5, 1, 2, 4, and 6 ppm using a cement mixture. The treated soil was added to 3 gallon plastic pots and tomato seedlings were transplanted and allowed to grow for 45 days. Plant growth in terms of height and leaf numbers was monitored weekly. Prior to harvest, chlorophyll concentration in the leaves was estimated by a SPAD meter. At harvest, the plants were clipped at the soil surface and separated into leaves and stems. The total leaf area of the plants was measured and then the aboveground plant parts were dried in a forced-air oven and dry weights were recorded. The root biomass was washed to remove all soil particles, dried in a forced-air oven, and the dry weight was recorded. Data were analyzed using ANOVA, and dose required to reduce biomass by 50% (GR_{50}) of the different herbicides was estimated by non-linear regression models. Results showed that aboveground and belowground biomass was affected by the herbicide type and the dose. However, there was no interaction between the herbicide type and the dose. Averaged over the herbicide doses, trifluralin resulted in the least aboveground biomass, whereas *s*-metolachlor resulted in least below-ground biomass. All three herbicides at doses greater than 2 ppm reduced total aboveground biomass. However, compared to the non-treated control (0 ppm) root biomass was reduced at a dose of 0.5 ppm with further reductions beyond 4 ppm. Non-linear regressions showed that the GR_{50} of trifluralin for both above- and below-ground biomass was lower than that of pendimethalin and *s*-metolachlor. Plant height was only affected by the herbicide type and dose had no effect. At each dose, plants treated with *s*-metolachlor were taller than those treated with trifluralin or pendimethalin. Chlorophyll concentration of the leaves, as estimated by SPAD units, at harvest were affected by the herbicide type and there was an herbicide type by dose interaction. Trifluralin was the only herbicide that reduced chlorophyll concentration at doses greater than 1 ppm. There was no significant difference between the herbicides for chlorophyll concentrations when the data was initially taken (2 weeks after transplant). Herbicide injury symptoms were observed from the third week after planting. Therefore, it can be concluded that all three herbicides tested reduced aboveground biomass at doses greater than 2 ppm; however, doses as low as 0.5 ppm caused reductions in belowground biomass. The effect on the herbicides on the roots at this low dose warrants further research. Future studies will examine the effects of these herbicides at doses ranging for 0.1 ppm to 1 ppm which are similar to residue levels detected by bioassays in grower fields showing dinitroaniline herbicide injury.

Hybridization and the Selection of Adaptive Traits in Large Statured Invasive Grasses. Randall Long, Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, CA

Invasive grasses are a particular problem for conservation and resource managers. A closely related group of Large Statured Invasive Grasses (LSIGs) comprised of Giant Reed, *(Arundo donax)*, and Common Reed, *(Phragmites australis)* are current and emerging species of concern throughout California and the Southwest. *Arundo donax* has been considered an invasive problem in riparian areas, and is a cause of habitat and biodiversity loss as well as a fire promoter. *Phragmites australis* has become a dominant invader in wetlands throughout the world. Within *P. australis* there are many different genotypes within the species, each that exhibit varying levels of invasiveness. The specific genotype that is responsible for most invasions is the type M haplotype from Europe, there are also a number of native haplotypes that occupy specific niches within an ecosystem and do not tend to become invasive. While type M has become established in the bay area and San Joaquin delta, it has not spread to wetlands and riparian areas of southern California. A rapid spread of *P. australis* has occurred recently in the Las Vegas area of Nevada and it has been confirmed that this invasive type is a hybrid of the native and Type M *P. australis.* Current work is being completed with the Southern Nevada Water Authority to track the spread of the hybrid throughout the watershed. Thirty-six populations from Utah, Nevada, and California were sampled for leaf tissue to determine the genetic origin, and over 1,000 seed from each location was collected to determine the viability of hybrid seed compared to the native and M haplotypes. Vegetative rhizomes were collected and planted in a common garden to evaluate the physiological traits of the different haplotypes. This research will provide information on the risk of the hybrid *P. australis* of spreading into the southwest.

Large Statured Invasive Grasses are able to thrive in a diverse group of ecosystems, ranging from coastal wetlands to interior deserts. Both species are considered to utilize the typical C3 photosynthetic pathway that is susceptible to photorespiration in dry or hot environments. However, it has been shown that different ecotypes of *P. australis* exhibit traits that are closer to that of a C4 photosynthetic pathway. I hypothesize that the reason these grasses are able to thrive in different locations is an adaptive trait that allows for a spatial or temporal adaptations to their photosynthetic pathways. Samples have been collected for both species from different locations that would favor either C3 (moderate temperatures and abundant water) or C4 (hot and dry) photosynthesis. They will be analyzed for $\delta^{13}C$ values and compared to the standard values of $\delta^{13}C$ for C3 plants average around -28 and $\delta^{13}C$ values of around -13 for C4 plants. Values that are higher than the standard for C3 plants will indicate that LSIGs are an example of a C3-C4 intermediate plant. Further studies would involve reciprocal transplants and greenhouse studies to see if populations of either species are (1) able to adapt to variations in temperature and moisture over a season or (2) they are genetically predisposed to one type of pathway. Plasticity in their photosynthetic pathways could reveal one adaptive trait that has allowed these grass species to be so successful across a range of ecosystems.

Duration of Weed-Free Period in Organic Lettuce: Crop Yield, Economics, and Crop Quality. Sarah R. Parry*, Ryan Cox, and Anil Shrestha, Department of Plant Science, California State University, Fresno, CA.
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Lettuce is the number one crop in terms of acreage of organically produced crops in California. Estimates show that organic lettuce is produced in about 33,431 acres in California. Weed management in organic cropping systems has been cited as a major challenge. Organic cropping systems generally rely on mechanical, physical, or cultural methods of weed control and hand weeding is often an important component. Therefore, weed management accounts for a substantial portion of farm budgets in organic systems. Critical period for weed control (CPWC) is an important component of integrated weed management systems. CPWC is the period in a crop's growth cycle during which weeds must be controlled to prevent yield losses due to irreversible damage through competition. A sub-component of CPWC is duration of weed-free period, which is the minimum amount of time the crop needs to be kept weed-free to avoid crop yield and quality loss. Knowing the duration of weed-free period in a crop is useful in making decisions on the need for weed control. The determination of duration of weed-free period is even more so important in organic cropping systems in crops such as lettuce, which rely on substantial amount of hand weeding. Therefore, the objective of this project were to determine the effect of duration of weed-free period on 1) crop yield, 2) weed biomass, and 3) crop quality of transplanted organic lettuce.

The experiment was conducted in the certified-organic plot at the California State University, Fresno in fall 2014. Romaine lettuce was grown for 8 weeks, with 8 different durations (weeks) of weed-free periods [0 (no weed control), 1, 2, 3, 4, 5, 6, 7 (weed-free entire 8 weeks)]. The plots were kept weed-free by hand weeding once a week. The experiment was designed as a randomized complete block with four replications. All standard organic production practices were followed. Data were collected on total fresh weight (crop yield), hand weeding costs, weed density, weed biomass, crop quality rating, chlorophyll concentration (SPAD units) of the leaves at harvest, and anthocyanin content. The crop was rated for quality using a 1 to 4 scale (where 4 = excellent, 3 = good, 2 = fair, and 1 = poor). Leaf samples from each plot were taken for analysis of anthocyanin content using a high-performance liquid chromatography (HPLC). Data were analyzed using non-linear regression models at a significance level of 0.05.

Results showed that the critical weed-free duration for lettuce yield was up to four weeks after transplant. The marketable quality of the lettuce based on visual ratings and SPAD readings showed a similar trend. However, total stand counts and diseases incidences were not affected by the duration of weed-free period. The major weed species in the plots were lesser swinecress (*Coronopus didymus*) and burning nettle (*Urtica urens*). Weed biomass data also showed that there was not much benefit in controlling weeds beyond four weeks after lettuce transplant. Therefore, it can be concluded that a weed-free duration of four weeks after transplanting will be sufficient to produce quality Romaine lettuce with optimum yields and weed management costs in organic production systems.

Uncovering the Mechanism of Resistance to Propanil in Ricefield Bulrush (Schoenoplectus mucronatus (L.) Palla) from Rice Fields of California.

Rafael Pedroso, University Of California, Davis, CA

Schoenoplectus mucronatus (L.) Palla (ricefield bulrush; SCPMU) is a problematic annual weed (Cyperaceae) of rice in 43 countries. In California, SCPMU management was complicated by the evolution of resistance to acetolactate-synthase (ALS)-inhibiting herbicides in 1997; ALS-resistant (R) populations are now widespread throughout CA rice fields. In the wake of resistance to ALS inhibitors, applications of the post emergent photosystem II (PSII)-inhibiting herbicide propanil (3, 4-dichlopropionanilide) were increased to control ALS-R SCPMU and other weeds of rice. Lack of proper control following propanil spraying was detected in 2012 suggesting resistance to this herbicide might have also evolved in some SCPMU populations. The objectives of this research were to confirm resistance to propanil, ascertain resistance levels, and establish the underlying mechanisms of resistance in SCPMU biotypes collected in rice fields of California. Our results indicate biotypes derived from field-collected populations displayed a high level of resistance to propanil (R/S ratio equaled 6.5). When rice cv. M-206 and propanil-susceptible (S) and –R SCPMU were sprayed with propanil jointly with the insecticide carbaryl (a known propanil synergist that inhibits propanil degradation in plants), all plant species except propanil-R SCPMU experienced significant growth suppression, suggesting propanil metabolism is not the mechanism of resistance in the R biotypes used. Afterwards, experiments were conducted to determine whether or not P450 monooxigenases and esterases are involved as a mechanism of resistance to propanil. Since such enzymes and inhibited by the organophosphate insecticide malathion, propanil was sprayed jointly with this herbicide onto rice cv. M-206 and propanil-R and –S SCPMU biotypes. Results indicated a 48% decrease in the resistance level of R biotypes (which was not detected in S biotypes or rice) and thus suggested involvement of either P450s or esterases; inhibition of these enzymes, however, did not yield results of similar magnitude to those reported for other propanil-R weeds displaing metabolic resistance, and could be a secondary resistance mechanism. Interestingly, propanil-R biotypes were found to be cross-resistant to other PSII-inhibiting herbicides (diuron, atrazine, bromoxynil, and metribuzin), although resistance to atrazine is weak. These results suggested propanil resistance might involve the PSII-inhibitor binding site at the target protein D1 of PSII. Therefore, we sequenced the herbicide-binding region of the chloroplast *psbA* gene, which codes for propanil's target site (e.g. the D1 protein), where a valine to isoleucine substitution at amino acid residue 219 was identified. This mutation had already been identified in *Poa annua* biotypes resistant to diuron and metribuzin and in propanil-R *Cyperus difformis* from California, and is not associated with resistance to atrazine in agreement with our results. Therefore, unlike resistance in grasses and selectivity in rice - at which resistance is attributed to enhanced propanil degradation, the mechanism of resistance to propanil in SCPMU from CA resembles propanil resistance recently discovered in another weedy sedge (*Cyperus difformis*) and is endowed by a single mutation at the D1 protein, which affects binding of propanil at its target-site. For control of propanil-R SCPMU (and given the widespread resistance to ALS inhibitors in

CA rice fields), it is thus necessary to switch herbicide modes of action away from PSII and ALS inhibitors, and prevent spread of resistant populations by preventing seed contamination by performing proper cleaning of tillage and harvest machinery. Further research has also indicated that other herbicides used in rice are effective against propanil-R SCPMU, such as carfentrazone, benzobicyclon, and thiobencarb. Since applications of malathion and propanil in combination decreased the biomass of propanil-R SCPMU but not rice cv. M-206, future research will be carried out in the field to evaluate the feasibility of use of this mixture as an option for management of propanil-R ricefield bulrush.

Herbicide Discovery: The Search for New Modes of Action. Olena Castello, Cliff Gerwick, Tim Johnson, Paul R. LePlae Jr., William Lo, and Joshua J. Roth, Discovery Research, Dow AgroSciences LLC, Indianapolis, IN

Herbicide-resistant weeds were first reported in the 1950s and the number of weeds resistant to existing herbicides has grown over time. At the same time, Global food demand continues to increase and the regulatory requirements for new agricultural products shift and expand. To address these challenges, one approach Dow AgroSciences is pursuing is the discovery of herbicides with novel modes of action. Using an imidazole carboxylic acid herbicide hit as a case study, the process of herbicide discovery, addressing mode of action concerns, and the optimization of chemical structures will be presented.

Herbicide Discovery Screening – Back to the Future? *Rex Liebl, Global Herbicide Product Development, BASF, RTP, North Carolina*

Herbicide discovery involves the identification of screening hits and optimization of those hits to achieve the necessary efficacy, crop selectivity, and regulatory attributes. Once a compound that fulfills these requirements has been identified it will enter the commercial development phase.

Historically, herbicides have been discovered by “randomly” screening compounds for activity on weeds. Starting in the 1950s through the 1980s this approach was widely successful, resulting in the discovery of essentially all herbicides in commercial use today. In the 1990s, as the pace of discovery slowed, the agrichemical industry turned to new *in vitro* screening and molecular design technologies complemented by advancements in functional genomics to pick up the pace of discovery. But despite the promise, these new approaches have yet to deliver new herbicide candidates. Consequently there is renewed interest in screening compounds directly on target plants. But this time around we are able to combine whole plant testing with the speed of in vitro screening using robotics and automation. High throughput in vivo screening coupled with new diagnostic tools for rapid mode of action determination should greatly aid in the identification of new herbicide candidates.

Managing Junglerice and Other Summer Grasses in Orchards.

Brad Hanson, Marcelo Moretti, and Seth Watkins, University of California, Davis, CA

California orchardists and pest control advisors have noted increasing problems with junglerice (*Echinochloa colona*) and other summer grasses in recent years. In many cases, the problem is due to suspected or confirmed resistance to glyphosate. However, summer grasses like junglerice can be challenging even in orchards treated with preemergence herbicides because they emergence and grow during summer, long after dormant season herbicide applications.

Junglerice is quite variable in form, ranging from 1-3 ft tall and can be either erect or prostrate and is often confused with a closely related species, barnyardgrass (*Echinocloa crus-galli*), at the seedling stage. Junglerice usually has a flattened sheath, relatively hairless leaves, and no ligules or auricles. The most distinctive feature of junglerice in most populations is the red or purple bands on the leaves; however, this too can be variable and is not present in all populations or in all light environments. For more information on junglerice, refer to the UC-IPM site at http://www.ipm.ucanr.edu/PMG/WEEDS/junglerice.html

Glyphosate-resistant junglerice has been documented and confirmed in numerous orchards in the Sacramento and San Joaquin Valleys. Interestingly, there appears to be a range of levels of resistance which suggests that more than one mechanism of resistance may exist in California populations. This indicates that resistance likely developed independently several times in different areas of the state and is not simply due to movement of seed from one location to new areas. Research on the phenology, genetics, mechanism of resistance, and potential for gene flow among weedy Echinocloa species is ongoing at UC Davis.

In herbicide trials conducted during 2013 and 2014, results did not indicate any cross-resistance of glyphosate-resistant junglerice to herbicides with other modes of action. Postemergence herbicide including rimsulfuron, clethodim, sethoxydim, fluazifop, paraquat, and glufosinate all worked well on emerged junglerice seedlings. However, those products with no residual activity did not always provide good control if new seedlings continued to emerge following the application; these cases would require additional treatments.

Preemergence herbicides including oryzalin, penoxsulam/oxyfluorfen, rimsulfuron, pendimethalin, and indaziflam also performed well on both glyphosate-susceptible and –resistant junglerice populations. In general, preemergence treatments that included pendimethalin or oryzalin were very effective on summer grass weeds, particularly if these dinitroaniline herbicides were applied in late winter or early spring as part of a sequential treatment program.

