Herbicidal Crop Injury Mechanisms and Routes of Exposure. *Brad Hanson, UC Cooperative Extension Specialist, UC Davis*

Herbicides can provide an amazing level of weed control in many situations; however, they can also cause unexpected crop injury in some cases.

A great deal of research goes into developing herbicide uses for labeled crops to ensure rates and use patterns will allow good crop safety and performance. In labeled crops this may be due to an inherent tolerance, timing or placement of the herbicide relative to the crop, or herbicide safeners. In non-labeled crops, safety is usually achieved through separation in time (e.g. rotation crop restrictions) or in space by using buffer zones or application techniques to mitigate drift.

When crop injury occurs, it typically is due to either a foliar route or a root uptake route. The effects of foliar exposure can be very dramatic when applied directly to a sensitive crop (wrong herbicide, wrong field) or from mixer/loader errors such as a rate miscalculation or sprayer mis-calibration. In situations with lower margins of safety, injury can also occur from excessive spray overlaps or use of “hot” surfactants. In-field foliar exposure problems can also be less dramatic and variable such as in the case of low doses due to sprayer contamination or drift from poorly set up spray booms. Usually, these scenarios don’t have a clear pattern in the field or may be associated with sprayer tank loads if a loading mistake.

Foliar exposure can also happen from drift onto a sensitive crop from an adjacent field, field margin, or neighboring area. This can be dramatic or subtle and is due to direct movement of spray droplets out of the targeted area before they ever reach the soil or foliage. A few herbicides are somewhat volatile and can move in the vapor phase after deposition on the target. This is more common under moist warm conditions and is generally limited to only a few herbicide active ingredients. Importantly in most cases of drift, either as droplets or volatiles, there will be some sort of pattern in the field. Because the dose will be higher nearest the source of the drift, often a gradient of injury is visible and gets less dramatic further from the source area.

Herbicide injury from root uptake is usually due to something done in that field, not due to neighboring field operations. Herbicides can be in the soil due to an application in a preceding crop persisting at too high of a level for the next crop in the rotation. Planting a sensitive crop too soon after a long–residual herbicide is one factor that can contribute to this type of exposure. Excessive application rates or slower-than-expected dissipation rates can also contribute to injury in this scenario. Another route of crop injury caused by herbicide soil exposure is from herbicides used in that crop but being incorporated too deeply, either mechanically or by excessive downward movement with irrigation or rain water. Depending on the situation, this type of injury can range from patchy and sporadic to fairly uniform across the field and have a wide range of severity. When patterns of injury are noted, it sometimes can be associated differences in soil, water, or application rates in areas of the field.

When trying to diagnose herbicide symptoms on any crop, it's important to think about how they work (mode of action), how they move in soil or plant tissue. This information can provide important clues as to expected symptoms, timeline, and duration of injury. Remember that symptoms can vary widely depending on the crop species, part exposed to the herbicide, the dose/rate of exposure, and the time since exposure. Additionally, many biotic and abiotic disorders can be confused with herbicide injury so it's important to avoid jumping to conclusions.

When in the field, take good photos of the symptoms and include both overviews and close-ups. Describe the timeline of events and symptom development on crop and non-crop plants. Question the growers and advisors about herbicides and other practices used at the site in question as well as think about the weed control practices used in surrounding areas. Look for patterns in the field – these can be especially important in diagnosing application errors or soil issues and may reveal other cultural practices that can cause crop damage.

Finally, symptomology can never be fully diagnostic of herbicide injury – when in doubt, collect leaf and tissue samples and freeze in case it becomes necessary to confirm herbicide exposure through laboratory analyses.

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

Processing tomato planting in the San Joaquin Valley has transitioned to the use of transplants, buried drip irrigation, and shallow tillage. The use of buried drip tape with shallow tillage on semi-permanent beds has also facilitated the rotation of crops due the 10-12" depth of the tape and its durability. The use of pre-plant herbicides in tomato production were generally safe and caused no negative effects on plant health. However, in recent years, there are reports of dinitroaniline injury symptoms in processing tomato fields that had been treated with regular pre-plant herbicides in these systems. These injury symptoms consisted of stunted plant growth and reduced root development. It is suspected that the breakdown of pre-plant herbicides was facilitated more when deep tillage was done after harvest than under the current grower practices. Therefore, a greenhouse study was conducted in Fresno, CA in summer 2015 to assess plant injury to simulated residues of pre-plant herbicides. The objective of this study was to evaluate above- and below-ground response of transplanted tomato to pre-plant herbicides. The herbicides included trifluralin (Treflan), s-metolachlor (Dual Magnum), and pendimethalin (Prowl H_2O) at doses of 0, 0.03, 0.06, 0.12, 0.25, and 0.5 ppm. The experimental design was a two factor (herbicide type and dose) randomized complete black with four replications. Field soil was collected and mixed with herbicides in a cement mixer. The treated soil was placed into 3 gallon pots and tomato seedlings were transplanted and grown in it for 45 days. Plant growth (height and leaflet numbers), chlorophyll concentration of leaves, and stomatal conductance were monitored weekly during the growth period. At 45 days, plants were clipped and separated into roots, stems, and leaves. The roots were carefully washed to remove the soil. Total leaf area for each plant was measured and then all the above- and below-ground plant parts were placed into a forced-air oven at 60° C for 72 h and dry weights were recorded. Data was analyzed using ANOVA procedures, and non-linear regression models were used to calculate the dose required to reduce biomass by 50% ($GR_{50\%}$). The above- and below-ground biomass was differentially affected by herbicide type and doses. All herbicides resulted in some reduction of above- and below-ground biomass of the tomato plants at the higher doses compared to the non-treated plants. Trifluralin and *s*-metolachor resulted in greater reductions in above- and below-ground biomass than pendimethalin. The GR_{50} of trifluralin and *s*-metolachlor was estimated to be 0.45 and 0.48 ppm, respectively for above-ground biomass and 0.5 and 0.22 ppm, respectively for below-ground biomass. Pendimethalin caused some reductions in the above- and below-ground biomass only at the highest dose. Leaf area and final plant height was also reduced by about 50% and 30% in the *s*-metolachlor treated plants at 0.5 ppm. Chlorophyll concentration and stomatal conductance of the leaves was generally reduced at the higher doses of all herbicides compared to the untreated control, again the reductions were greater in the trifluralin and *s*-metolachlor treated plants. It can be concluded that, among the herbicides tested, *s*-metolachlor had the greatest potential to cause injury to the tomato plants followed by trifluralin. Although pendimethalin caused some injury at 0.5 ppm, it was generally safer than the other two herbicides.