Growers facing the challenge of winter annual weeds plus emerging problems with summer grasses such as junglerice, should consider tankmix and sequential applications of preemergence herbicides in order to reduce the density of weeds that will have to be controlled later with postemergence herbicides. There are no one-size-fits-all approaches to season-long weed control in California orchards, but several herbicides are available and can be used to manage difficult summer weeds, including glyphosate-resistant junglerice.

Pre and Post Emergent Control of Horseweed in Vineyards; A Season Long Approach.

Mick Canevari[1], Paul Verdegaal[1], Don Colbert[1], Randall Wittie[1]; [1]University of California Cooperative Extension, San Joaquin County

Introduction

Horseweed/Marsetail *Conyza Canadenses* is a major weed issue for many California tree and vine growers. Horseweed is especially problematic because it is a prolific seed producer setting 200,000 seeds in a single large mature pant with 86% of the new seeds that can germinate immediately upon seed shed. Its long germination time extends from fall to spring and can act as an annual or biennial. It is a tall stout plant reaching 4-5 feet high growing into the grape canopy that interferes with cultural and harvesting practices. It has a deep tap root that will compete efficiently for water and nutrients. In addition, years of widespread reliance on a glyphosate dominated program has led to development of a resistant biotype spreading across the San Joaquin and Sacramento valleys.

Methods and Procedures

In 2014 a series of Pre and Post emergent herbicides trials were conducted in the Lodi wine grape district with new and existing products to evaluate an effective long term control program. Pre-emergent trials were initiated beginning November 2013 to January 2014. Vineyards sites of heavy populations of horseweed where selected and preparation of trials was done by removing all leaves, debris and old horseweed carcasses. Any new germination of horseweed was removed with a combination of Roundup and Rely tank mix to insure only new emerging plants were recorded. All treatments were made with a Co2 backpack sprayer 35psi and spray volume was 37 gpa. On December 9, 2013 observed a few horseweed plants germinating in the check plots and herbicide treatments were all free of weeds. A substantial number of horseweed plants were observed in the check plots, cotyledon to 2 leaves and 0.25" diameter on January 22, 2014. Evaluations were done on monthly intervals until June.

Summary

Results for pre-emergent control trials are shown in PowerPoint graphs listed as Table 1& 2. Long term pre-emergent activity up to six months was provided best with Alion and Chateau 98 & 100 percent respectively. Mission, Matrix, Zeus and Trellis began to break after four months but when in tank mix combination with Alion or Chateau remained at 100% for six months.

Post emergent trials were set up to evaluate horseweed escapes or situations of herbicides breaking. Post trials began with timing **A** initiated February on 17, 2014 and timing **B** beginning March 17 of 2014 to various sizes of horseweed plants growing in a Lodi vineyard. Plot were 5 by 14 ft. arranged in a randomized complete design with three replicates. Applications were made with a CO_2 backpack sprayer. Hasten (MSO) 1%V/V and Ammonium Sulfate (fertilizer) 8.5 lb/100 Gal was added to all treatments. Table 3. A PPT graph showing results of post herbicide treatments at different horseweed growth stages.

<u>Application "A"</u> was an early timing on small plants. For each treatment three horseweed growth stages were flagged in each treatment/rep with a total of 10 plants in each plot. **Growth stage #1** = <1 inch diameter; **Growth stage #2** = 1 to 2 inch diameter and **Growth stage #3** = >2 inch to 3 inch diameter and prior to bolting. Visual observations were used to determine plants to be dead or alive and results were reported as % Dead Plants. Also, an overall % horseweed control rating was made for each treatment on each observation date.

Timing “A” Summary On Controlling The Three Horseweed Growth Stages Ranging from <1” to 3” in Diameter.

Horseweed Size #1 = <1” diameter; Size #2 = 1-2” diameter; Size #3 = >2-3” diameter

Shark gave poor control on all three horseweed growth stages. Rely, Roundup Powermax, Treevix, Gramoxone and Rely + Powermax gave complete control of the three horseweed growth stages. Broadworks *mesotrione* controlled all 10 horseweed Size #1 plants (<1” diameter), killed 9 out of 10 plants Size #2 (1-2” diameter) and Size #3 (>2” -3” diameter). Broadworks was slow acting with both soil and postemergence activity; it took 25 DAT to obtain maximum control of horseweed.

Application “B” was made March 17, 2014 in 57 gpa of water to larger horseweed plants. For each treatment four horseweed growth stages were flagged, 10 plants for each growth stage.

Growth stage #1 = 3 to 4 inch diameter, bolting, 1 inch height. **Growth stage #2** = >4 inch to 5 inch diameter, bolting, 1 inch height. **Growth stage #3** = >5 inch to 6 inch diameter, bolting 1 to 1.5 inch height. **Growth stage #4** = >6 to 7 inch diameter, bolting, 1.5 to 2.5 inch height. Plants were observed and determined to be dead or alive and results were reported as % Dead Plants. Also, an overall % horseweed control rating was made on each observation date.

Timing “B Summary on Controlling The Four Horseweed Growth Stages Ranging From 3 - 7” Diameter (Early Bolting)

Size #1 = 3”- 4” diameter, bolting, 1” height; Size #2 = >4”-5” diameter, bolting, 1” height; Size #3 = >5”-6” diameter, bolting 1.5” height; Size #4 = >6”-7” diameter, bolting 1.5-2.5” height.

Rely 1.17 lb ai/A: Killed 10 out of 10 plants horseweed Size #1, Size #2 and Size #3, growth stage ranged from 3-6” in diameter, bolting, 1-1.5” height. Killed 9 out of 10 plants Size #4 growth stage <6” - 7” diameter, bolting 1.5 to 2.5” height.

Rely 1.5 lb ai/A: Quite similar to Rely 1.17 lb ai/A; killed 10 out of 10 plants Size #1, #2 and #4 with 9 out of 10 Size #3.

Roundup Powermax 2.75 lb ai/A: Killed 9 out of 10 horseweed plants Size #1 with only 3 plants dead out of 10 for the larger growth stages.

Treevix 0.0438 lb ai/A: Killed only 6 to 8 plants out of 10 on the four horseweed growth stages.

Gramoxone 1.0 lb ai/A: Killed only 6 to 8 plants out of 10 on the four horseweed growth stages.

<u>Broadworks 0.188 lb ai/A:</u> Killed 10 out of 10 plants Size #1, 9 out of 10 for Size #2 and #3 and 7 out of 10 for Size #4.

<u>Rely 1.17 lb ai/A + Powermax 1.38 lb ai/A:</u> Killed 9 out of 10 horseweed plants Size #1 and #3 and 10 out of 10 plants for Size #2 and #4.

<u>Rely 1.5 lb ai/A + Roundup Powermax 1.38 lb ai/A:</u> Killed 10 out of 10 horseweed plants Size #1 and #4, 9 out of 10 plants Size #2 and #3.

Best post treatments for controlling the larger four horseweed growth stages were Rely applied alone and Rely tank mixtures with Roundup Powermax followed by Broadworks, Gramoxone Inteon, Treevix and Roundup Powermax.

Table1. Pre-emergent Horseweed control extending for six months.

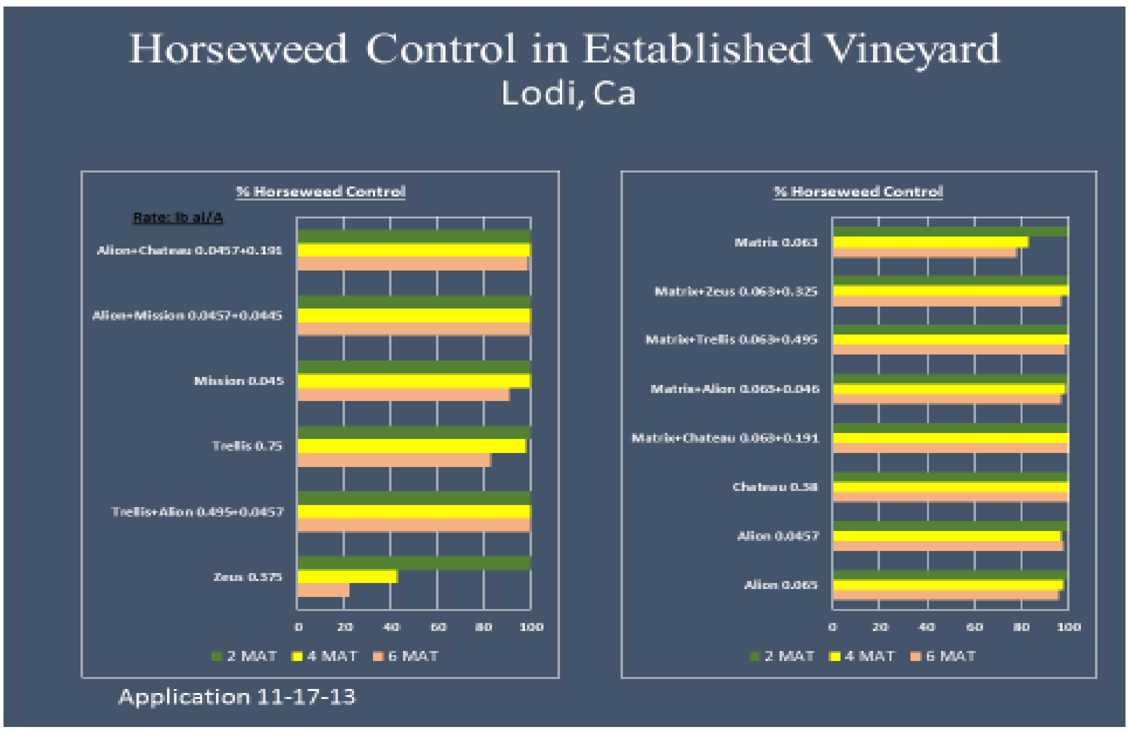


Table 2. Pre-emergent Horse weed control extending for 5 months.

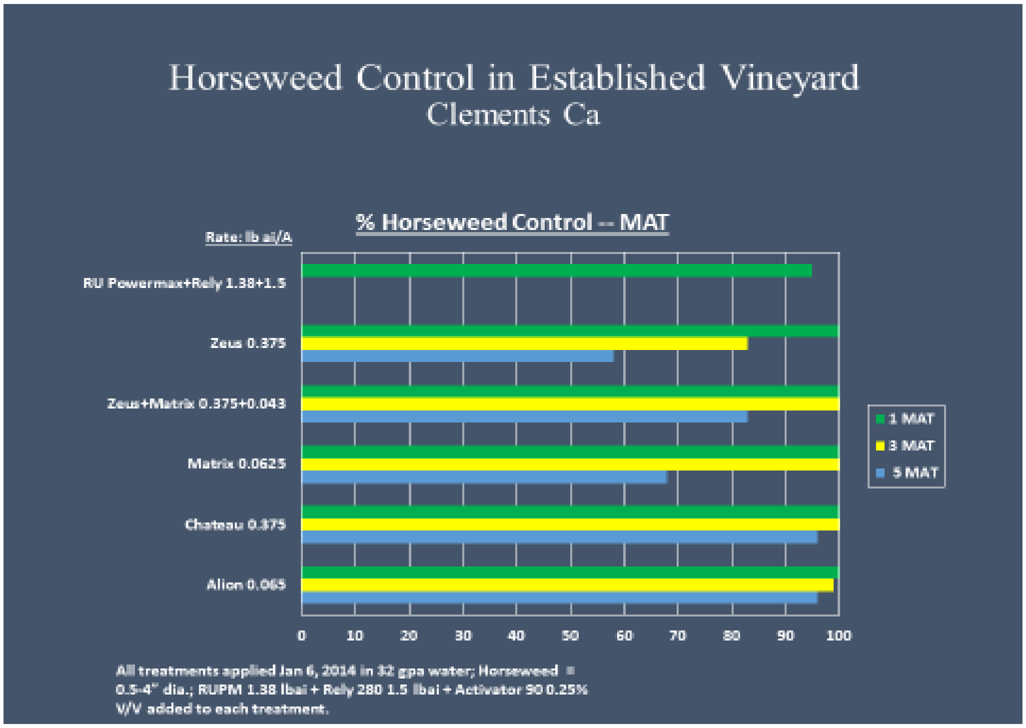
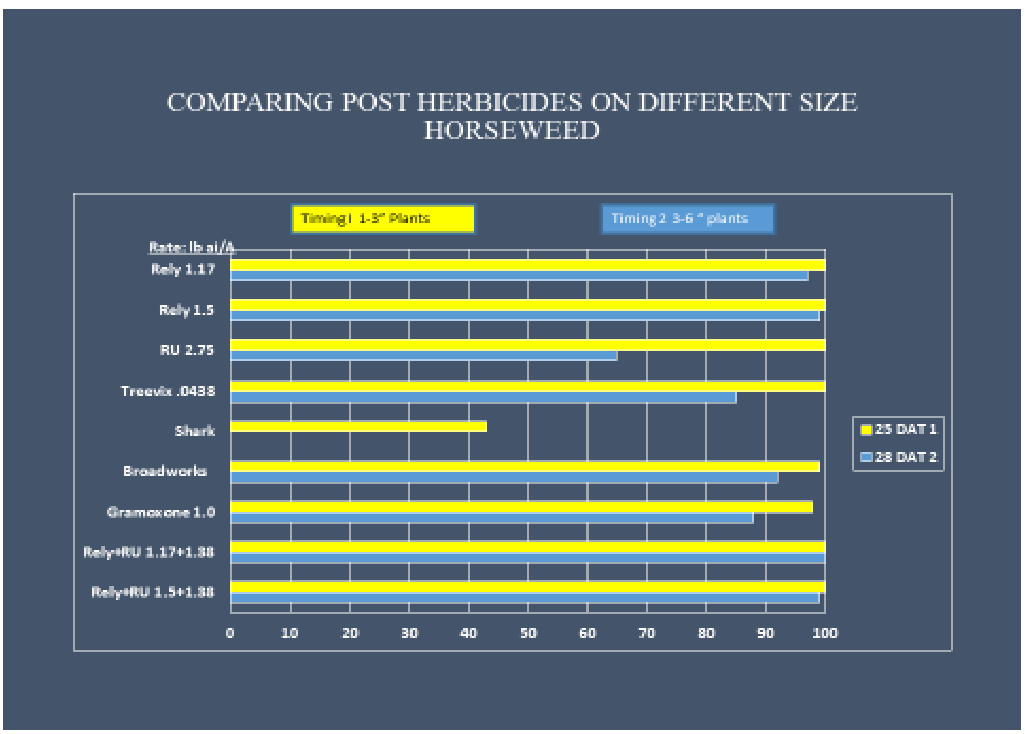


Table 3. Post Herbicide Evaluations on different size Horseweed plants.



Burn-down Control of Tough Weeds in Grapes with Flazasulfuron.

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Weed control with postemergence herbicides can be challenging for grape growers in California, given the diversity of weeds and their sensitivities to the various herbicides, the need for ample equipment and labor to be able to treat in a timely manner, the presence of herbicide-resistant species, and the type of trellis system used, which influences canopy development and the ability to spray the weeds without injuring the grapevine foliage or fruit. While it would be ideal if we could treat emerged weeds and kill them the first time without having to re-spray, this is not always the case. Failures in postemergence herbicide activity often come down to late spray timing and/or lack of weed sensitivity to the materials used. In particular, *Conyza canadensis* (horseweed), *C. bonariensis* (hairy fleabane), *Urtica urens* (burning nettle), and *Epilobium brachycarpum* (panicle willowherb) are difficult to control with postemergence herbicides alone, particularly when glyphosate is used. In most cases, these weeds require combinations of pre- and postemergent sprays to be managed effectively. Flazasulfuron (Mission) was recently registered for use in grapes in California and is known to have preemergence activity on some key weeds, including *Conyza* spp. However, little is known on the postemergence activity of flazasulfuron on hairy fleabane and other problematic weeds. Two field trials were conducted in 2014 to evaluate the effect of flazasulfuron as a postemergence treatment in grapevines to kill well-established horseweed, hairy fleabane, burning nettle, and panicle willowherb. In both trials, flazasulfuron was used in combination with glyphosate, flumioxazin, and glyphosate + flumioxazin and compared to a grower standard treatment of glyphosate alone. For each trial, treatments were arranged in a Randomized Complete Block design with three replications. Herbicides were applied using a CO_2-pressurized backpack sprayer with 8004 spray nozzles in a spray volume of 39 gpa. Ammonium sulfate and a methylated seed oil were added to all treatments. In the first trial, combining flazasulfuron plus glyphosate gave 95-99% control of established horseweed and hairy fleabane plants, regardless of size or age. Control was similar when flumioxazin was added to this mix. Glyphosate applied alone only provided 20% control of horseweed and hairy fleabane and adding flumioxazin to the glyphosate only marginally improved control to 30%. In the second trial, combining flazasulfuron with glyphosate gave 99-100% control of burning nettle, panicle willowherb, and hairy fleabane. Adding flumioxazin to this mix controlled these weeds completely. As in the first trial, glyphosate used alone did not provide effective control, giving 40%, 43%, and 67% control of burning nettle, panicle willowherb, and hairy fleabane, respectively.

Revisiting the Principles of Integrated Weed Management in Vineyards.

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Herbicides are an important component of weed management in vineyards and have contributed to the economic production of raisin, table, and wine grapes for several decades. However, in recent years, the evolution of several herbicide-resistant weed species have compelled researchers, educators, and growers to explore alternatives to chemical weed management in vineyards. Although an alternative mode of action may be available for the control of weeds that have evolved resistance to a certain herbicide, it is important to remember that there are only about 25 different herbicide families based on their site of action and less than half of these are actually labeled and registered for use in vineyards. Additionally there are none to very few new herbicide modes of action in the development pipeline. Therefore, it is important to protect the herbicide resource we have and prevent the onset of new herbicide-resistant weeds. It is not only essential to rotate herbicide families but also important to revisit the principles of integrated weed management in vineyards.

Integrated weed management advocates the use of several weed control tactics including physical, cultural, biological, mechanical, and chemical weed control. Again, sole-reliance on one particular technique will select for weed species that will become adapted to the method of control. Further, cost-effectiveness of one particular method can also be an impediment to adoption as the sole method of control. Therefore, these techniques should also be used in a truly integrated manner. There are several principles of integrated weed management that have been developed for annual cropping systems that can be adapted to vineyards and other perennial cropping systems. For example, it is very important to start clean with good weed control during vineyard establishment as the critical period for weed control in vineyards is the first 12 weeks of vine growth. Uncontrolled weeds during this period can reduce and stunt vine growth and serve as a refuge for various invertebrate and vertebrate pests, and pathogens for vine diseases. Care should be taken while selecting appropriate control tools during this phase of vineyard establishment as the vines can be susceptible to damage by chemical and other methods of weed control. Once the grapevines have been established, they are more tolerant to weed competition and can withstand greater weed densities. Although certain densities of weeds in established vineyards may not directly result in yield or quality loss in the grape berries, the weeds can again be an impediment in surface irrigation systems, harvesting machines, and refuges for pests. Also, it is important not to let weeds set seeds as a single weed can produce thousands of seeds that increase the size of the seedbank where the seeds can live for several years.

Other tools for weed management in vineyards include mechanical and thermal weed control methods, to name a few. Mechanical and thermal (flaming in particular) tools can generate dust and smoke and this can have implications associated with air quality regulations in the San Joaquin Valley (SJV). Also, their application timing and efficacy can be affected by soil moisture levels. However, mechanical methods in general can be very cost-effective and can provide excellent weed control. Again, reliance on mechanical weed control alone can cause weed species shifts. For example, continuous reliance on implements that control weeds by shallow cultivation tends to select for grassy weed species and sedges that become the dominant weeds in consecutive years. Therefore, mechanical tools should also be combined with other strategies such as spot-treatment with herbicides, etc.

Monitoring is also an important component of integrated weed management. Proper monitoring of vineyards is essential for the evaluation of weed management methods and for the development of future weed management strategies. In summary, integrated weed management is not a new concept but it is time to revisit its principles to prevent the evolution of new herbicide-resistant weeds and protect the existing herbicide families registered for use in vineyards from becoming ineffective, prevent the adaption of certain problem weeds to a particular method of weed control, and manage weeds in an ecologically sound manner.

Grower Perspective for Weed Control in Grape Vines. Todd Berg, Viticulturist/PCA Trinchero Family Estates, St. Helena, CA

The more difficult to control winter weeds such as filaree and Malva can be controlled effectively when the weed size is relatively small. Likewise, early treatments of pre-emergent herbicides of Prowl or Surflan in October or November has proven to be effective for Italian ryegrass.

However, the grower is faced with a dilemma of starting early for better control of more difficult Winter weeds, but giving up a shorter lasting residual program for many of the problematic Summer weeds such as: barnyard grass, pannicle willowherb, bristly oxtongue, shortpod mustard, horseweed, field bindweed and fluvellin.

Growers can overcome this by applying contact burn down applications of Goal and Shark, prior to leaf drop, which have proven very effective to clean up dense populations of filaree and little mallow. After leaf drop, an application of glyphosate and oxyfluorfen (goal) has proven to be a highly effective combination. Pre-emergent products targeted for summer weed control can then be delayed to extend their performance longer into the summer months.

Another approach is to use a split application for better overall control. This would consist of starting early post harvest and then re-treating again at a later date.

Finally, where the site allows, growers should consider an integrated approach where they can use mechanical cultivation combined with chemical control. In this program a berm is built in the fall to get early weed growth under control. A delayed pre-emergent program is applied and mechanical cultivators are used in the late summer months when drift from contact products is a concern.

Action Threshold Based Cyanobacteria Management for Preserving Drinking Water. *Dave Blodget*[1], Shaun Hyde[2], and West Bishop[3]; [1]SePRO Corporation, Bakersfield, CA, [2]SePRO Corporation, Carmel, IN, [3]SePRO Corporation, Whitakers, NC.*
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Cyanobacteria can cause significant impacts to drinking water quality through increased water treatment chemical demand (e.g. chlorine), elevated levels of disinfection by-products, and production of metabolites like volatile organic compounds (e.g. taste and odor compounds). These taste and odor compounds (e.g. geosmin and MIB) are of particular concern due to the difficulty and expense of removal during the drinking water treatment process as well as the ability for humans to detect an off flavor at extremely low levels (5-10 ppt) and associate this detection with safety of consumption. Managing source water to offset cyanobacteria blooms is an effective approach to enhance the quality of finished water. Silverwood Lake is a popular recreational resource and domestic water supply for an estimated 3 million residents in Southern California. The California Department of Water Resources (DWR) and Metropolitan Water District of Southern California routinely monitor Silverwood Lake and adjacent waterbodies to test for cyanobacteria and the associated taste and odor (T&O) compounds geosmin and 2-methylisoborneal. When cyanobacteria and T&O levels reach action thresholds, these agencies work to implement management practices including treatment of source water prior to entering the water treatment plant. As geosmin levels began to increase in Silverwood Lake in June 2014, DWR collaborated with SePRO Corporation and to assess, prescribe and implement a treatment program. The algaecide PAK® 27 was applied to the lake on July 1 and 2, 2014 targeting the cyanobacteria (dominated by *Anabaena* spp.) as the identified culprit of taste and odor production. The treatment provided rapid decline in cyanobacteria one day after application and sustained a >90% reduction for over two weeks after treatment. No further treatments were required to maintain water below action threshold levels for the remainder of the growing season. Geosmin concentrations dropped 56% seven days after treatment and continued decreasing with a 98% reduction documented 21 days after treatment and non-detect MIB and geosmin at 28 DAT. This targeted source approach to drinking water management can provide significant and rapid relief of nuisance and potentially harmful cyanobacteria, improve source water quality, and decrease in-plant management inputs required to achieve drinking water objectives.

Abundance and Size Distribution of Aquatic Plant Fragments Following Typical Mechanical Harvesting Operations at Lake Tahoe.

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Due to prohibitions against using aquatic herbicides in Lake Tahoe, the management of excessive biomass produced by Eurasian watermilfoil, curlyleaf pondweed, and coontail in the Tahoe Keys marina as relied on mechanical harvesting. The presence, abundance and distribution of these plant impairs ecosystem services associated recreations uses and impedes establishment of native fish. The harvesting operations occur in the two main "lagoons" in South Lake Tahoe and provide open "lanes" for boat traffic. This management method also produces fragments of the target plants that can spread within the lagoons and may be transported to Lake Tahoe proper. At four sites in the Tahoe Keys, we deployed a rectangular net from a boat along fixed linear transects to capture, measure, count and identify (to species) the fragment present before and after typical harvest operations. Results showed that number of fragments and size (length) of fragments increased after harvest and that the relative abundance of species fragments mirrored the relative species abundance found in prior plant surveys. The data suggest that some improved methods to capture fragments could be employed, but also point to the physical limitations on efficacy associated with using large harvesters in the lagoons where access to near-shore plants is limited.

Controlling Invasive Aquatic Weeds in the Sacramento-San Joaquin Delta.

Angela Llaban, California State Parks, Division of Boating and Waterways, Sacramento, CA

The California State Parks Division of Boating and Waterways (DBW) is the designated lead State agency for cooperating with agencies of the United States and other public agencies in controlling water hyacinth (*Eichhornia crassipes*), *Egeria densa*, and South American spongeplant (*Limnobium laevigatum*) in the Sacramento-San Joaquin Delta, its tributaries and the Suisun Marsh. Other aquatic invasive weed species such as curly leaf pondweed (*Potamogeton crispus*) may also be targeted for control in 2015. Program objectives are to keep waterways safe and navigable by controlling the growth and spread of non-native, invasive plant species and to minimize negative impacts on navigation, public safety, recreation, ecosystem services and agricultural activities in Delta waterways. Because of the continued survivability and persistence of these invasive aquatic weeds in the Delta, legislative mandate is for control, rather than eradication. The primary method of control has been chemical treatment, supported by manual removal and mechanical removal. Biological controls are being researched in collaboration with the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) and California Department of Food and Agriculture. DBW's Aquatic Weed Control Programs balance potential impacts of invasive aquatic weed management by working to minimize non-target species impacts and prevent environmental degradation in Delta waterways and tributaries.

Eurasian Watermilfoil Control in the Western U.S. John D. Madsen, USDA-ARS EIWRU, UC-Davis, Davis, CA

Eurasian watermilfoil (*Myriophyllum spicatum* L.) is a widespread submersed aquatic weed in Western U.S. water resources. Introduced from Europe and Asia, it is well-adapted to invade lakes, rivers, reservoirs, permanent irrigational canals, and estuaries. As might be suspected from a pest of such diverse habitats, a range of management options have been used to fit these environments. I will present scenarios from a range of habitats covering research from the past 25 years, and demonstrate both effectiveness and selectivity in managing this pest. The key to managing Eurasian watermilfoil in western water resources is understanding the water exchange characteristics of the site. Laboratory-based concentration / exposure time studies for specific combinations of herbicides and target plants have provided an excellent basis for selecting herbicides for water exchange conditions. For low exchange sites, the use of long exposure time products may provide excellent control at relatively low cost. For intermediate exchange sites, auxin-mimic products like 2,4-D and triclopyr provide excellent control with intrinsic selectivity. As expected exposure time decreases, tank mixes of auxins and contact herbicides have provided good control. At the shortest exposure times, contact herbicides such as endothall or diquat are the best choices for control.

A Historical View of Weed Control Technology that Informs Current Practice and Future Development. Carl Bell, Emeritus, University of California, San Diego, CA
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The domestication of wild plants to become desirable crops was the beginnings of agriculture. Weeds were the concomitant domestication of unwanted plant species along with the crop species in the same site. So the history of weed control technology is co-existent with the history of agricultural technology. Weed control technology started out in 8000 BCE as the plow and hand-weeding (which includes hand-pulling, cutting with a knife, hoes and mattocks), and it stayed that way for the next 10,000 years until the 18th Century CE; there was not much change. An important factor, one that is sadly overlooked, for this 10 millennia lack of improvement is that there was an abundance of labor, mostly women and children, to hand-weed.[1] It is not surprising, therefore, that the beginning of the industrial age in Europe was accompanied by improvements in weed control technology; not just because it was an age of invention but also because women and children were being pulled off farms to work in industry.

The name that stands out in the industrial age with regard to weeds is Jethro Tull (1674-1741), a gentleman farmer in England. He invented the grain drill and cultivation tools. Actually, Romans and farmers in India were using similar tools 2,000 years ago, but they were never in widespread use (likely because of the abundance of labor); so maybe we should say that Tull re-invented these tools. Regardless, Tull's grain drill and cultivation ideas were widely adopted and replicated in the 18th Century, aided by the ease of creating and distributing printed materials like newspapers, books and pamphlets. Tull's creations fostered the rapid development of these types of tools in Europe and North America, and formed the basis of what was called the British Agricultural Revolution. The grain drill did a simple thing; it planted the grain crops in rows. Before the drill, crops were hand-scattered over plowed fields. The weeders, the women and children, had to take time to make sure they were weeding just the weeds and not the crop; so knowing that anything outside the crop row was a weed made the job much simpler. It also allowed Tull's cultivation tool, a horse-drawn harrow to be used between the crop rows to loosen the soil between the drill rows and to kill weeds.

Cultivation tools have been the mainstay of weed control for nearly three centuries. These tools, using animal traction and later tractors, became quite varied and specialized. One of the most useful and inventive tools in California was the sled planter system. This tractor-drawn implement was a platform with runners that ran in the furrows. The sled hugged the beds and kept the platform closely in line with the bed-top. During a cropping season, the sled was first

[1] See http://croplifefoundation.files.wordpress.com/2012/05/solving-africas-weed-problem-report1.pdf for an excellent discussion of this issue as it exists today in Africa. This Crop Life Report states that smallholder farms spend 50-70% of their labor handweeding; that women contribute 90% of the handweeding labor; and 69% of farm children aged 5-14 miss school during peak weeding periods.

outfitted with planters, which sowed seed in very straight lines. After the crop germinated, cultivation tools were fitted on the sled just off the seed lines. This tool allowed cultivation very close to the emerging crop, usually within two inches on both sides of the seedline. Some of the other ingenious cultivation tools, many developed on farms in California for specific purposes, include flexible tine and rod weeders; rotary hoes; and finger weeders. In orchard crops cultivation implements like the French Plow cultivate weeds, but then through a mechanism, are automatically pulled back away from the vine or tree trunk. These tools are discussed thoroughly in the fourth edition of Principles of Weed Control. The success of cultivation for weed control has been remarkable, but close guidance to crops, especially between crops in the seedline has always been the major challenge. The realization of robotic weeders and thinners in recent years has been very exciting. Robotic systems and digital guidance only happened, in my opinion, because there was a highly developed practice of mechanical cultivation to build upon.