Effect of Shade and Soil Moisture Level on the Efficacy of Selected Postemergence Herbicides in Control of Junglerice (*Echinochloa colona*).

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Junglerice (*Echinichloa colona*) is a problematic weed in annual and perennial cropping systems of California. Further, the discovery of glyphosate-resistant (GR) populations of junglerice in the Central Valley has aggravated the problem. Two alternatives that have been identified in perennial cropping systems are sethoxydim and glufosinate, both of which are postemergence herbicides. However, the performance of these herbicides can be influenced by environmental conditions such as light intensity and soil moisture. Junglerice, in orchards, are usually growing under shaded conditions. Further, increasing incidents of drought in the Central Valley are promoting regulated deficit irrigation (RDI) of crops. The combination of drought and RDI can create soil moisture stress conditions. Both shade and soil moisture deficiency can reduce the efficacy of these herbicides on plants that are growing under stressful conditions.

A study was conducted in Fresno, CA in summer 2015 to evaluate the effect of light intensity and soil moisture levels on the efficacy of sethoxydim, glufosinate, and glyphosate on potted junglerice plants. Four to 6-leaf stage junglerice plants were grown in 3" size plastic pots containing field soil. Three levels of shade (70% shade, 50% shade, and 0% shade) were imposed using shade cloth of various transparency and three soil moisture regimes (100% , 50%, and 25% of field capacity) were imposed using the gravimetric method. The plants were treated with label rates of the selected herbicides between the second leaf and the first tiller stage. An untreated control was also included. Shade was simulated by using shade cloth of various transparencies. The experimental design was a split-split-split plot with shade as the main effect, soil moisture as the sub-effect, and herbicide type as the sub-sub effect. Mortality and other biomass of these plants were evaluated every 7 days after treatment. Data were analyzed using analysis of variance procedures in SAS at a significance level of 0.05.

Results indicated that mortality of the plants was affected differentially by light intensity, moisture level, and herbicide type. There was a significant interaction between light intensity and soil moisture level. Therefore, data were analyzed separately for each shade level. Interactions occurred between moisture level and herbicide type under shade but not under full sun. Glufosinate provided 100% control of the junglerice plants at all light and moisture levels. Sethoxydim provided 70 to 100% control of the plants under full sun. Although all the plants were controlled at 100% FC with sethoxydim under 50 and 70% shade, mortality of the plants was reduced to 20 to 50% at 50% FC. Similarly, the efficacy of glyphosate was also affected by shade and moisture levels. The efficacy of glyphosate was generally greater under shade than under full sun conditions and mortality was greater at 100% and 75% FC than at 50% FC. Among the herbicides compared, glufosinate was the best treatment under all levels of shade and moisture conditions. Control of junglerice with sethoxydim was lower under shaded and low moisture conditions, whereas control with glyphosate was better under shaded conditions at 100% and 75% FC moisture conditions. Therefore, both shade and soil moisture conditions should be taken into consideration when selecting postemergence herbicides for control of junglerice.

A Comparison Between Automated Thinners and Hand Thinning of Lettuce in the Salinas Valley: Weed Control and Efficacy. Elizabeth Mosqueda[1], Richard Smith[2], and Anil Shrestha [1], [1]Department of Plant Science, California State University, Fresno, CA [2]University of California Cooperative Extension, Monterey, CA

California's agriculture industry has been hindered by a severe labor shortage during the past years. As the leading producer of vegetable crops, a highly labor intensive commodity, this problem is even more detrimental in California. In 2012, growers of California's Salinas Valley, the leading producer of lettuce in the nation, began to implement the use of automated lettuce thinners. These innovative implements are meant to take the place of a hand thin crew in ensuring a lettuce crop is adequately spaced and weeded. As these implements are new to many growers, assessments on their efficiency to thin and weed lettuce are needed. Therefore, a study was conducted during the 2014 and 2015 lettuce season in the Salinas Valley. The experimental design was a randomized complete block design. During the 2014 season, 7 fields acting as a block were split into two plots and assigned a treatment (hand thinned or automatically thinned). During the 2015 season, one field was split into 4 blocks, and each block into two plots and were each assigned a treatment. During both seasons each block consisted of 5-10 randomly chosen sub plots from which data was acquired. Parameters measured were plant, weed and double (two closely spaced plants) counts, all done by performing counts prior and after thinning, and plant spacing measurements performed after thinning. Timings were also taken during the initial thinning process as well as the double/weed removal pass. The average lettuce thinning time was 3 to 4 times quicker with the automated than with the manual system. The automated system tended to leave more doubles than the manual system; however, the time required for removal of the doubles was similar between the two systems. Spacing of plants within rows was also similar between the two systems. In terms of weed removal, the automated system was as efficient as the manual system. The major weed species present were shepard's purse (*Capsella burla-pastoris*) and annual sowthistle (*Sonchus oleraceus*). Therefore, automated thinning holds great potential to aid lettuce growers in the Salinas Valley.