In Asia, rice was domesticated about the same time as cereal grains in the Mideast. But because it is grown in water, crop production practices were different but weeds were still a problem. By at least 3,000 BCE grass carp were a part of rice production in flooded paddies. This might have been serendipity, some fish got into the paddy because of a monsoon rain or a break in the dikes and the farmers noticed that they ate weeds and some insect pests. So putting fish, mostly grass carp but also tilapia and other species, into rice paddies is a common practice from Japan to India. The fish is also an agricultural commodity, so it's a win-win situation. Another rice growing practice is using transplanted seedlings instead of direct seeding - the common practice in the US. Transplants minimize weed and some other pest problems because the rice plants have a head start over the weeds. So Asia initiated agricultural practices that conform to the Integrated Pest Management (IPM) philosophy long before it came to be a part of our language in the west.

In the New World there were no draft animals, so plowing never developed. Instead a common farming method was 'slash and burn' (also known as 'fire and stick'), where an area of forest or brush is burned, then roughly cleared for planting. Crops are sown by making a small opening into the soil with a stick and dropping in seed. In what is called the Milpa system in Mexico and the three sisters in the US, three crops were sown together. These were corn (maize), squash and bean. The squash germinated and grew quickly, creating a cover crop for the corn and bean. The corn grew tall, providing a pole for the beans. This integrated system delivered carbohydrates from the corn, protein from the bean and anthocyanins plus fiber from the squash; simple and nutritious. When the notion of cover crops was being introduced in the US in the 1980's, the Milpa was often referenced as the model.

For most agronomists and weed scientists in the 20th century, the history of technology in weed control is the history of herbicides. For some it didn't begin until the introduction of synthetic herbicides in about 1950. In reality, herbicides, in the sense of chemicals used intentionally on a crop for weed control started in the mid 19th Century. The first herbicides were inorganic salts such as sodium chloride, sodium chlorate, arsenic salts and carbon bisulfide as a fumigant. In addition various oils, inorganic acids like sulfuric acid, and solvents were used as burn-down herbicides. All of these chemicals were used at what today would be unbelievable rates, 600-1000 pounds per acre for sodium chlorate for example. They were toxic and some were extreme fire hazards. The discovery of 2,4-D and the chemical synthesis process that allowed for this discovery opened the floodgates for herbicides. The ninth edition of the Herbicide Handbook published by the Weed Science Society of America in 2007 includes more than 200 herbicides presently in use or in development in the US.

It has been known for a long time that the use of weed control technologies is inversely correlated with poverty and the abundance of women and children for weeding. So technology is not something that is uniformly available. It may be hard to imagine that the latest technology, the robotic weed control machines, will ever be developed for small scale use on a family farm in Pakistan, but it is perhaps better to ask, “Why not?”

Impact of Automated Thinners on Weeds and Lettuce Production. Richard Smith, Vegetable Crop and Weed Science Farm Advisor, University of California Cooperative, Extension, Monterey County, CA

Thinning crops is a labor intensive activity. As a result, over the years, growers and researchers have sought a means of mechanizing this practice. Efforts by Land Grant Universities and private companies to develop automated thinners for sugar beets extend back over 100 years. Early designs incorporated various swinging or spinning blades, but no plant detection technology was employed and thinning was therefore done on a rote spacing method that did not account for skips in the stand. In the early 1960's, John Deere made a commercially available beet thinner that utilized a plant detection mechanism (moisture sensitive metal plate) which greatly improved the resulting stand because accounted for skips in the stand and accurately achieve the desired spacing. The development of computer processing of digital images of crop stands made it possible to make precise decisions on which plants to remove and achieve accurate spacing. Automated weeding machines developed in Europe that used this technology such as the Tillet (Garford Corp., England) were developed for weeding transplanted vegetables. They were evaluated for thinning lettuce, but did not perform well as a thinner partially due to the slowness of the mechanical kill mechanism (a spinning blade). In 2011, the first thinners that had a spray kill mechanism were introduced. The spray mechanism had the advantage of low inertia and simplified mechanical design. In 2013-14 four companies had developed commercially available machines for thinning lettuce that use the spray kill mechanism: Agmechtronix: Silver City, NM. http://www.agmechtronix.com/; Blue River Technology: Sunnyvale, CA. http://bluerivert.com/; Foothill Packing: Salinas, CA. http://www.foothillpacking.com/; and Vision Robotics Corporation: San Diego, CA. http://www.visionrobotics.com/ . These machines remove unwanted lettuce plants and associated weeds in a four inch wide strip around the seedline and within 3/8 to ½ of an inch to either side of the keeper plants. Materials used to remove the unwanted lettuce plants include salt and acid based fertilizers such as AN20 and NpHuric, as well as herbicides. In 2014 a 24c registration for carfentrazone was granted, specifically for thinning lettuce. A registration is being reviewed for a carboxylic acid herbicide for use in organic production. If the plants are wet at the time of application the efficacy of fertilizers is reduced. Carfentrazone and the 9% v/v rate of carboxylic acid are effective under these conditions which is important because it allows the machine to operate effectively early in the morning when there is dew on the plants. Thinning by hand or automated thinner removes weeds in the seed-line however, weeds that are close to the keeper lettuce plants are not removed by the automated thinner if they are in the unsprayed zone. Hand thinning also leaves plants because it the worker may not notice a weed plant tucked up close to a keeper lettuce plant and the hoe also has limits regarding how close it can safely get to a lettuce plant without damaging it. In an evaluation conducted in 2014, hand thinning removed 72.6% of the weeds and the automated thinner 68.4% during the thinning operation. The technology used to guide the automated thinner is a powerful new tool in vegetable crop production. It is expected that this technology can be further developed in the future to be used for other purposes such as for specifically removing weeds in vegetable crops production operations.

Using Your Smartphone for More Than Facebook and Fantasy Football: Apps That Can Make You a Better Weed Scientist.

Lynn M. Sosnoskie, Project Scientist, University of California, Davis, CA

Currently, smartphone owners account for almost 65% of the total number of mobile phone users in the United States; this fraction is expected to rise to 80% in the next two to three years. The bulk of smartphone users spend the majority of their time on apps (short for application software, which are self-contained programs designed to run on mobile devices and accomplish specific functions), primarily for entertainment (i.e. YouTube, various games) and social networking (i.e. Facebook, Twitter) purposes.

In response to the rising adoption of smartphone technology in rural/agricultural regions of North America (estimates of ownership range from 40-70%), many farm-related apps have been developed to assist growers with routine tasks, including weed management. The available programs can be divided into three general types of apps, including:

- Information delivery (such as weather apps [e.g. Weather Channel, National Weather Service) or apps that provide access to pesticide labels[e.g. Label Guide]),
- Assessment tools and calculators (apps to assist with weed identification [e.g. ID Weed, Ag Weed ID] and pest plant mapping [e.g. Connected Farm Scout], and apps designed to help growers with the selection of spray nozzles [Spray Select], calibrating sprayers [e.g. Calibrate my Sprayer], and identifying the potential chemical interactions when designing tank mixes [e.g. Mix Tank]),
- Information dissemination (social media apps that allow growers to interact with university, regulatory and industry personnel, each other, and the general public [e.g. Twitter, Facebook]).

Smartphone applications designed to work with the major operating systems can be easily found and accessed using your mobile device or via the internet. Online compilations of farming related smartphone apps can be found at:

- http://www.ssca.ca/index.php/smartphone-apps
- http://aged.illinois.edu/sites/aged.illinois.edu/files/resources/Apps-for-Ag-Revised.pdf
- http://www.farmingwithapps.com/
- http://farmindustrynews.com/precision-farming/top-agricultural-mobile-apps-your-smartphone#slide-0-field_images-54491
- http://www.croplife.com/editorial/matt-hopkins/13-new-mobile-agriculture-apps-for-2013/

The Role of Biotechnology in Weed Research and Weed Management.

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Biotechnology has long been used as a tool in many areas of science to research genetic and molecular processes. Its use in weed science is continuously expanding as our knowledge of resistance mechanisms increases. Here we review three contributions these techniques are making to weed research focusing around 1. The genetic engineering (GE) of crop plants. 2. Improving our understanding of resistance mechanisms in weeds and 3. Looking at weed behavior and relating it back to the plant genome.

The genetic engineering of crop plants has made a major impact in the variety of weed management programs that are available to growers. Many traits make attractive targets for GE crop varieties such as those with enriched nutrient production, insect resistance and abiotic stress tolerance. Of major impact to weed management was the introduction of herbicide tolerant GE varieties. These varieties have allowed growers to use previously unavailable herbicide chemistries in their cropping systems, use less toxic herbicides, and have reduced the cost of weed management through reduced pesticide use. Along with the ability to use different chemistries, these systems can also promote the dependence and repeated use of a single chemistry over long periods of time. This increased selection pressure on weed species contributes to the evolution of resistant weed populations.

The ability of GE herbicide resistant varieties to be used in the long-term relies on the ability of growers to use different mode-of-action chemistries. Some such varieties in the pipeline for release include 2, 4-D and dicamba tolerant crops. Resistance to these chemistries can be achieved through metabolism of the herbicide in the cell, before it is able to cause detrimental effects in the plant.

New products that focus on these included Dow Agrosciences Enlist ™ Weed control system. These products contain multiple genes allowing the GE plant to metabolize 2,4-D and will have resistance to 2,4-D, glyphosate and glufosinate (www.enlist.com). Monsanto have developed the product range Roundup Ready Plus Xtend System®. These products have been modified with a gene allowing the plant to metabolize dicamba and will have resistance to glyphosate, glufosinate and dicamba (www.roundupreadyplus.com).

Biotechnology approaches are also being taken to investigate the evolution and spread of resistance in weed species. A current study is investigating glyphosate resistant junglerice (*Echinochloa colona*) in California. A survey of junglerice populations across the central valley showed that glyphosate resistance was present in multiple samples. These populations contained varying levels of resistance and sequencing revealed that multiple target site mutations were present. A high throughput approach will be used to investigate the genetic diversity of these populations with the aim to determine; if glyphosate target site (TS) resistance is moving from glyphosate resistant plants to susceptible plants in close proximity, if these TS mutations can converge in single individuals (gene stacking) and if this resistance can move into closely related *Echinochloa* species such as *E. phyllopogon* (Late water grass) and *E. oryzoides* (early water grass). Detection of single nucleotide polymorphisms (SNPs) will be used to detect genetic differences between populations. Genetic diversity between resistant populations within an orchard suggests that resistance has evolved independently multiple times; genetic similarity suggests a ‘founder effect’ where one plant has evolved resistance and seed has dispersed from this plant. Genetic diversity between populations across California suggests resistance may have evolved independently in response to selection pressure numerous times, however genetic similarity can suggest the movement of a resistant biotype via seed dispersion over large distances for eg. via irrigation channels, farm machinery contamination and seed contamination. This understanding can help to tailor management strategies that mitigate this spread.

Next-generation technology is also being used in weed research. Recently Gaines, T.A. *et al*[2] used RNA-seq to identify genes involved in diclofop resistance in *Lolium rigidum*. This technology provides a snapshot of gene expression levels in a plant at the time the tissue is harvested. In this study candidate genes were identified as those being differentially expressed in resistant and susceptible *L.rigidum* before and after treatment with diclofop. As a result of this work, Gains *et. al*. identified four candidates for major contributors to diclofop resistance.

As biotechnology advances in all areas of science, and the cost of these large scale technologies reduces, the contribution to weed research will increase. These technologies allow new integrated approaches to investigate the evolution and spread of resistance weeds with the ultimate goal of providing better management strategies for weeds.

[2] Gaines, T. A., Lorentz, L., Figge, A., Herrmann, J., Maiwald, F., Ott, M.-C., Han, H., Busi, R., Yu, Q., Powles, S. B. and Beffa, R. (2014) ‘RNA-Seq transcriptome analysis to identify genes involved in metabolism-based diclofop resistance in *Lolium rigidum*.’ The Plant Journal, 78: 865–876. doi: 10.1111/tpj.12514

Invasive Plant Management at East Bay Regional Parks. Casey Brierley and Pam Bietz, East Bay Regional Park District, Alameda and Contra Costa Counties

Overview of Invasive Plant Management at East Bay Regional Park District. The district encompasses 119,000 acres in Alameda and Contra Costa Counties. It is primarily a wildland park district which includes shoreline, parks, lakes, golf courses, botanic garden, bike trails, cattle grazing, and historic buildings and sites.

The presentation will examine the IPM program at the district. Topics will include invasive weeds in grazing lands, aquatic weeds, toxic algae, eucalyptus removal, thistle programs and the constant battle against non-native species using a variety of techniques for control.

Computer Controlled Chemical Injection Spray Truck Used at Solano Irrigation District. Jeff Null, Solano Irrigation District, Vacaville, CA

The use of computer controlled, chemical injection spray trucks is common in the roadside herbicide application field. Because each truck is typically custom built to fit the needs of the business or agency, an understanding of the components of these trucks is necessary in making an informed decision on the design. This presentation will discuss the various types of applications that are common at Solano Irrigation District and the components of an injection spray truck that are utilized to meet the spray application needs. The presentation will also discuss the advantages of a computer controlled, chemical injection spray truck as compared to a typical tank mixing spray truck.

Bare Ground and Invasive Weed Treatments in the North State.

Dustin Johnson, Vegetation Control Supervisor, Siskiyou County Dept. of Agriculture

With California being one of the most ecologically diverse states in the US, agriculture and its practices vary greatly from one end of the state to the other. With that in mind I would like to share some of the aspects of my job as the vegetation control supervisor for the Siskiyou County Department of Agriculture.

The first thing I would like to discuss is the roadside bare ground treatments conducted annually from March thru April. This is a very important part of my program that has its ever changing challenges. This last year presented many obstacles, mainly due to the extreme drought and the extremes that came with it. However it was an exciting year for testing products that were new to my department as well as the state. I am always looking to better my program, and an important part of that is keeping up with the new chemistry, technology and methods in the industry. One product that seemed intriguing for my roadside program was Perspective. With promising results from many test plots, I am excited to share my findings. Another product I was excited to work with was Esplanade 200 SC, using different rates and tank mix partners this too is a great product I am excited to speak about.

The second part of my program that I would like to share is the invasive weed treatments my crew and I perform throughout the county annually. There are many California A rated weeds that are targeted every year, but let’s not forget about some of the lesser rated weeds that have a significant impact to our environment. Dyers woad is weed that I would like to spread concern about. I have seen this plant do considerable damage to crops, rangeland and displace many desirable or rare species. Even with a California B rating it is not a weed to be taken lightly. I would also like to share some of our success stories about Squarrose knapweed, Leafy spurge and other invasive pests. The invasive weed program in Siskiyou County is taken very seriously and has grown to a fairly large seasonal program. I hope to bring awareness and share any information that may assist others in their battle with invasive weeds or keeping their roadsides safe and free of obstruction.

Comparing the Performance of Newer Products to Older Standards. Scott Nissen, Colorado State University, Fort Collins, CO

Total vegetation control is desirable in many situations including road sides, rights of way, oil and gas pads, and power substations, just to name a few. Off target movement of some commonly used bareground herbicides is an issue associated with surface runoff and sheet erosion. Herbicides currently registered for bareground weed weed control have a wide range of chemical properties that will influence off target movement. A general discussion of herbicide movement and how it is influenced by these chemical properties will be presented.

Landscape Weed Control. John Law, Director of Tech Services, ValleyCrest Companies, Oakland, CA

Discussion of weed control on commercial landscapes or the “built” environment. Ornamentals are irrigated for much of the year. Civil engineers specify that the soil be strengthened by compaction during site development to ensure a stable base for foundations, infrastructure and stability during earthquakes. Consequently the soil has high bulk density. Weeds are controlled by a combination of:

- Preemergent herbicides
- Postemergent herbicides
- Hand weeding
- Management of water
- Mulch
- Often maintaining a continuous plant cover that shades the soil.