Comparison of Weed Control Methods in Organic Broccoli. Sarah R. Parry*, Larissa Larocca de Souza, Julie Pedraza, and Anil Shrestha, Department of Plant Science, California State University, Fresno, CA *Corresponding Author's Email: sarahparry13@mail.fresnostate.edu

Weed management in organic cropping systems is a major challenge. These systems generally rely on mechanical, physical, or cultural methods of weed control. Furthermore, there are very limited number of herbicides labeled for use in organic cropping systems and most of these are postemergence herbicides which are generally expensive. Therefore, weed management accounts for a substantial portion of farm budgets in organic systems. For example, 2010 estimates show that broadcast application of organic herbicides can cost approximately $400-600/acre. However, in recent years, some newer certified-organic herbicides have been registered in California. One such herbicide is Suppress® a postemergence, broad spectrum, contact herbicide. The active ingredients in this herbicide are caprylic acid and capric acid.
Broccoli is an important commodity in California and the state accounts for 91% of organic broccoli production in terms of sales nationwide. Estimates from 2008 show that the area under organic production of broccoli is approximately 4300 acres. Weed management in organic broccoli production is a concern as in any other organic cropping systems and cost-effective weed control measures need to be developed for the sustainable production of this crop. Therefore, a study is being conducted in Fresno, CA comparing several weed management treatments in organic broccoli production. Treatment comparisons include hand weeding once a week, hand weeding alternate weeks, propane flaming once a week, propane flaming alternate weeks, herbicide (Suppress) application twice during the growing season, herbicide application once + hand weeding, herbicide application once + propane flaming. An untreated control was also included. The experiment was designed as a randomized complete block with four replications. Data are being taken on weed densities by species. Time taken to implement each of these weed control treatments are being recorded. Amount of propane used during each application and herbicide costs will also be estimated. At harvest, weed biomass in each treatment plot will be estimated. Crop yield, quality, and chlorophyll concentration of the broccoli leaves will also be recorded at harvest. It is anticipated that this study will provide valuable information on comparative weed management methods in organic broccoli production.

Biological Control of Aquatic Weeds: Research in California.

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Weed biological control has a long history in California and the western U.S. The choice of selecting which of the many possible plants to target with weed biological control is often driven by available financial support. This selection method may not consistently select the most problematic, most feasible, or weed with the greatest likelihood for success. The presentation will describe a new selection process that maximizes demand and benefits for improved long term success of weed biological control projects. The presentation will also include an overview of the current weed biological control projects that the USDA's Exotic and Invasive Weeds Research Unit are focusing their research efforts on.

The Reboot of Aquatic Plant Management in the Delta. Angela Llaban, CA State Parks Division of Boating and Waterways

The California State Parks Division of Boating and Waterways (DBW) is designated as the lead State agency for cooperating with agencies of the United States and other public agencies in controlling invasive aquatic plants in the Sacramento-San Joaquin Delta and its tributaries. By using an integrated pest management approach, DBW currently implements control measures for water hyacinth (*Eichhornia crassipes*), Brazilian waterweed (*Egeria densa*), South American spongeplant (*Limnobium laevigatum*), and curly leaf pondweed (*Potamogeton crispus*). Other aquatic plant species such as water primrose (*Ludwigia* spp.), Eurasian watermilfoil (*Myriophyllum spicatum*), fanwort (*Cabomba caroliniana*), and coontail (*Ceratophyllum demersum*) are identified as candidate species for future management. The Aquatic Invasive Species Program's objectives are to keep waterways safe and navigable by controlling the growth and spread of invasive plant species and to minimize negative impacts on the environment, public health, and economy. Faced with challenges of invasive aquatic plant management in the Delta, DBW recognizes an opportunity to strengthen its scientific and holistic approach through research and interagency collaboration.

Management of Submersed Aquatic Vegetation in Lakes and Ponds. Joseph D. Vassios. United Phosphorus, Inc., Rocklin, CA, USA. joseph.vassios@uniphos.com

Submersed aquatic plants are a vital part of the aquatic ecosystem, but nuisance and invasive species can drastically effect the economic and ecological value of lakes and ponds. These negative impacts may occur through alteration of habitat, water quality, recreational uses, irrigation, and municipal uses. For this reason, it is important to manage these plants to maintain the usage of these water bodies. There are a number of these species that occur across California, and each of them have distinguishing features that can be used to identify the species and determine the appropriate management approach. There are a number of mechanical, biological, physical, cultural and chemical methods available for control, and each can be appropriate based on the features of an individual water body. One of the most common control methods is the use of herbicides. These herbicides are separated into two groups, contact and systemic herbicides. Contact herbicides generally require shorter exposure times, and will generally act faster than systemic herbicides. Systemic herbicides generally require longer exposure times, and are often used for larger scale or whole-lake treatments. While different conditions present at the time of treatment can effect which product or management method is the best option, implementing a suitable method can provide management of the species at a level that will allow for continued use of the water body, and maintain its ecological and economic function.

Life History and Aquatic Weed Management. John D. Madsen, USDA ARS Exotic and Invasive Weed Research Unit, Davis, CA

Under Integrated Pest Management, the goal is to achieve long-term control of the weed population. While this is a laudable goal, a valid question is to ask, what is the population that you should target? What is an individual? For aquatic weed management, the best way to address this issue is to better understand the life cycle and biology of the target plant species. Most aquatic weeds will follow one of three life history patterns: annual, herbaceous perennial, or evergreen perennial. For each of these life history patterns, there are identifiable propagules or stages that can be targeted for management. Management success can be evaluated by monitoring the population of the target propagule. The application of this concept will be reviewed using four species: Waterchestnut (*Trapa natans*), curlyleaf pondweed (*Potamogeton crispus*), flowering rush (*Butomus umbellatus*), and Eurasian watermilfoil (*Myriophyllum spicatum*).

Weed Management Challenges and Options for Subtropical Crop Orchards in California.

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Introduction

In Southern California, there is a diverse acreage of subtropical tree crops, such as date palms, macadamias, pomegranates, mangos, citrus, avocados, dragon fruit, and cherimoyas to name a few. Many of the growers of these tree crops range from large scale production operations with hundreds of acres to small grower parcels that are only a few acres. In addition there are certified organic growers. Subtropical crop integrated weed management (IWM) programs typically utilize a combination of control practices, like cultural, mechanical, and chemical, to minimize competitive effects of weeds on crop productivity. Weed management can be an expensive part of the total subtropical tree crop production program and resources invested here can provide significant economic returns. However after assessing these high value commodities this past year it looks as if weed management has not been a top priority, or seems as if there is a need for more research, outreach, additional herbicide mode of action (MOA) labels and in general alternative weed management methods that can be suitable for the continuing growth of organic acreage .