Research Update New Product Options Control of English Lawn Daisy, Kikuyugrass and Annual Bluegrass. Mark Mahady, President, Mark M. Mahady & Associates, Inc. markmahady@aol.com

Introduction

English lawn daisy (*Bellis perennis*), kikuyugrass (*Pennisetum clandestinum*) and annual bluegrass *(Poa annua or Poa)* are troublesome turfgrass weeds throughout California.

The objectives of this presentation are as follows:

1. to present the results of recent replicated field trials comparing the performance of "industry product standards" and "new product options" for control of English lawn daisy, kikuyugrass and *Poa annua*, and,

2. to describe the strengths and limitations of the industry standards and new product options relative to efficacy, turf injury, use with various turf types, and incorporation into practical agronomic programs to reduce the potential for weed resistance.

English Lawn Daisy

English lawn daisy or English daisy (*Bellis perennis*) is a difficult to control broadleaf turfgrass weed. English daisy continues to frustrate turf managers due to its ability to adapt to a wide range of cultural practices and to resist and tolerate many presently registered broadleaf herbicides.

English daisy is a fibrous rooted perennial with basal leaves and a prostrate, spreading growth habit. The leaves are nearly smooth or loosely hairy, entire margined or variably toothed, broad above, and narrowed at the base to a long stalk. Flower heads are white or pinkish with yellow centers. Flower stalks generally exceed the leaves in length.

This aggressive and invasive broadleaf weed spreads through a rapidly advancing rhizome system, and exhibits the potential to root and produce new plants at each node along individual rhizomes. English daisy also appears to be a prolific seed producer. Germinating seedlings have been observed in Northern California from April until late September. Once established in turf this dual propagation system contributes to the rapid spread and invasion of English daisy in adjacent turfgrass areas. English lawn daisy was introduced from Europe as a garden plant and today there are thought to be at least six known biotypes in California.

Penoxsulam: The Industry Standard for English Daisy Control

Today penoxsulam, trade name Sapphire (Dow AgroSciences), is the industry standard for English daisy control. Penoxsulam exhibits the following classifications and characteristics:

- Sulfonamide herbicide classification
- Postemergence herbicide, ALS (acetolactase synthase) inhibitor
- Mobile, but not persistent
- Low volatility
- Reduced risk pesticide due to its favorable human health risk profile

From 2004 to 2008 five replicated field research trials and two superintendent applied split fairway demonstration trials were conducted on golf courses in the Monterey Peninsula in order to evaluate the performance of penoxsulam for English daisy control. Results were as follows:

- In a replicated field trial conducted on a golf course fairway in 2006-2007, two late summer treatments of penoxsulam applied at 0.02 lb (9 grams) ai/A resulted in 96% English daisy control 345 days after the second application. In a replicated field trial conducted on a golf course fairway in 2007-2008, two late summer treatments of penoxsulam applied at 0.02 lb (9 grams) ai/A resulted in 100% English daisy control 70 days after the second application.

- If late summer penoxsulam treatments are to be deployed, maintain soil volumetric moisture levels above 20% prior to application. Sporadic injury to *Poa annua* and perennial ryegrass has been observed with late summer applications when soil volumetric moisture levels fall below 15%. If adequate soil moisture is a concern during late summer, consider early spring applications when soils are often still moist from late winter rainfall. For spring treatments deploy three sequential applications at 0.01 lb ai/A at 21-day intervals. Use a non-ionic surfactant at standard label rates with all applications.

Pylex (Topramezone or BAS670): a Future Option for English Daisy Control

Topramezone (BAS670), trade name Pylex (BASF), shows encouraging potential as a future English daisy herbicide. Pylex is not yet registered in California. Registration in California is expected by the end of 2017.

Topramezone exhibits the following classifications and characteristics:

- Pyrazolone herbicide classification
- Postemergence herbicide, HPPD enzyme inhibitor resulting in disruption of carotenoid synthesis
- Systemic herbicide absorbed by leaves, roots and shoots
- Weeds stop growing soon after application and within days exhibit a bleached appearance followed by necrosis and death
- Mobile, but not persistent

In a replicated field trial conducted on September 21, 2012 on the fairway of the 7th hole at Laguna Seca Golf Ranch in Monterey, California the following results were observed:

- BAS670 (1 oz/A) + MSO (1%v/v) exhibited 85.1% English daisy control 42 DAA2.
- BAS670 (1 oz/A) + Drive XLR8 (64 oz/A) + MSO (1%v/v) exhibited 94.4% English daisy control 42 DAA2.
- Sapphire (8 oz/A) + NIS (0.25% v/v) exhibited 99.5% English daisy control 42 DAA2.

Drive + BAS670 + MSO exhibited faster burn-down than Sapphire the industry standard, but Sapphire exhibited a slightly higher level of control (99.5%).

If BAS670 (Pylex) is registered in California in the future, the opportunity to utilize two modes of action in an English daisy best management program (Sapphire ALS inhibitor and Pylex HPPD inhibitor) should reduce the potential for English daisy weed resistance.

Kikuyugrass

Kikuyugrass *(Pennisetum clandestinum)* is a warm season grass native to East Africa. Kikuyugrass was introduced into Southern California during the 1920's by the Soil Conservation Service to control erosion along water ways. This highly aggressive and invasive perennial exhibits medium leaf texture and a yellow green color that spreads by rhizomes, stolons and seeds.

During 2008, 2010 and 2011 replicated field trials were conducted in a rough area located on the 14th hole at the Pebble Beach Golf Links in Pebble Beach, California. The site was heavily inundated with mature kikuyugrass. The first replication had a mixture of kikuyugrass, perennial ryegrass and *Poa annua*. Replications II, III and IV consisted of virtually 100% mature, highly stoloniferous kikuyugrass. Key results and the top performing treatments from three replicated field trials conducted during 2008, 2010 and 2011 are presented in the table below.

Treatment	Rate	2008 % KK Control	2010 % KK Control	2011 % KK Control
Turflon Ultra Ester	32 oz/A	*	99.2%	92.8%
Turflon + Drive XLR8	32 + 43.5 oz/A	99.7%	99.9%	*
Tenacity	5 oz/A	95.7%	*	*
Tenacity + Turflon	5 + 8 oz/A	97.7%	*	*
Drive XLR8	43.5 oz/A	52.8%	53.9%	77.1%
Drive + QuickSilver (QS)	43.5 + 2.7 oz/A	*	93.9%	*
Drive + Pylex	43.5 + 1.0 oz/A	*	*	82.0%
SpeedZone Southern+Drive+QS	80+43.5 +2.7 oz/A	*	94.7%	95.4%

Key Take Home Messages: from the 2008, 2010 and 2011 kikuyugrass field trials:

- Turflon alone or Turflon + Drive: highly efficacious (99%+), virtually no regrowth. Safe for use on perennial ryegrass and Poa mixtures. Highly injurious to fine fescue and bentgrass.

- Tenacity: highly efficacious (95.7%), minimal regrowth. Safe for use on perennial ryegrass, Poa and fine fescue mixtures. Highly injurious to bentgrass. Bleaching without Turflon.

- Drive + QuickSilver: good control (93.9%). Safe for use on perennial ryegrass, Poa, fine fescue and creeping bentgrass.

- SZS + Drive + QuickSilver: good control (95.1%). Safe for use on perennial ryegrass, Poa, fine fescue and creeping bentgrass.

Annual Bluegrass (*Poa annua*)

Ethofumesate (Prograss 1.5 EC: Bayer Environmental Science) is an active ingredient that has been used successfully for postemergent control of *Poa annua* in overseeded bermudagrass fairways for many years. Perennial ryegrass is very tolerant to ethofumesate applications.

Previous field research conducted by Mark M. Mahady & Associates, Inc. in the Palm Springs, California perennial ryegrass overseeding market, showed that two sequential treatments of Prograss 1.5 EC applied at a rate of 1.125 lb ai/A (0.75 gal/A) at 21-day intervals beginning approximately December 7, resulted in very high control levels (90%-99%) of annual biotypes of *Poa annua* control in perennial ryegrass overseeded bermudagrass fairways.

The *Poa annua* control information presented in the table below is based on the results of five replicated field trials conducted from 1997 to 2005 in the Palm Springs area by Mark M. Mahady & Associates, Inc. From 1997 to 2005 two sequential applications of Prograss 1.5 EC resulted in extremely high levels of *Poa annua* control (90.4% to 100.0%).

Year	**Location**	**Treatment**	**Rate**	**No. Appl.**	**% Poa Control**
‘97-’98	**Desert Dunes GC**	**Prograss**	**0.75 gal/A**	**2**	**90.4%**
’98-’99	**Desert Dunes GC**	**Prograss**	**0.75 gal/A**	**2**	**97.0%**
‘98-’99	**Sun City West GC**	**Prograss**	**0.5 gal/A**	**2**	**97.7%**
‘02-’03	**Indian Wells CC**	**Prograss**	**0.75 gal/A**	**2**	**99.0%**
‘04-’05	**Indian Wells CC**	**Prograss**	**0.5 gal/A**	**2**	**99.0%**
‘04-’05	**Indian Wells CC**	**Prograss**	**0.75 gal/A**	**2**	**100.0%**

Unfortunately, by 2009 several golf courses in the Palm Springs area were reporting *Poa annua* escapes following properly timed and accurately deployed Prograss applications. Results from these five replicated field trials shown below reveal the extremely poor control (32%-36%) observed at the Vintage Club and Rancho La Quinta Country Club from 2009 to 2014.

Year	**Location**	**Treatment**	**Rate**	**No. Appl.**	**%Poa Control**
’09-’10	**Vintage Club**	**Prograss**	**0.75 gal/A**	**2**	**34.6%**
’10-’11	**Vintage Club**	**Prograss**	**0.75 gal/A**	**2**	**32.0%**
’10-’11	**Vintage Club**	**Prograss**	**0.75 gal/A**	**2**	**36.0%**
’12-’13	**Rancho LQ**	**Prograss**	**0.75 gal/A**	**2**	**35.3%**
’13-14	**Rancho LQ**	**Prograss**	**0.75 gal/A**	**2**	**36.5%**

From 2010 to 2014 a new series of replicated field trials were initiated at the Vintage Club in Indian Wells, California and Rancho La Quinta Country in La Quinta, California for the purpose of evaluating new Prograss tank mix partners to improve *Poa annua* control. The results are presented in the following table.

Year	Location	Treatment	Rate	No. Appl.	% Poa Control
'10-'11	Vintage Club	Prograss	96 oz/A	2	34.8%
'10-'11	Vintage Club	Prog+Trim	96+8 oz/A	2	89.0%
'12-'13	Rancho LQ	Prograss	96 oz/A	2	35.3%
'12-'13	Rancho LQ	Prog+Trim	96+6 oz/A	2	61.7%
'12-'13	Rancho LQ	Musketeer	20 oz/A	4	79.1%
'13-'14	Rancho LQ	Musketeer	20 oz/A	6	87.0%
'13-'14	Rancho LQ	Prog+Msk Fb Musk	64+20 oz/A 20 oz/A	2 3	90.6%
'13-'14	Rancho LQ	Pro+Tr+Pr Fb Tr+Pr	64+6+6 oz 6+6 oz/A	2 3	90.6%

Key Take Home Messages: from the 2011 to 2014 *Poa annua* control field trials.

- With repeated use over many years, specific Poa biotypes show reduced sensitivity to Prograss 1.5 EC resulting in unacceptable levels of Poa control (32%-35%).
- Tank mixing Trimmit (paclobutrazol) with Prograss, improves herbicide activity and Poa control (61%-89%).
- Four sequential applications of Musketeer alone (paclobutrazol + trinexapac-ethyl + flurprimidol) showed 79% *Poa annua* control.
- To date the two best performing programs include the following:

    1. Two applications of Prograss 64 oz/A + Musketeer 20 oz/A followed by three applications of Musketeer 20 oz/A (90.6% control).

2. Two applications of Prograss 64 oz/A + Trimmit 6 oz/A + Primo 6 oz/A followed by three applications of Trimmit 6 oz/A + Primo 6 oz/A (90.6% control).

Summary and Practical Perspectives

Be open minded, but always question performance claims when considering the use of new products and/or new agronomic strategies. Always test new products and programs on a small scale before moving to larger acreage.

Weed Community Composition and Species Shifts in Conservation- and Conventional-tilled Cotton-Tomato Rotations with and without Cover Crops. Anil Shrestha[1], Kurt Hembree[2], and Jeff Mitchell[3]; [1]California State University, Fresno, CA, [2] University of California Cooperative Extension, Fresno, CA, [3]University of California, Davis, CA

Cotton-processing tomato rotation is quite common in the Central Valley. However, the use of reduced tillage systems and cover crops is not a common practice in this rotation. A replicated field study was conducted in Five Points, CA from 1999 to 2011 to explore the potential of the use of reduced tillage and cover crops in this rotation. Concerns about weed densities and species shifts are a concern in reduced tillage systems as tillage is an important weed management tool. Another concern is weed seed return from uncontrolled weeds and addition of these seeds to the weed seedbank. Therefore, the objective of this study was to characterize the weed community composition and the weed seedbank size after 12 years of this rotation. Treatment comparisons included standard tillage with no cover crop (STNO), standard tillage with cover crop (STCC), conservation tillage with no cover crop (CTNO), and conservation tillage with cover crop (CTCC). The four treatments were maintained in the same plots for the duration of the entire experiment. The cover crop included a mix of Juan triticale (*Triticosecale* Wittm.), Merced rye (*Secale cereale* L.), and common vetch (*Vicia sativa* L.). A glyphosate-tolerant upland cotton variety was used in the study. Weed management practices in the tomato phase of the rotation included a pre-transplant application of glyphosate. These applications were followed by a post-transplant application of sprinkler-incorporated rimsulfuron. This herbicide program was slightly modified in 2005 with the addition of a post-transplant application of sethoxydim. In 2007 and 2008, glyphosate was applied with a hooded sprayer along with S-metalochlor. In the cotton plots, trifluralin was applied preplant with two to four pre- and in-season applications of glyphosate. Weed density, by species, in each plot was assessed in 2003, 2006, and 2011. In 2011, soil cores were taken from each plot to estimate the weed seedbank size and species composition by the seedling emergence method. Seedlings that emerged were counted by species and the data were subjected statistical analysis. Results demonstrated that tillage systems and cover crops had differential effects on total aboveground weed densities and on specific weed species in this rotation. It could not be conclusively stated that CT systems increased total weed densities compared to ST systems. However, in general, weed densities were greater in the plots with cover crops than in those without cover crops. The seedbank size was the largest in the CTCC system and the weed community composition of this system was distinctly different from the others with shepherd's-purse, black nightshade, henbit, and common chickweed being the most prevalent species. Barnyardgrass and horseweed were associated with the CTNO system. None of the weed species demonstrated an association with the ST systems. It can be concluded that although weed densities were not consistently different between the ST and CT systems in this rotation, the CT system resulted in higher numbers of weed seeds in the seedbank than the ST system in the long-term. Having a cover crop in the CT system further exacerbated this problem by increasing the seedbank size comprised mainly of winter annual species. Therefore, more competitive cover crops or more efficient cover crop/crop management systems need to be developed to limit the weed seedbank in CT cotton-tomato rotations in the SJV.

Impact of Weed Seed in Dairy Manure & Weed Spread in Agronomic Crops.

Steven D. Wright, Tulare County, David W. Cudney, University of California, Riverside, Thomas A. Shultz, Tulare County

Acknowledgments: Jeanie Katovich, Roger Becker-University of Minnesota, Jerry Doll-University of Wisconsin, Pete Huerta, Mike Cummings- Innovative Ag. Hanford, Deanne Meyer- University of California, Davis

Manure is an important soil amendment. In addition to providing valuable nutrients, manure enriches the microbial population and adds organic matter. Many of our high yield crops in the San Joaquin Valley are a consequence of inputs of dairy manure. Manure is a valuable nutrient amendment, but may harbor weed seeds. Many assume manure is always rich in weed seeds. The opposite is probably the case as some of our harvested forage/hay is relatively free of weed seeds. Exceptions obviously exist. The biggest contribution of weed seed can come from contaminated hay and grain, however, a portion of weed seed present in feed can remain viable after passing through an animal's digestive tract.