Need for Weed Management

Weeds can impact cultural operations, tree growth, and yields by altering the spray pattern of low-volume irrigation systems, intercepting soil-applied chemicals (fertilizer and agricultural chemicals), reducing grove temperatures during freeze events, and interfering with pruning and harvest operations. The presence of weeds in a subtropical grove can also affect insect populations and create an environment for dangerous vertebrate pests such as coyotes and venomous snakes which can be hazards to hand picking crews. For example, in the Coachella Valley, there has been an increase in rattlesnake bites during date harvest season due to the lack of vegetation management in the grove. Weeds growing around tree trunks may also create a favorable environment for pathogens that infect the trunk and roots (Futch and Singh, 2010). Weed species compete with trees in many ways and with varying intensities; management of more competitive weeds such as hairy fleabane, horseweed, johnsongrass, dallisgrass, and vetch should be prioritized. While some weeds (e.g., puncturevine, spiny cocklebur, stinging nettle, bull thistle, and bristly oxtongue) may have low competitive effects on citrus trees, they can also hinder labor operations and may also rank high for active management. In addition, in the southern California mild climate, certain annuals may behave as biennials or short-lived perennials- for example, horseweed, fleabane, and mallow.

Cultural

Preventive programs are often overlooked, but are an important component of cultural practices and are cost-effective. Practices, such as sanitation, spot spraying, and/or hand removal of weed escapes before they produce new seed are examples of prevention. While preventive programs may not stop the spread of all weed species, these practices may slow the spread of undesirable species, thereby reducing long-term weed control costs.

Mechanical

Cultivation or tillage has been used in the past in citrus production. However this practice does not fit all subtropical trees since many have a shallow fibrous root system and tillage increases the risk of root and trunk damage. In addition, some subtropical trees such as avocados are planted on steep mountain sides and bringing in any type tractors or machinery can be a challenge and even dangerous. However when used, tillage is an effective method of controlling annual weeds effectively by severing weed stems and roots. Tillage can be counterproductive for perennial grasses or sedges that can propagate vegetatively. Soil erosion concerns are cited as a reason why tillage use is decreasing as more groves are planted on raised berms. With the use of low-volume irrigation systems and closer in-row planting distances, tillage in both directions is no longer possible in some groves. Mechanical mowing is generally more expensive than tillage and can throw seed under the tree canopy, increasing weed pressure next to the tree trunk.

Chemical

The amount of products that are registered for certain specialty subtropical crops can also be a challenge. Currently there are only 13 preemergent and 13 postemeregnt herbicide registered for a few of the leading subtropical trees, avocados, citrus, pomegranates, and dates and even then there are many restrictions and specific label instructions that must be followed (Table 1.).

Preemergence herbicides are generally applied two to three times per year, so the maximum amount of herbicide is in the upper soil profile (0 to 2 inches) slightly before peak weed emergence. Herbicides applied too early, before weeds emerge, will not provide adequate weed control due to herbicide leaching or degradation on the soil surface or within the soil profile. Preemergence herbicides must be incorporated (mainly by rainfall or irrigation) and are usually broadcast on the entire orchard floor since growers do not know where weeds will emerge and to reduce risk of frost damage. Growers using drip irrigation or micro-sprinkler irrigation have a difficult time adequately incorporating preemergence herbicides, so they usually try to treat prior to predicted rainfall (Rector et al. 1998). Soil type can influence herbicide selection and rate used. Many preemergence herbicides including Goal, Prowl, Surflan, Treflan, and Visor can be used on sandy soils without injuring citrus trees (McCloskey and Wright 1998). However some premergent herbicides that are registered for avocados should still be used with caution due to sandy soils. Tree age is also an important consideration when selecting which herbicide(s) to use. Unfortunately, due to the cost of water, rain becoming less unpredictable, risk of mishandling and damaging sensitive root systems, and price, preemergents are seen less and less in weed management regimes.

Postemergence herbicides are used to control weeds that escape control by preemergence herbicides or mechanical cultivation. These herbicides are effective on small annual weeds and usually only suppress growth of perennials. It should be noted that the majority of organic herbicides are contact herbicides. Currently, glyphosate seems to be the herbicide of choice for these tree crops. Growers appreciate the convenience of the broad label and wide-ranging spectrum of weeds that it can eradicate. It's inexpensive, readily available and can be used in just about any stage of the tree's development. Though continuous use over time will likely lead to the development of resistant populations in some weed species. To help reduce likelihood of herbicide resistance development, it should be rotated and/or mixed with herbicides having different modes-of-action. While it is well known that horseweed and fleabane have been confirmed resistant to glyphosate in the central and northern parts of California, verifying if these biotypes have developed south of the grapevine is still in question. Nevertheless, I have received several calls from growers that weeds in their groves are not being controlled by their favorite choice of herbicides and these problems are starting to become more frequent in subtropical tree crops.

Cover crop benefits and complications

Vegetated orchard floors can accentuate frost hazard, often experiencing 3-5°F cooler ambient temperatures than do bare orchard floors, depending on vegetation height and atmospheric conditions (Steinmaus 2014). Alternatively, ground cover in the row middles can reduce soil erosion, reduce sand blasting during windy conditions and help retain nutrients. Ground covers can also be beneficial if they are less competitive than other weeds potentially present in the grove, and for erosion-prone situations such as on steep slopes or poorly structured soil. Cover crops may require additional management steps such as rotation to a different species or species mixture every few years to avoid pathogen buildup. Currently, there are no cover crops that will fit all situations and provide all possible benefits (Steinmaus 2014). Water requirements for vegetation regrowth after mowing can impact water availability within the grove, with grasses typically using more water than broadleaves post-mowing. This form of weed control is mostly seen in the organic production side.

Organic Tree Production

Organic groves are probably the biggest challenge when it comes to weed management, as they lack available herbicide chemistries. Most organic operations are usually the smaller scale growers that cannot simply afford weed management.

Summary and Conclusions

Weed control options are limited in some cases by economic, environmental, or practical limitations. Additionally, there are relatively few herbicide mode of actions registered in these specialty tree crops. Our challenge is to start thinking about IWM strategies and revisit basic principles such as using pre- and post- emergent herbicides in combos and rotating MOA’s. Alternative tools for weed management need to be evaluated.

Table 1. Herbicide Registration on CA Subtropical Crops (*Updated October 2015- UC Weed Sciences)*

	Herbicide-Common Name *(example trade name)*	Site of Action Group[1]	Avocado	Citrus	Date	Fig	Kiwi	Pomegranate
Preemergence	dichlobenil *(Casoron)*	L / 20	N	N	N	N	N	N
	diuron *(Karmex,Diurex)*	C2 / 7	N	R	N	N	N	N
	EPTC *(Eptam)*	N / 8	N	R	N	N	N	N
	flazasulfuron *(Mission)*	B / 2	N	N	N	N	N	N
	flumioxazin *(Chateau)*	E / 14	NB	NB	N	NB	N	R
	indaziflam *(Alion)*	L / 29	N	R	N	N	N	N
	isoxaben *(Trellis)*	L / 21	NB	NB	N	NB	NB	NB
	napropamide *(Devrinol)*	K3 / 15	N	N	N	N	R	N
	norflurazon *(Solicam)*	F1 / 12	R	R	N	N	N	N
	oryzalin *(Surflan)*	K1 / 3	R	R	N	R	R	R
	oxyfluorfen *(Goal, GoalTender)*	E / 14	R	NB	R	R	R	R
	pendimethalin *(Prowl H2O)*	K1 / 3	N	R	N	N	N	R
	penoxsulam (*Pindar GT*)	B / 2	N	N	N	N	N	N
	pronamide *(Kerb)*	K1 / 3	N	N	N	N	N	N
	rimsulfuron (*Matrix*)	B / 2	N	R	N	N	N	N
	sulfentrazone *(Zeus)*	E / 14	N	R	N	N	N	N
	simazine *(Princep,Caliber 90)*	C1 / 5	R	R	N	N	N	N
Postemergence	carfentrazone *(Shark)*	E / 14	R	R	R	R	R	R
	clethodim *(SelectMax)*	A / 1	N	R	N	N	N	N
	clove oil (*Matratec*)	NC[3]	R	R	R	R	R	R
	2,4-D *(Clean-crop, Orchard Master)*	O / 4	N	N	N	N	N	N
	diquat (*Diquat*)	D / 22	NB	NB	NB	NB	NB	NB
	d-limonene (*GreenMatch*)	NC[3]	N	R	N	R	R	N
	fluazifop-p-butyl *(Fusilade)*	A / 1	NB	R	NB	NB	N	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	N	R	N	N	N	N
	halosulfuron *(Sandea)*	B / 2	N	N	N	N	N	N
	paraquat *(Gramoxone)*	D / 22	R	R	N	R	R	R
	pelargonic acid (*Scythe*)	NC[3]	R	R	R	R	R	N
	pyraflufen (*Venue*)	E / 14	N	N	R	R	R	R
	saflufenacil (*Treevix*)	E / 14	N	R	N	N	N	N
	sethoxydim *(Poast)*	A / 1	NB	R	NB	NB	N	NB

Notes: R = Registered, N = Not registered, NB = nonbearing. This chart is intended as a general guide only. Always consult a current label before using any herbicide as labels change frequently and often contain special restrictions regarding use of a company's product.

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Junglerice (*Echinocloa colona*) Growth and Development in Response to Temperature and Shade. L. M. Sosnoskie*[1], A. Ceseski[1], S. Parry[2], A. Shrestha[2], B. D. Hanson[1]; [1]University of California, Davis, Davis, CA, [2]California State University, Fresno, CA

Glyphosate-resistant junglerice (*Echinocloa colona*) in orchards and vineyards is a significant concern as there are few herbicide options registered for its control, relative to non-specialty crop systems. It is, therefore, critical to understand the biological and physiological factors driving the evolution and spread of this species in order to develop effective and economical management options. In 2015, we conducted several experiments to describe the germination, growth, and development of seven (A3, A8, C6, H5, L2, N3, SV2) junglerice accessions from California to differing temperature (15, 20, 25, 30, 35, 40°C) and light conditions (0, 30, and 60% shade) that could be encountered in tree and vine crops throughout the Central Valley.

Temperature and germination: Junglerice seed were scarified in concentrated sulfuric acid for 30 minutes; 50 seeds of each biotype were placed in Petri dishes containing 7.0mL of 0.2% Captan fungicide solution. The Petri dishes were held in nested cardboard flats to exclude intense, direct light and minimize desiccation potential. Seed germination was monitored, daily; a seed was considered germinated when the protruded radicle was as long as the length of the seed coat. Germinated seeds were counted and then discarded at each observation point. Results showed that the rate of seed germination increased with increased temperature. All biotypes reached 50% germination 2-4 days after plating for all temperatures except 15°C, where it took 5-37 days to reach 50% germination. Maximum germination was reached by 49 days after plating for all biotypes at 15°C; by 40 days for all biotypes, but L2, at 20°C; and by 5 days for most biotypes at temperatures between 25-40°C. This study is currently in the process of being repeated.

Temperature and growth: Seedlings of each biotype were planted in 1600 cm plastic pots filled with a mixture of peat, compost, sand and perlite, grown out to the 3-tiller stage, and then placed into growth chambers programmed to constant temperatures between 20-40°C. Plant growth and development was monitored for 28 days after which each specimen was destructively harvested and the aboveground biomass separated into three, distinct tissue classes: stems, leaves, and panicles. Results from this experiment demonstrated that junglerice growth and development can occur over a wide range of temperatures (20-40°C). Maximum basal stem production occurred at 25°C and ranged from 37 stems/plant (C6) to 67 stems/plant (SV2) with an average (across accessions) of 53 stems per plant. Per plant panicle production was greatest at 30-35°C; maximum panicle production ranged from 18 panicles per plant (C6) to 45 panicles per plant (N3) with an average maximum production of 24 panicles per plant (across all accessions). This study is currently being repeated in its entirety.