Two studies in Nebraska characterized the effects of the digestive tract and manure on weed seeds (Harmon and Keim 1934). Weed seeds were fed to calves, horses, sheep, hogs, or chickens. 1. 25% of the seeds fed to hogs & cattle were recovered in the manure. 2. 10 to 12% were recovered from horses and sheep. 3. Chickens were the most effective in destroying weed seeds with only 2% of the velvetleaf seeds fed recovered. None of the bindweed, sweet clover, smooth dock, smartweed, wild rose and pepperweed seeds fed was recovered. Digestion of weed seeds by animals kills many, but not all seeds. Although few in number, 62% of the velvetleaf seeds that survived the trip through a chicken germinated, suggesting that the grinding action of the gizzard may have actually scarified the seed and stimulated germination.

The fermentation process that is part of ensiling corn or forages can reduce the viability of weed seed, as can digestion in the rumen of cattle. A Weed Seed in Dairy Manure Study was conducted in Tulare/Kings Co. 1989-1992- (Cudney, Wright, Shultz). Samples were taken from 5 Tulare Co. and one Kings Co. dairy considered typical of San Joaquin Valley. 350-1,500 cows with traditional open corral with shades. Seven samples taken: In first year, one in April, July, Oct., and Dec. In 2nd year, one in April, July, and Oct. Each sample was taken from 2 ft. deep into pile, and weighed 2.2 lbs. Dairy manure collected for 2 years from various sites in seven Central California dairies was found to contain viable weed seed. Weed seed contamination was most severe when manure was taken from dry cow pens (21,755 viable weed seeds/ton of manure) and liquid manure sedimentation handling facilities (15,827 viable weed seeds/ton of manure). Dairy manure from producing cows had fewer weed seeds than manure from dry cows, presumably because the dry cows received lower quality (weedier) feed. While composting did not eliminate all viable weed seed, on average, correctly executed composting decreased viable weed seed to less than 2,000 viable weed seeds per ton of composted manure. It is recommended that dairies compost longer than the typical 6 to 8 weeks, in deeper piles, and to add supplemental water to increase temperatures.

Moisture (>35%) optimum for kill. Work in Nebraska showed that moist compost killed cocklebur, morningglory, pigweed, sunflower, velvetleaf (except for 14%), foxtail, smooth brome and shattercane faster and more completely than dry compost, in part due to increased compost temperatures when moist (Eghball and Lesoing 2000).

Some hard-seeded weeds such as velvetleaf and field bindweed would require temperatures in the range of 160 to 180o F and longer composting times to kill all seed. (Larney and Blackshaw 2003). Avoid feed high in weed content. Livestock vary on the effect their digestion has on weed seeds, but all decrease weed seed viability.
Well executed composting destroys most weed seeds. Weed species with hard seed coats like field bindweed and velvetleaf present the greatest risk of surviving composting. However, if the manure pile or compost is moist, reaches the desired temperature, and completes its full cycle of decomposition, even seeds of these species can be killed. Focus manure piling on dry cow and sedimentation areas. In summary an aggressive mgmt. program is needed using herbicides, tillage, rotation. Reduced till in SJV has a large source of weed seed. Weeds are killed then in 1. field 2.ensilage 3. livestock 4. piling + heat 5. Field.

Rule 4565: Biosolids, animal manure, and poultry litter operations

Table 2 – Composting/Co-composting Facility_Mitigation Measures	
Class One Mitigation Measures	
1.	Scrape or sweep, at least once a day, all areas where compostable material is mixed, screened, or stored such that no compostable material greater than one inch (1") in height is visible in the areas scraped or swept immediately after scraping or sweeping, except for compostable material in process piles or storage piles.
2.	Maintain a minimum oxygen concentration of at least five percent (5%), by volume, in the free air space of every active and curing compost pile.
3.	Maintain the moisture content of every active and curing compost pile between 40% and 70%, by weight.
4.	Manage every active pile such that the initial carbon to nitrogen ratio of every pile is at least twenty (20) to one (1).
5.	Cover all active compost piles within 3 hours of each turning with one of the following: a waterproof covering; at least six (6) inches of finished compost; or at least six (6) inches of soil.
6.	Cover all curing compost piles within 3 hours of each turning with one of the following: a waterproof covering; at least six (6) inches of finished compost; or at least six (6) inches of soil.
7.	Implement an alternative Class One mitigation measure(s) not listed above that demonstrates at least a 10% reduction, by weight, in VOC emissions.

Recent Research Development on Palmer Amaranth and Junglerice in the Southern San Joaquin Valley.

Sonia Rios[1], Steve Wright[2], Anil Shrestha[3], and Sarah Parry[2]
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Glyphosate is the most popular herbicide for weed management in agriculture and non-crop areas globally. However, heavy reliance on glyphosate has resulted in the evolution of several glyphosate-resistant (GR) weed species globally. Two species of great concern in the Sothern San Joaquin Valley are GR Junglerice and potentially GR Palmer amaranth (*Amaranthus plameri*). GR Junglerice populations have been confirmed throughout the San Joaquin Valley (SJV) and GR Palmer amaranth have been confirmed in southeast U.S. since 2005 causing huge economic losses. In recent years, growers in the SJV have observed poor control of Palmer amaranth in some glyphosate-tolerant crops and other crop and non-crop areas. It is not known if these are GR populations or application of glyphosate at more tolerant stages of the weed. These studies evaluated Palmer amaranth populations from 23 different locations of the SJV. Plants from two locations that showed some tolerance to glyphosate at the label rate (840 g ae ha^{-1}) were further compared to a known GR population from New Mexico. Five- to 8-leaf stage plants were treated with glyphosate rates ranging from 0 to 3.36 kg ae ha^{-1}. Most of the SJV plants died at the label rate. Hence, the presence of GR Palmer amaranth in the SJV could not be definitely determined. Plant mortality was also evaluated at 3 different growth stages with several herbicides under greenhouse and field conditions. Tolerance to some herbicides including glyphosate was observed at more mature growth stages. Several herbicides and herbicide mixtures were identified for control of junglerice and Palmer amaranth should GR populations of Palmer amaranth be definitively documented in the SJV in future.

Managing Field Bindweed in Field Crops and Vegetables. Kurt J. Hembree, University of California Cooperative Extension, Fresno, CA, kjhembree@ucanr.edu

Convolvulus arvensis (field bindweed) is a deep-rooted perennial broadleaf weed that was first documented in California in 1884 in San Diego. Field bindweed now infests millions of acres of productive farm land throughout the state and is considered by some to be one of California's worst weeds. Field bindweed can have an extensive underground rhizome and root system, extending 20′ deep or more, making eradication very difficult once established. After re-growth from underground rhizomes occurs, typically in the spring in the southern San Joaquin Valley, the above-ground canopy of field bindweed develops and spreads out quickly, smothering newly emerged field and vegetable crop plants, reducing and/or eliminating crop stands. Well-established crop plantings are also affected as field bindweed's vine-like stems climb the stems of crops to envelope the crop canopy. In garlic, patches of field bindweed can reduce harvest efficiency and increase risk of bulb rot associated with increased relative humidity at the soil surface. Field bindweed management options in field and vegetable crops are limited. While seedling field bindweed plants can be fairly easily killed with pre- and postemergence herbicides or cultivation, established plants are more difficult to manage. Trifluralin can be used pre-plant incorporated in tomatoes to control seedling plants and delay growth of established plants. Cultivation is often used for cutting plants below the soil surface along bed tops and shoulders, but is not effective within the crop rows, so hand removal is used. In some vegetable crops, like processing onions, cultivation is not an option due to the close plant row spacing. Here, hand removal is usually required to preserve the crop stand. Shielded sprayers are sometimes used to treat field bindweed with herbicides between rows, but multiple applications during the season are usually required. Some growers will plant glyphosate-tolerant alfalfa, corn, or cotton varieties so glyphosate can be sprayed over-the-top to manage field bindweed, without harming the crop. Perhaps the most effective method of management is to treat with systemic herbicides (like glyphosate plus dicamba) in the fall (after crop harvest) before field bindweed plants enter dormancy. Here, the herbicides are transported down through the rhizome and root system along with the plant's carbohydrates to help hinder re-growth the following season. Treatment should occur when plants are at about 10% bloom. A pre-irrigation may be needed if plants appear droughty. This type of fallow treatment can be very effective, but requires special attention to crop replant intervals if the herbicides used have soil activity. Finally, irrigating in the fall, spraying with a high rate of glyphosate, waiting 7-10 days, then undercutting rhizomes at least 16" deep can result in field bindweed suppression for a season or two.

Poisonous Plants in California: Identification, Animal Physiology, and Control. Julie A. Finzel, UCCE Kern, Tulare and Kings Counties

Poisonous plants occur throughout California and encompass a number of different species. Common toxic substances found in poisonous plants, include nitrates, glycosides, alkaloids, tannins and alcohols. Each toxin produces unique symptoms, however, symptoms can vary between and within species based on the level of toxicity of each plant, amount eaten, time of year, current weather conditions and more. Basic control options vary, but are generally limited to mechanical or chemical control because many cultural practices are not viable.

Influence of Herbicides and Native Plant Revegetation on Medusahead Infested Sites at Clear Lake National Wildlife Refuge. Rob G. Wilson, IREC Center Director/Farm Advisor; Darrin Culp & Kevin Nicholson, IREC Staff Research Associates. University of California Intermountain Research & Extension Center, 2816 Havlina Rd., Tulelake, CA. 96134 Phone: 530/667-2719 Fax: 530/667-5265 Email: rgwilson@ucdavis.edu

Clear Lake National Wildlife Refuge administered by the U.S. Fish and Wildlife Service consists of approximately 33,500 acres. Sagebrush uplands on the Refuge support pronghorn antelope and mule deer as well as many species of birds including greater sage grouse (*Centrocercus urophasianus*). Sage grouse populations are allied closely with sagebrush (*Artemisia* spp.). Sage grouse also rely heavily on the availability of highly nutritious perennial forb species within sagebrush ecosystems. On July 3, 2001 a lightning strike ignited a wildfire on the Clear Lake "U" which burned 3,800 acres on the refuge. Following the fire, cheatgrass and medusahead quickly invaded the burn. Little or no recovery of sagebrush and native vegetation occurred on burned sites over the last 11 years. Cheatgrass and medusahead populations, however have increased in size and severity.

In 2010, CLNWR managers and University of California researchers formed a collaborative project to research methods for habitat recovery on burned sites on the Clear Lake U. The primary objective was re-establishment of healthy low and big sagebrush (*Artemisia* spp.) communities. Reducing infestations of exotic annual grasses was seen as vital to minimize fire ignition hazard and prevent competition with native vegetation (perennial grasses, shrubs, and forbs). Funding was secured for two years, and an experiment was established at the Refuge in fall 2010. The experiment examined the influence of herbicides on native vegetation, with or without reseeding.

The same experiment was established at three sites infested with medusahead with differing baseline plant communities. Site 1 had a healthy low sagebrush over-story and sporadic perennial grasses and perennial forbs. Sites 2 and 3 were burned by wildfire that destroyed most low sagebrush. Site 2 had a healthy perennial grass stand and sporadic forbs. Site 3 was a near monoculture of medusahead with sporadic perennial grasses and forbs.

Three herbicide treatments were evaluated: fall-applied imazapic at 1.5 fl oz ai/A, fall-applied rimsulfuron at 1 oz ai/A, and spring-applied glyphosate at 3.75 oz ae/A. Herbicide rates and application timings were designed to maximize annual grass control while minimizing non-target plant injury. Plots were reseeded in March one year after herbicide treatment using a native seed mix containing sagebrush, squirreltail, Idaho fescue, and Great Basin wildrye. Percent cover of all plant species was evaluated in early spring and mid-summer for three years following herbicide application. Seeded species density and cover were measured the year of seeding and year after seeding.

Herbicides had a similar effect on annual grasses at all sites. Imazapic and rimsulfuron reduced medusahead and cheatgrass cover by more than 95% the year of treatment compared to the untreated control. Unfortunately annual grass cover in both herbicide treatments rebounded one and two years after treatment. Glyphosate reduced annual grass cover by 60 to 70% the year of application, but annual grass cover quickly rebounded one year after treatment.

Glyphosate caused unacceptable injury to several native annual and perennial forbs. Rimsulfuron and imazapic were safe on perennial forbs, but they caused unacceptable injury to multiple annual forbs. As a result, forb cover in herbicide treated plots was lower or similar to the untreated control the year of application. Both annual and perennial forbs prospered one year after herbicide application in imazapic and rimsulfuron treatments. Total forb cover was 75% to 250% higher in these herbicide treatments compared to the untreated control. The increase in forb cover was temporary and total forb cover declined back to near pre-treatment levels two years after treatment.

Glyphosate caused unacceptable injury to most perennial grasses. Rimsulfuron was safe on perennial grasses except perennial bluegrass species. Imazapic was safe on all established perennial grasses. Perennial grass seeding establishment ranged from 0 to 1.2 grass seedlings per 1 m^2. At the two sites that lacked sagebrush, seeded grass establishment was highest in the rimsulfuron and imazapic treatments. Seeded sagebrush establishment was highest in the rimsulfuron and imazapic treatments at all sites. Imazapic was the only herbicide treatment with higher perennial grass cover compared to the untreated control two years after treatment.

Most herbicide effects on vegetation were limited to the year of application and year following application except for permanent reductions in perennial grass cover. Final year results point to annual grass cover returning to pre-treatment levels for all herbicides at all sites. Glyphosate did not match land-use objectives due to unacceptable injury to native forbs and grasses. Imazapic and rimsulfuron appear to have the best fit with land use objectives related to increasing forb and sagebrush cover. Both herbicides temporarily increased forb cover for species important to several wildlife species including sage grouse. Both herbicides also temporarily increased established sagebrush cover and sagebrush seeding success.

Herbicide Use in Forest Management. Vanelle F. Peterson and Richard K. Mann, Dow AgroSciences LLC, Indianapolis, IN, vfpeterson@dow.com

California has approximately 33 million acres of land in public and private forests with about 5 million acres in private forest industry holdings. The California Forest Practice Act (1973) requires that landowners regenerate their forest after a timber harvest or leave it in a stocked condition within 5 years. Foresters use mechanical, cultural, chemical, and other tools to prepare sites for planting seedling conifers and to help provide the new seedlings the resources (light, water, and nutrients) necessary for growth. Herbicides are used in forest management in order to prepare sites for planting ("site preparation") by reducing vegetation on the site and later in the life of a plantation to release conifers ("conifer release") from undesired plant competition.

Site Preparation and early conifer release treatments may be applied in 1 or 2 fall or spring applications to prepare the site and to keep grasses and herbaceous vegetation from out-competing the conifers once they are planted. Some common weeds targeted for site preparation and early plantation release applications are: annual grasses such as downy brome (*Bromus tectorum),* wild oats (*Avena fatua),* marestail (*Conyza canadensis),* bull thistle (*Cirsium vulgare)*, and prickly lettuce (*Lactuca serriola).* Woody brush species can be problematic early in the life of a plantation if the seedlings begin to germinate soon after planting. Target brush species include: manzanita species [greenleaf (*Arctostaphylos patula,* whiteleaf, *A. viscida* and hairy, *A. columbiana*)], deerbrush (*Ceanothus integerrimus*), snowbrush (*C. velutinus*), squawcarpet (*C. prostratus),* chinquapin (*Chrysolepis chrysophylla),* and whitethorn (*Acacia constricta*). Common herbicide active ingredients used for woody brush control include: triclopyr, imazapyr, hexazinone, glyphosate, fluroxypyr, and 2,4-D.