Light quantity and growth: In the summer of 2015, two to three seedlings (at the three tiller stage) of each biotype were transplanted into field plots (1 m wide by 15 m long) that were exposed to either full sunlight (0% shade) or 30% and 60% shade environments. The shade treatments were established by covering the entire plots with black, plastic fabric of differing mesh size on PVC frames. Plant growth and development was monitored for four weeks after which each specimen was destructively harvested. Each shade environment was replicated three times and the entire study was conducted at two locations: UC Davis and CSU Fresno. With few exceptions, junglerice plants were largest when gown in full sunlight. In general, tissue number and biomass (stem, leaf, panicle) decreased as the amount of transmitted light decreased. For example, tiller number per plant averaged between 79 and 134 at 0% shade; at 30% shade, tiller number ranged from 62 to 88 per plant; at 60% shade, the mean number of tillers per plant did not exceed 61. Similar observances were made with respect to leaf number and panicle production. Knowledge of the growth and development of junglerice under different environmental conditions is critical for understanding the species' invasive potential. Results from our study show that junglerice populations collected from the Central Valley of California can grow and develop under a range of temperatures and light environments. Continuing analyses will help us describe how multiple environmental variables affect the potential for junglerice invasion across a diverse array of habitats.

New Herbicides Broadworks & Zeus: Where's the Fit for Tree & Vines?

Mick Canevari, UCCE Emeritus, San Joaquin County

For decades, herbicides have been used for weed management in perennial tree and vine crops in California. When used under the right conditions, herbicides provide effective control of a large variety of weeds both summer and winter and aid crop growth and productivity. The nut and grape industry in California continues to grow at a significant pace, with almonds leading the way as the largest tree crop estimated at 1,000,020 acres followed by walnuts, 400,000 and pistachios, 215,000 acres. Vineyard acreage is 928,000 as of 2014. The production areas occur in the San Joaquin and Sacramento valleys from Butte County in the north to Kern County in the south. New orchard and vineyard developments continue to expand in coastal regions and the east side of the valleys into the rolling hills. The registration of new herbicide mode of action is important as the industry continues to grow and typically uses multiple herbicide applications per season. California orchards and vineyards are beginning to see resistant weed issues occurring similar to other areas of the U.S. Glyphosate and paraquat are foundation post herbicides used repeatedly in pre and post herbicide applications. The frequent and repeated use of these two products is increasing efficacy issues and confirmed resistant's developing on conyza species fleabane and horseweed.

<u>New Herbicides</u>

Broadworks™ *mesotrione* is new active ingredient registered in California nuts and pome fruits in 2015. It is not registered in grapes! It is a class of HPPD inhibitor (group 27) that is designed for preemergent programs controlling broadleaf weeds. It will not control grasses so a tank mixture with a grass active herbicide is highly desirable. It does have some post activity on select type of broadleaf weeds such as fleabane, marestail, annual clover, which is seen as a secondary benefit. Table 1. There is one use rate of 6 oz per acre recommended at the winter weed germination window between November and February. There are also summer weeds it controls such as lambsquarter, knotweed and more to be determined. It has shown suppression of bindweed, when used in combination with glyphosate or glufosinate. Trees need to be established for 12 months and it has a 30 PHI. Having a new mode of action that controls fleabane and marestail is especially important as glyphosate and paraquat resistant's is spreading in these two species. The tank mixtures with either Princep, Prowl, Surflan, Matrix, Alion and Chateau, all having different mode of action, offer a flexible resistant management program while increasing control of many more weeds. Table 2.

Zeus *sulfentrazone* is a new active ingredient for California registered in 2014 for use in nut crops and vineyards. Crops include grape, lemon, orange, pistachio and walnut, <u>but not almonds</u>. It is a group 14 herbicide classified as a PPO inhibitor. Other herbicides in this class are Goal, Chateau and Shark to name a few but all have a unique weed spectrum at different levels of post and pre emergent actively. It has a use rate is 10-12 fl oz/A. Zeus has some post activity on broadleaf's and sedges but is recommended together with Roundup, Rely or Gramoxone aiding in better control of emerged weeds. Crops must be established for 3 years, the PHI is 3 days and at least a 0.5" or more of rain or sprinkler irrigation is needed for herbicide placement within the seed zone and overall weed performance. Zeus shows some interesting activity on yellow nutsedge ranging from moderate to excellent control in trials. In our research, the variability of nutsedge control was determined to be the amount of water after herbicide application to incorporate the herbicide into the zone of nutlets. So timing to nutsedge emergence and enough water is very important for maximizing control. Table 3. Trials in San Joaquin County and Kearney research station have also shown good efficacy on fleabane and marestail. Tank mixing with other preemergent herbicides is an integral part to improve grass control and provide a longer interval of general weed control. Some of the best tank mix programs include Prowl, Alion and Matrix. Table 4.

Summary. The addition of two new registered herbicides Zeus and Broadworks, brings new opportunities for weed control in an expanding market of crops that are moving into new agricultural areas which bring new challenges. Both herbicides offer solutions to help manage against herbicide resistant's, improve weed efficacy, while opening new possibilities to control some of our more difficult perennial species. Like all new tools, we remain on a learning curve to develop better effectiveness and understand how they best fit into our cultural practices.

Table 1.

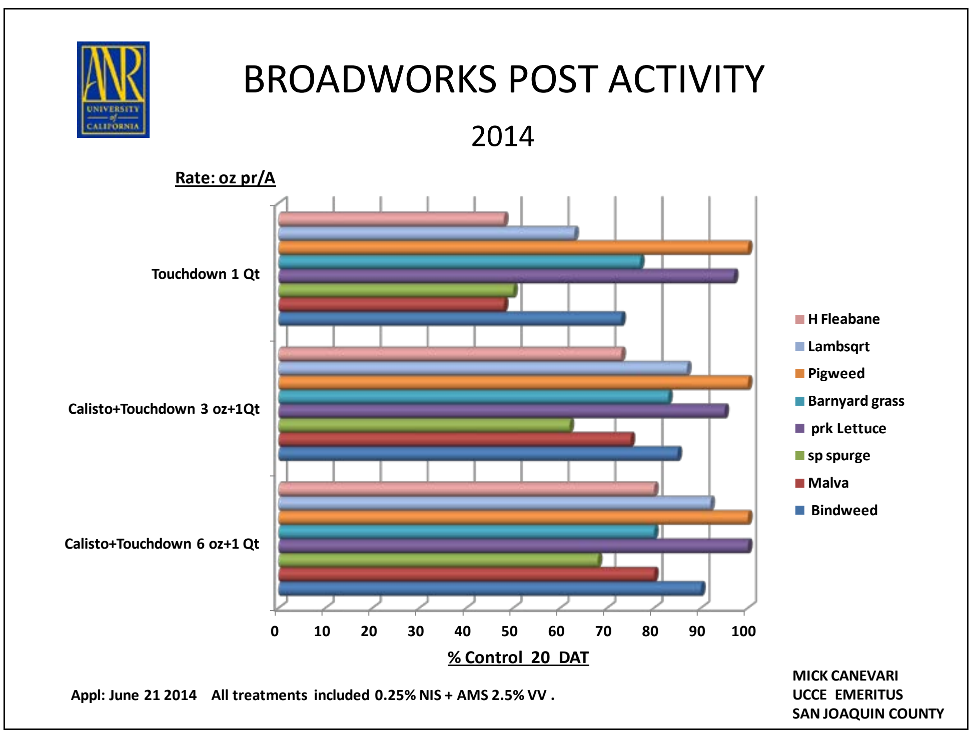


Table 2.

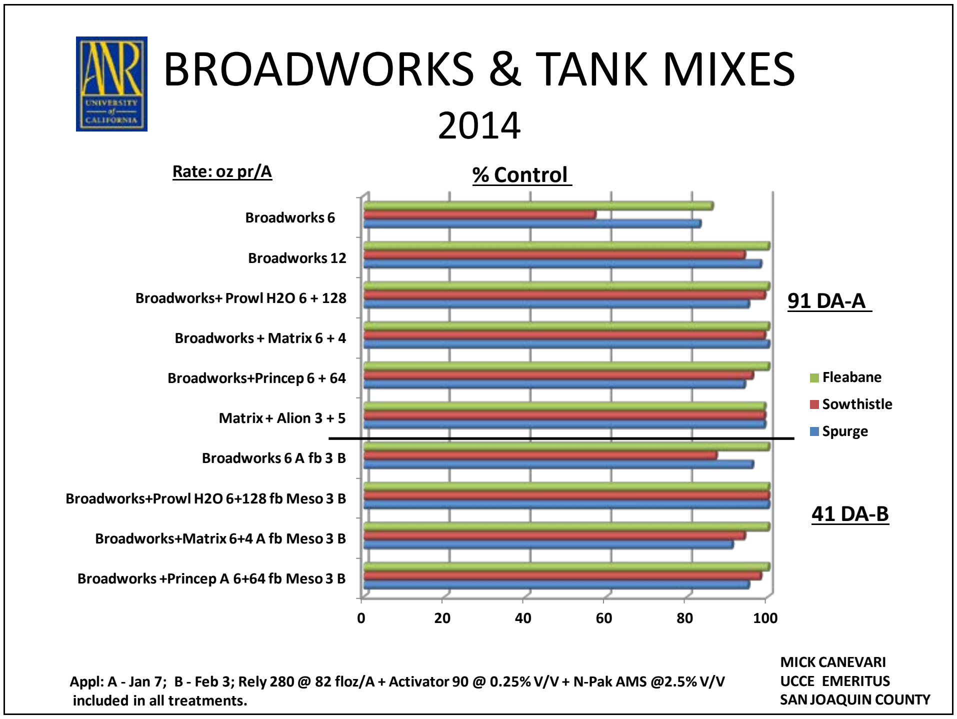


Table 3.

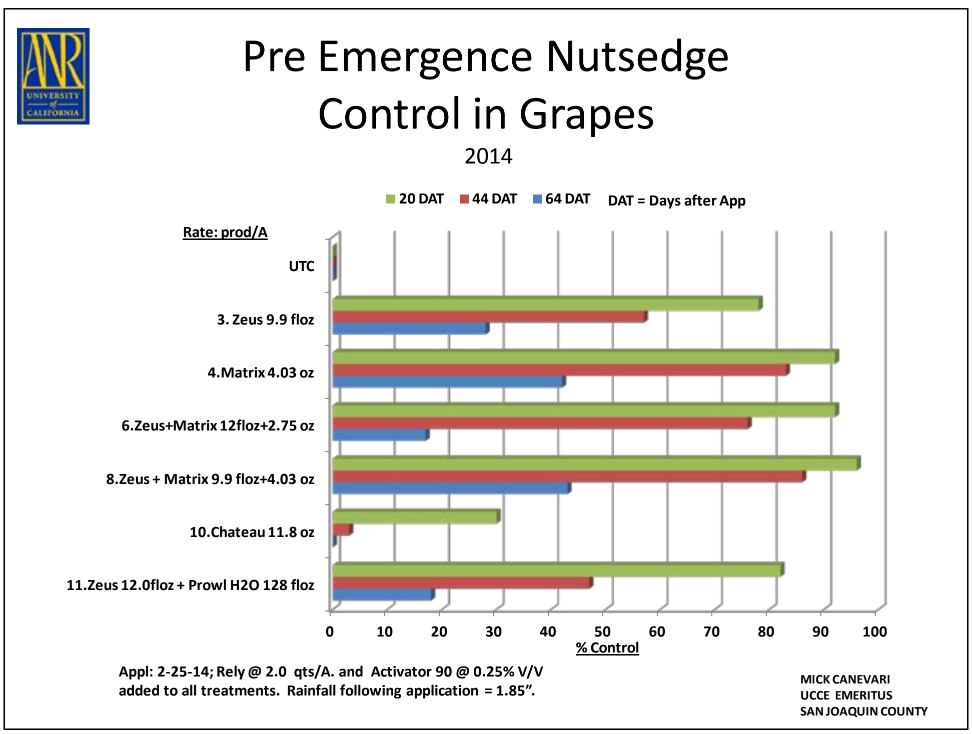
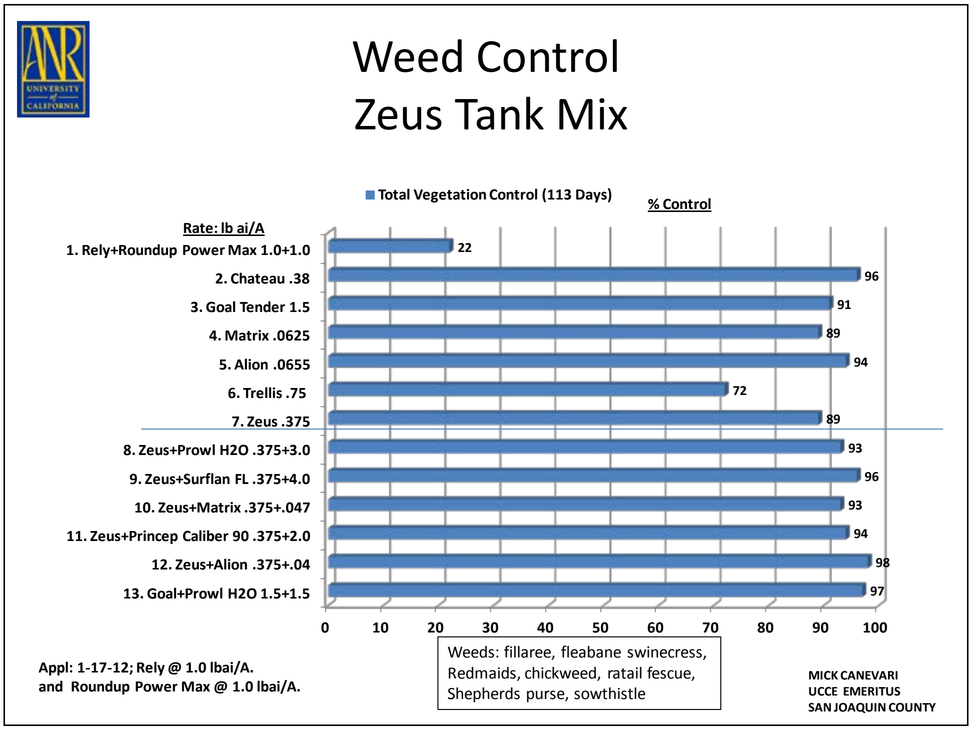