Pindar® GT herbicide is a pre-emergence and early post-emergence herbicide currently registered for use in tree nuts and noncropland. It contains penoxsulam at 0.083 lb/gallon plus oxyfluorfen at 3.96 lb/gallon in a soluble concentrate formulation. Over 20 small plot research trials have been established in northern California to study conifer tolerance and efficacy on key weeds. Pindar GT exhibited excellent conifer tolerance when applied for site preparation prior to planting and as a broadcast application over the top of seedling conifers such as Douglas-fir (*Pseudotsuga menziesiii*) and Ponderosa pine (*Pinus ponderosa*). Conifer tolerance was also excellent when applied prior to planting or over the top of conifers such as sugar pine (*Pinus lambertiana*) or white fir (*Abies concolor*) that are intolerant to hexazinone. Pindar GT provides foresters another tool in their herbicide tool box and controls weeds that impede conifer growth. Surprisingly, Pindar® GT controlled seedlings of 2 woody brush species: squaw carpet and deerbrush. When applied in the early spring prior to seedling emergence, 3 pints/A of Pindar GT reduced cover of squaw carpet from 60% cover to 10 - 20% cover, facilitating the survival and growth of conifer seedlings. This reduction in squaw carpet cover doubled the conifer volume growth in treated plots over the conifer volume growth in the non-treated plots. When applied in the fall, 4.5 pints/A of Pindar GT controlled 85% of deerbrush seedlings the following spring.

Herbaceous and woody plant weed control provided by Pindar GT at 3 to 4.5 pints/A during preparation or conifer release improved conifers stands. A Special Local Need (SLN) for Pindar GT registration for use in California forestry was submitted to California Department of Pesticide Registration in September 2014.

Defoliation to Control Medusahead Jeremy J James[1*], P. Brownsey[1], E. Gornish[2], E. A. Laca[2]. University of California Sierra Foothill Research and Extension Center, Browns Valley, CA[1], University of California Davis, CA[2]. *corresponding author jjjames@ucanr.edu

Medusahead (*Taeniatherum caput medusae* (L.) Nevski) is an invasive annual grass that continues to spread across much of California's rangeland. This species shares many traits that are similar to other desirable annual grasses making selective control costly and logistically challenging. Defoliation through grazing is often viewed by managers and ranchers as the most economically viable and practical means for control. In some situations defoliation by mowing may also be a feasible management option. We quantified rate of medusahead phenological progression across multiple sites and years in California and evaluated how these changes relate to forage quality and susceptibility of seed production to defoliation. We then integrate these data to identify optimal treatment windows for controlling medusahead through grazing and defoliation. Lastly we evaluate how these responses vary deepening on medusahead seedbank density and habitat type (grassland vs. oak woodland). Defoliation across a range of grazing intensities reduced medusahead abundance compared to ungrazed plots. Medusahead maintained adequate crude protein to support beef cattle nutrition until seed head emergence and during this stage resulted in a 3 to 8 fold decrease in medusahead seed production, depending on grazing intensity. Defoliation via clipping latter in the growing season prior to kernel formation provided similar results. By seeding oak woodlands and grasslands at a range of medusahead densities we found that medusahead establishment and seed production in oak woodlands was over 10 fold lower than in open grasslands. Other desired grass species only showed about a 2 fold reduction in density in oak woodlands compared to open grasslands. Collectively these data help identify optimum treatment windows for medusahead via defoliation and how these responses vary across habitat types.

Herbicide Symptoms on Cool Season Vegetables in the Coastal Production District. Richard Smith, Vegetable Crop and Weed Science Farm Advisor, University of California Cooperative Extension, Monterey County

The cool season vegetable production area extends from Monterey, Santa Cruz and San Benito counties in the north south to Santa Barbara and Ventura counties in the south. This is an intensive production system with multiple crops grown on the same piece of land each year. The most common soil active preemergent herbicides used in the cool season vegetable production district include bensulide, cycloate, DCPA, flumioxazin, oxyfluorfen, pendimethalin, prometryn, pronamide, and *S*-metolachlor. A number of contact materials are used in the production fields and adjacent areas to provide post emergence weed control. Some crops are exclusively direct seeded while others are nearly all transplanted, and in general, the fields are small (<20 acres) with a mosaic of crop species mixed in the agricultural landscape; to further add to the complexity of the situation, production spans from the cold soil temperatures of late winter through spring and summer and back into cool soils in the fall. Given the intense rotations, it would seem that issues with herbicide carryover from one crop to another might be a huge issue; however, in spite of the rapid turnover of one crop to another, herbicide issues are relatively rare. However, in spite of grower's and PCA's best efforts, each year a limited number of issues from misapplication, drift or carryover of herbicides occur. Diagnosing these herbicide related issues can be difficult at times given the large number of factors that can be in play. Herbicide toxicity on vegetables can result from application of the wrong herbicide to the crop from a contaminated tank or a mistaken application. In addition, too high rates of the correct herbicide for a crop can cause significant problems as well; this issue is most often observed on sandy soils and can be exasperated in cool soil conditions in the winter and early spring. Drift from herbicides with contact action such as carfentrazone, flumioxazin, oxyfluorfen and paraquat cause non-descript necrotic spots on leaf tissue. However, many other chemicals such as fertilizers or phytotoxicity from other pest management materials cause necrotic spotting on leaves; to determine which chemical may be responsible for an issue, it takes careful observation of the pattern of symptoms in the field as well as background information on the history of pesticide applications to make a reasonable diagnosis. A good understanding of the age of affected tissue (young vs older tissue) and the type of symptoms (e.g. type of yellowing: diffuse, interveinal, mottled) can give clues as to the type of chemical that may be responsible for symptoms. Lab confirmation of the responsible chemical can be very useful; however, if the samples are obtained too late, the material can be diluted to below the detection limit of the lab which would give a false negative result. Finally, it needs to be kept in mind that 'herbicide like' symptoms can also be caused by other factors such as disease, environmental stress, adverse soil conditions, as well as some nutrient deficiencies.

Vegetable Weed Control Update for Arizona and Summary of Recent Research. Barry Tickes, University of Arizona Cooperative Extension

Lettuce, cole crops and melons are the principle vegetable crops grown in Arizona. There is a low tolerance for both weeds and crop injury by vegetable growers and the number of registered herbicides for these crops are is low. The loss of Kerb on leaf lettuce has resulted in an increase of broadleaf weeds, especially mustards. An Emergency Exemption (Sec 18) has been applied for in Az. although no action has occurred. Kerb is normally applied from 2 to 10 days after sprinkler irrigation is initiated to avoid leaching the herbicide prior to weed germination. Split applications have been tested to achieve the same goal and are now registered. Research has indicated that split applications can be beneficial in some instances. The use of Prefar has increased with the loss of Kerb on leaf lettuce. Research has indicated that increased levels of water applied by sprinklers helps incorporate this herbicide and improves control. Prowl was registered on cole crops in recent years and and trials have indicated that the highest labeled rate of 2.1 pts/ac. is too low in many situations .4.2pts./ac. is significantly more effective. Both older and new compounds are being tested on vegetables although most have been ineffective or unselective.

Prometryn and Linuron: Discussion of labels for the two herbicides as applicable to Cilantro

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This label update and subsequent discussion during the vegetable section of the CA Weed Science Society provides a brief overview on the current supplemental labeling of Caparol as one of the primary material for weed control in Cilantro. Supplemental labeling was presented to further explain application guidelines, approved recommended rates, pre harvest intervals as well as soil type precautionary statements in regards to Caparol herbicide. In addition, information was provided in regards to a 2012 cilantro herbicide trial conducted by Richard Smith, Farm Advisor, University of California Cooperative Extension, Monterey County. This trial was aimed towards evaluating weed control efficacy of Caparol, Lorox and Prefar applied preemergence and Caparol and Lorox applied at the first true leaf stage. On a side note it was important to mention that this field trial had good weed pressure throughout the evaluation period, with redroot pigweed (*Amaranthus retroflexus*), purslane (*Portulaca oleracea*), hairy nightshade (*Solanum sarrachoides*) and lambsquarters (*Chenopodium album*) being predominant. Preemergence applications were evaluated on August 22, 2012 based on the following rates: Caparol (1.5 lbs. a.i. /A) and Lorox at (1.5 lbs. a.i. /A) both provided complete weed control on this date. Prefar controlled pigweed, purslane and lambsquarters, but was weak on hairy nightshade and had a total of (22.0 weeds/3 ft2). Subsequent pictures taken of the trial where showcased each with the appropriate headline representing the specific treatment and rate of product utilized as well as whether or not the treatment was applied pre-plant or post-plant.

New Tools for Nutsedge and Other Difficult Weeds in Strawberry. Steven A. Fennimore*[1], Tom C. Miller[2], Husein A. Ajwa[1]; [1]University of California, Davis, at Salinas, CA, [2]Consultant, Salinas, CA. * safennimore@ucdavis.edu

Fumigant soil treatments were evaluated in lab studies, in field stations trials and on commercial strawberry production fields in coastal California during 2000 to 2014. This presentation will focus on the performance of several fumigants for the control of yellow nutsedge (*Cyperus esculentus*) tubers. IRF135 (Dominus, allyl isothiocyanate, AITC) was evaluated to determine the lethal dose required to kill 90% of weeds (LD_{90}). Dominus LD_{90} data show that sweet clover and pigweed LD_{90}'s required >396 lbs/A Dominus, yellow nutsedge required 92 lb/A. Annual bluegrass and sowthistle were controlled by $\leq$13 lb/A Dominus. In field studies to evaluate nutsedge control with Dominus, the 20 GPA rate resulted in 14% (b) viable nutsedge while the Dominus 40 GPA rate resulted in 0% viable nutsedge (c), i.e., 100% control. The nutsedge viability in the untreated control by comparison was 80% (a). Barrier films are becoming more widely used in California to trap fumigants in the soil and reduce fumigant emission. In a comparison of TIF (totally impermeable film, Vaporsafe) and HDPE (standard high density polyethylene film) nutsedge control with Pic-Clor 60 (1,3-D 35%, chloropicrin 60%) was better under TIF than HDPE. Pic-Clor 60 applied under TIF controlled nutsedge at 200 lb/A while Pic-Clor 60 applied under HDPE did not fully control nutsedge at 300 lb/A.

Weed Control in Tomatoes and Other Warm Season Vegetable Crops

C. Scott Stoddard[1]

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Weed control methods in tomatoes and warm season crops in California are characterized by use of pre-plant weed management coupled with a limited number of registered herbicides, mechanical cultivation, and hand hoeing when appropriate. For some crops, most notably sweetpotatoes, pre-plant soil fumigation is an integral component of the weed management as well. No single herbicide or combination of materials will control all weed species under all production conditions. An integrated approach to weed management is always recommended and usually practiced.

Warm season vegetables are grown under a dizzying array of climates, and therefore the diversity of weeds species also varies tremendously. Common troublesome weeds include field bindweed (*Convolvulus arvensis*), nutsedge (*Cyperus esculentus*), pigweeds (*Amaranthus* spp), nightshades (*Solanum* spp), common purslane (*Portulaca oleracea*), common lambsquarters (*Chenopodium album*),velvetleaf (*Abutilon theophrasti*), barnyard grass (*Echinochloa* spp), and Johnsongrass (*Sorghum halepense*). All can become problematic for vegetable crop producers, but generally can be controlled with a combination of mechanical methods and/or registered herbicides.

Perennial weeds such as field bindweed have become more problematic in tomatoes in the last decade as the industry has largely shifted to subsurface drip irrigation. While perennial weeds can be present in any tillage system, they are more often a problem where tillage is minimal, such that occurs in no-tillage (NT) and conservation tillage (CT) systems. While most tomatoes are not being produced with classic CT or NT systems, most buried drip systems are installed with a life expectancy of at least 5 years, drip irrigation may also increase certain perennial weeds, especially field bindweed, because of the lack of aggressive cultivation or reduced crop rotation leaves viable roots behind. Effectively managing perennial weeds in annual cropping systems can often be greatly improved by rotating to glyphosate-resistant crops such as cotton or corn, as part of a long-term management approach. Recent research by Lynn Sosnoskie at UC Davis has shown increased field bindweed suppression by approximately 20% with the pre-plant application of Roundup in a typical processing tomato production system.

Annual weeds are typically the single largest category of weeds in vegetable crops; three common species include the nightshades (groundcherry, black and hairy nightshade), redroot pigweed, and barnyard grass. The main method of reproduction and spread is through seeds. Redroot pigweed for example can produce more than 100,000 seeds per plant. Cultivation and herbicides applied before flowering is necessary to reduce the soil seed bank and effectively manage these weeds.

Unfortunately, herbicide development for vegetable crops is not a priority for R&D departments of various agriculture chemical companies. The available herbicides are limited, and tend to “trickle down” from the larger acreage agronomic crops. Dual Magnum (S-metalocholor) for example, has been registered in corn since 1965, but tomatoes were not added to the label until 2002. Around 2000, Roundup (glyphosate) added in-season use on sweetpotatoes when using a hooded sprayer. In the 21st Century, registered herbicides for fruiting crops (e.g. tomatoes, peppers) include Sandea (halosulfuron), Matrix (rimsulfuron), clethodim, and Zeus (sulfentrazone). Matrix can be applied both PRE and POST in tomatoes and significantly improves nightshade and field bindweed suppression, but has very long (>10 months) plantback restrictions for many crops, which often limits its use. Tomatoes and melons often have reduced weed pressure when following a glyphosate resistant crop such as Roundup Ready cotton or corn.

Many factors can degrade the performance of herbicides that normally show good weed suppression under the right conditions. The declining use of sprinklers in warm season vegetable crops because of reduced water availability removes an excellent method to incorporate pre-plant herbicides. Delayed incorporation of trifluralin can result in substantial volatilization losses and subsequent poor weed control. While herbicide resistant weeds have been shown to be mainly a problem in agronomic crops, at least 14 herbicide resistant weed species were reported in vegetable cropping production systems last year (Ian Heap, 2014). However, since vegetable rely much more on mechanical weed control as compared to agronomic crops, it is unlikely that herbicide resistant weeds will become a significant factor in vegetable crop weed management in the near future.

CEQA Mitigation Measures for Pest Control Recommendations. Scott Johnson, Wilbur-Ellis Company, sjohnson@wilburellis.com

Per the standard language on all California pest control recommendations, the Pest Control Adviser who signs that document should be able to "certify that alternatives and mitigation measures that would substantially lessen any significant adverse impact on the environment have been considered and, if feasible, adopted". This language comes from the California Environmental Quality Act, or CEQA. This presentation will briefly define what CEQA is and explain how it is connected to the pesticide registration and regulatory program of the California Department of Pesticide Regulation (CDPR). It will discuss what mitigation measures are, and also give examples of using drift retardants to mitigate, or lessen, adverse impact of pesticides that might move off target during a pesticide application.

Globally Harmonized System of Classification and Labeling of Chemicals (GHS). Richard Spas, Department of Pesticide Regulation, Sacramento, CA
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The Occupational Safety and Health Administration has adopted the United Nation's Globally Harmonized System of Classification and Labeling of Chemicals (GHS). While the U.S. EPA has established that pesticide labeling is not required to reflect the new label language on federally regulated products, the labeling will be required on California Only registrations. The California Department of Pesticide Regulation (DPR) has adopted the GHS for California Only registered products and recognizes the challenges that the registrants will have in updating their labels. To assist with this process, DPR has created a self-certification template to help registrants update their labels on file.

Proposed Changes to Pest Regulation by the California Department of Food and Agriculture. Dean G. Kelch, Primary Botanist, California Department of Food and Agriculture dean.kelch@cdfa.ca.gov

The pest classification system of the California Department of Food and Agriculture evolved as a system to indicate actions recommended by the department to control pests. Inclusion on the various pest lists was based on the expert opinions of departmental staff. As part of an effort to expedite effective regulatory action and in order to increase the biological rigor of pest classification, CDFA currently is putting into regulation an explicit pest risk analysis protocol for pest classification. The methodology is a simplified one using the most relevant and predictive questions from other pest risk assessment models. A standard model will be used for weeds, insects, plant disease organisms, and nematodes. This proposed approach will allow the public to see why (or why not) an organism was given a pest rating. It will also change regulated pest lists as contributions by extra-departmental experts are submitted. It also allows for regulation modifications as additional data becomes available.

Local Regulatory Issues / Pesticide Regulations and Compliance: Santa Barbara County. Tashina Sanders, Agricultural Biologist, Santa Barbara County
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This presentation was a pesticide laws and regulations update which discussed requirements for second generation anticoagulant rodenticides, changes to groundwater protection regulations, employee pesticide handler requirements, and a review of pesticide labels and issues local to Santa Barbara County. Second generation anticoagulant rodenticides were designated as California restricted materials, effective July 1, 2014. The active ingredients for these products are Brodifacoum, Bromadiolone, Difenacoum, and Difethialone. These products have been designated as restricted materials due to the hazard they present to non-target wildlife, particularly predator species. The use of these products now requires a restricted materials permit and can only be used in and within 100 feet of structures to protect them from house mice, Norway and roof rats. Structural pest control companies are exempt from restricted material permit requirements and are the only type of pest control businesses that are allowed to apply these materials. Requirements for Ground Water Protection CCR § 6800 were discussed including additions of active ingredients that have the potential to contaminate groundwater based on chemistry and environmental fate and removal of products unlikely to contaminate groundwater. Requirements for Wellhead Protection CCR § 6609 for mixing and loading pesticides or applying pre-emergent herbicides listed in CCR § 6800 within 100 feet of a well were also discussed. The presentation also covered complying with the pesticide label, how to interpret label statements and General Application of Standards CCR § 6601 relating to personal protective equipment for owner applicators. The presentation also focused on requirements for employee pesticide applications, not found on pesticide labels including requirements for training, personal protective equipment, decontamination and the use of coveralls. CCR § 6614 Protection of Persons, Animals and Property was also discussed and included definitions for substantial drift and due care found in CCR §6000. This code section places responsibility on the applicator prior to and while making an application to evaluate the equipment to be used, meteorological conditions, the property to be treated, and surrounding properties to determine the likelihood of harm or damage. Finally, local issues for Santa Barbara County were discussed including wildlife poisoning concerns due to possible use of second generation anticoagulant rodenticides, investigations of pesticide drift and growing public concern of pollinator protection, in part due to increasing use of neonicotinoid pesticides.

Assessment of Glyphosate and Paraquat Resistance in Hairy Fleabane and Horseweed Populations of the Central Valley. Marcelo L. Moretti*, M. Jasieniuk, B. D. Hanson. Plant Sciences Department, University of California, Davis, CA. *Corresponding author (mlmoretti@ucdavis.edu)

Resistance to glyphosate is a growing problem in California with confirmed cases in six weed species. Glyphosate-resistant populations of hairy fleabane (*Conyza bonariensis*) and horseweed (*C. canadensis*) were first documented in California in the mid-2000's and now are found throughout the Central Valley in orchards, vineyards, and non-cropped areas. Management of these populations relies on efficacy of herbicides other than glyphosate, but this approach is being jeopardized by the presence of glyphosate-paraquat-resistant populations of hairy fleabane. No cases of glyphosate-paraquat resistance have been reported in horseweed in California to date, but have been confirmed elsewhere in the United States. Resistance to glyphosate and paraquat in the same plant is rare with only three reported cases worldwide. Identification of herbicide resistance can aid in the implementation of management practices aiming to mitigate resistance spread. The objective of this research is to assess the distribution of resistance to glyphosate and paraquat in hairy fleabane and horseweed in California.

To assess the distribution of glyphosate and paraquat resistance, a total of 15 populations of Conyza spp. were selected, of which ten were hairy fleabane and five were horseweed populations. All populations were collected from orchards and vineyards in the Central Valley in 2010, and represent previously identified distinct genetic groups that correlate with geographical distribution. Additionally, reference populations were included: glyphosate and paraquat susceptible (GS) and glyphosate-resistant (GR) for both species, and glyphosate-paraquat-resistant (GPR) for hairy fleabane. In total, twenty populations were characterized simultaneously in greenhouse dose response experiments during summer 2014. The experiments included nine rates of glyphosate (0 to 54 kg ae ha^{-1}) or paraquat (0 to 40 kg ai ha^{-1}) and six replicates per treatment per population. The experiment was repeated. Plant mortality was assessed 21 days after treatment, and biomass was collected and dried. Data were analyzed using regression and the rate that reduced growth by 50% (GR_{50}) was used to compare level of resistance among populations.

All tested populations demonstrated some level of glyphosate resistance when biomass accumulation was compared to the reference GS population. The level of glyphosate resistance ranged from 2.5- to 25-fold among hairy fleabane populations, and from 5- to 35-fold among horseweed populations. Even the highest glyphosate rate (54 kg ae ha^{-1}) did not control all plants of some populations, but the reference GS lines of both species were controlled by 2 kg ae ha^{-1} of glyphosate or . Paraquat resistance was present in two hairy fleabane populations and one horseweed population. Levels of resistance ranged from 35- to 47-fold in the hairy fleabane, and almost 300-fold in the horseweed. In all cases, paraquat resistance was associated with glyphosate resistance. Glyphosate-paraquat-resistant populations were found in Merced County for horseweed, and in Kern, Fresno, and Merced counties for hairy fleabane.

In summary, this research confirms the first case of glyphosate-paraquat-resistance in horseweed in California. Glyphosate-paraquat resistance has now been found in two Conyza spp, and the resistant populations are found in several areas of the Central Valley.

Effect of Light Intensity on the Efficacy of Some Post-Emergent Herbicides on Different Biotypes of Hairy Fleabane from the Central Valley.

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Hairy fleabane [*Conyza bonariensis* (L.) Cronq.] is a problematic weed in California. This problem has been further aggravated by the discovery of glyphosate-resistant (GR) and glyphosate + paraquat resistant (GPR) biotypes. Therefore, alternative herbicides are being explored for their control. Saflufenacil (Treevix ™) is a fairly new herbicide labeled for tree crops. Although this herbicide is labeled to be effective against hairy fleabane, the influence of light intensity on its efficacy is unknown. Light intensity at the time of herbicide application can influence the efficacy of a protoporphyrinogen oxidase (PPO)-inhibiting herbicide like saflufenacil as these herbicides are light-activated. However, light intensity may also influence other post-emergence herbicides. Therefore, the objective of this study was to evaluate the effect of light intensity on the efficacy of saflufenacil, glyphosate, glufosinate, and pyraflufen on GR, GPR, and glyphosate-susceptible (GS) hairy fleabane plants.

Seeds of confirmed GR, GPR, and GS hairy fleabane plants were planted in a greenhouse. Once the seedlings reached the 2 to 3-leaf stage, they were transplanted into 2" pots containing potting soil. At the 5- to 8-leaf stage, the plants were treated with either glyphosate (28 oz/ac), glufosinate (82 oz/ac), saflufenacil (1 oz/ac), or pyraflufen (4 oz/ac). A 1% v/v methylated seed oil and crop oil concentrate was added to the saflufenacil and pyraflufen treatments, respectively. Ammonium sulfate was added at 2% w/v for saflufenacil and glyphosate treatments and 1% w/v for glufosinate treatments. The treatments were applied with a CO_2 backpack sprayer at a spray volume of 26 GPA. Immediately after treatment, the plants were exposed for 48h to 4 different light intensities in an open field and kept in mini-tents with shade cloth of different shade levels [0% (complete darkness), 50%, 70% and 100% (full sun]. The plants were then returned to the greenhouse and kept for an additional 28 days. Plant mortality was recorded weekly. Plants were harvested at 30 days after treatment (DAT) and the aboveground dry biomass was recorded. The experimental design was a split-split plot with four replications. Light was the main factor, biotype the sub-factor, and herbicide treatments the sub sub-factor.

The results showed that light intensity had no effect on the efficacy of the herbicides on any of the biotypes. The herbicides had differential effect on the different biotypes. Glufosinate controlled 100% of all three biotypes. Saflufenacil controlled 46, 55, and 58% of the GR, GPR, and GS plants, respectively. Glyphosate controlled 29, 38, and 100% of the GR, GPR, and GS plants, respectively. Pyraflufen controlled only up to 4% control of any of plants. Almost 50% of all three biotypes of the saflufenacil-treated plants regrew at all levels of light. The plants were completely necrotic at 7 DAT but by 30 DAT they regrew with healthy green leaves. Although light intensity had no effect on the mortality of the plants, the injury symptoms were greater at the 100% and 70% than at the 50% and 0% light levels in the saflufenacil and pyraflufen treatments. Plant biomass in these treatments was also lower at the higher light intensities. Therefore, this study showed that light intensity up to 48 hours after treatment did not influence herbicide efficacy. Glufosinate was the most effective treatment for control of all three biotypes. Saflufenacil was effective early on but many plants regrew. It is not known if moving them back to the greenhouse after 48 hours of treatment was responsible for this. This phenomenon should be further investigated.

Resistance of *Leptochloa fusca* spp. *fasicularis* (bearded sprangletop) to ACCase Inhibitors in California Rice. Whitney B. Brim-DeForest[1*], Rocio Alarcón-Reverte[1], and Albert J. Fischer[1]; [1]Department of Plant Sciences, University of California, Davis [*]wbrimdeforest@ucdavis.edu

Leptochloa fusca (L.) Kunth ssp. *fascicularis* (Lam.) N. Snow (bearded sprangletop) is a native weed of rice in California common to dry-seeded systems or systems where the water level has been allowed to recede. Herbicide resistance in *Leptochloa* species has been documented in other parts of the world, but this is the first reported instance in *Leptochloa fusca*. Resistance has not yet been found in the species *L. fusca* spp. *uninervia* (J. Presl) N. Snow (Mexican sprangletop), also a weed of California rice. Anecdotal evidence of resistance to cyhalofop has been recently noted by California rice growers. Growers are currently limited in the number of available herbicides that can control this species (cyhalofop, clomazone and thiobencarb). Thus, the objectives of this research were: 1) to confirm resistance to ACCase inhibitors in *L. fusca* spp. *fascicularis* (bearded sprangletop) in California rice; and 2) to determine a possible mechanism of resistance.

Seeds from two populations of *L. fusca* spp. *fasicularis* (bearded sprangletop) were collected from fields in Butte County, CA, in 2012 and 2013. Greenhouse experiments for whole plant bioassays were conducted at the Rice Experiment Station, in Biggs, CA in 2014. Single-seed lines of two populations, one presumed resistant (RI1) and one known susceptible (F) were used. Clethodim, cyhalofop and quizalofop were applied using a cabinet track sprayer when plants were at the 1-2 leaf stage. Clethodim was applied at 0, 26.3, 52.5, 105.1, 192.7, 280.2, 560.5 and 1121 g ai ha^{-1}, cyhalofop was applied at 0, 67.7, 156.3, 271, 302.2, 333.5, 667, 1334 g ai ha^{-1}, and quizalofop was applied at 0, 9.6, 19.3, 38.5, 65.5, 92.5, 185 and 277.4 g ai ha^{-1}. Partial sequencing of the *ACCase* gene in susceptible and resistant biotypes was conducted to elucidate the possible presence of resistance-conferring mutations.

Evaluation of the whole-plant bioassays confirmed resistance to cyhalofop and quizalofop, but not to clethodim. Resistance selected by cyhalofop use confers cross-resistance to quizalofop but not to clethodim. Preliminary evidence suggests that the mechanism of resistance to the cyhalofop and quizalofop involves a target-site alteration: the resistant biotype has a substitution at Trp2027Cys in the *ACCase* gene: a nucleotide change from guanine to thymine (TGG to TGT) at the third position of the codon encoding the amino acid tryptophan (Trp), which translates to a change from tryptophan to cysteine (Cys). This point mutation is known for conferring resistance to "fop" herbicides.

Since cyhalofop resistance appears to be target-site and unless another source of resistance is unveiled, current recommendations for growers are to use herbicides with a different mode of action, such as thiobencarb, clomazone or benzobicyclon.

Interactions between Glyphosate and Foliar Micronutrient Applications in Minimizing Corn Injury. Oscar Morales, Bahar Y. Kutman, Brad Hanson, Department of Plant Sciences, University of California, Davis

Herbicide drift may lead to reduction in growth and yield of non-target crops. Use of herbicides and herbicide-resistant crops increases the risk of drift injury for farmers who grow non-glyphosate-resistant plants nearby. A few studies in the literature point out the possibility of reducing glyphosate drift injury by foliar applications of micronutrients. The aim of this experiment was to investigate whether micronutrients (zinc (Zn), nickel (Ni), and manganese (Mn)) would prevent drift injury when applied prior to simulated glyphosate drift or correct or reduce injury symptoms when applied after glyphosate. In this greenhouse experiment, sweet corn (*Zea mays* cv. Precious Gem) was used as a model plant. Nine days after sowing (DAS), pots were sprayed with 3 glyphosate doses: 0, 1.5 or 3 % of a recommended glyphosate dosage (100% = 1 lb ae/A). Either two days before or after glyphosate application, the plants were treated with foliar applications of water, Mn, Ni or Zn. Height measurements were taken during the experiment and plants were harvested 14 DAS for dry weight determination. It was found that neither pre- nor applications of these micronutrients had a significant beneficial effect on glyphosate drift injury in corn. However, it was observed that post-glyphosate applications of micronutrients actually aggravated injury. Relative to control plants, 1.5% glyphosate-treated plants were 15% shorter and had 30% less shoot biomass, whereas 3% glyphosate-treated plants were 65% shorter and had 90% less shoot biomass. When compared to pre-treated plants, post-treated ones were reduced by 15% in height and 30% in dry weight. Although more trials need to be conducted to verify these observations, the timing of micronutrient sprays seems to be critical since post-drift applications may actually worsen the glyphosate drift injury symptoms.

The Effect of Spin-Aid on Spinach at Different Leaf Stages and Radiation Levels. Esteban Gonzalez.* R. Lati. California Polytechnic State University San Luis Obispo, CA. University of California Cooperative Extension, Monterey County, CA. *egonza46@calpoly.edu

Two fresh market spinach (*Spinacia oleracea*) varieties, Regal and Sardinia, were used to develop preliminary data about spinach response to cycloete (Ro-Neet) followed by phenmedipham (Spin-Aid) at several growth stages. A second set of experiments was conducted to evaluate the impact of light intensity and application timing on spinach tolerance to phenmedipham using the same two varieties. The first set of experiments showed that there was a significant reduction(~60%) in the weight of the Regal variety that were sprayed in the cotyledon stage when compared to those sprayed at the 2- leaf stage. There was a significant biomass reduction in both varieties under both 100% (full sun during summer in Salinas, CA) and 50% (half full sun during summer in Salinas, CA) radiation with the application of phenmedipham compared to the control. Overall there was a very low tolerance for phenmedipham at the cotyledon stage of both fresh market spinach varieties at any radiation level.