Table 4.


Weed Control
Zeus Tank Mix
Total Vegetation Control (113 Days)
% Control
Rate: lb ai/A
1. Rely+Roundup Power Max 1.0+1.0
2. Chateau .38
3. Goal Tender 1.5
4. Matrix .0625
5. Alion .0655
6. Trellis .75
7. Zeus .375
8. Zeus+Prowl H2O .375+3.0
9. Zeus+Surflan FL .375+4.0
10. Zeus+Matrix .375+.047
11. Zeus+Princep Caliber 90 .375+2.0
12. Zeus+Alion .375+.04
13. Goal+Prowl H2O 1.5+1.5
22
96
91
89
94
72
89
93
96
93
94
98
97
0 10 20 30 40 50 60 70 80 90 100
Appl: 1-17-12; Rely @ 1.0 lbai/A.
and Roundup Power Max @ 1.0 lbai/A.
Weeds: fillaree, fleabane swinecress, Redmaids, chickweed, ratail fescue, Shepherds purse, sowthistle
MICK CANEVARI
UCCE EMERITUS
SAN JOAQUIN COUNTY

Managing Tough Winter and Summer Weed Spectrums with Sequential Herbicide Programs. Brad Hanson, UC Cooperative Extension Specialist, UC Davis

As most orchardists and pest control advisors are well aware, glyphosate-resistant weeds have been one of the biggest weed management challenges in California orchard crops for several years.

Depending on where you are located in the Central Valley, your biggest challenges in the glyphosate-resistant weed department are probably one or more of the following winter annual weeds. In the San Joaquin Valley, hairy fleabane and horseweed (also known as mare's tail), dominate. While in the Sacramento Valley and in some North coast areas, annual or Italian ryegrass is more common. For an extra challenge, many growers have a mix of several of these, in addition to their other common orchard weed spectrums.

In developing management strategies for these winter annual weeds, we've typically focused our herbicide-based programs on timely applications of preemergence herbicides. Because preemergence herbicides generally work on germinating weed seed or very small seedlings, "timely" applications for these winter annual species usually means getting the herbicide treatments out in late fall or early winter. In normal rainfall seasons, this timing ensures water-incorporation of the herbicide at about the same time as the seeds germinate and, hopefully, good control. Mission accomplished, right?

Recently, we've been seeing new glyphosate-resistant weed challenges that require a different management approach. The species I mentioned a moment ago are all winter annuals, which means they typically germinate and emerge during our cool season and reach a reproductive stage by spring or early summer. However, several recently confirmed (or suspected) glyphosate-resistant species are summer annual grasses. Summer annual weeds typically germinate and emerge as our season warms up in the late spring and early summer and they grow well into the summer before reaching maturity. A few examples include junglerice, threespike goosegrass, and several other glyphosate-questionable species such as feather fingergrass, sprangletop, and witchgrass. So, how do these grasses present such a different challenge?

The challenge with glyphosate-resistant summer grasses is that even though we have a number of good preemergence herbicides that can work very well on grasses, these species emerge long after our typical orchard preemergence herbicide programs are applied. Thus, herbicide programs that are applied during mid-November to mid-February targeting winter annual weeds sometimes fail to control summer annual weeds that emerge in May-July. If spring applications of foliar materials like glyphosate fail because of resistance, problems can quickly become apparent. How can we use our existing preemergence herbicide tools to help address this problem?

To answer that question, it's useful to think about what happens to a preemergence herbicide when you apply it to the soil. Herbicides "dissipate" in soil, a term that encompasses a suite of processes by which the herbicide is either broken down or made unavailable. Chemists use terms like "half-life" to describe differences in dissipation rates but this doesn't exactly get at our interest in weed control performance. From a performance standpoint, it's more useful to think of a herbicide concentration threshold. When the amount of herbicide in the soil solution is above the threshold for a certain weed, it remains effective on that weed. However, dissipation processes will eventually reduce the herbicide concentration below the threshold and the herbicide begins to “break”. The threshold may occur at different levels for different weed species and dissipation rates may vary in different areas of the fields (wet vs dry areas, for example).

So, how do we typically account for dissipation of preemergence herbicides in orchard crops? I tend to think of three general strategies:

- Use mixtures of more than one preemergence herbicide
- Apply a higher (labeled!) rate of a preemergence herbicide
- Use a sequential approach to preemergence programs in orchards.

Mixtures: Using herbicide mixtures, particularly products with different modes of action, is a great strategy for managing and delaying herbicide resistance but doesn’t really help in this situation. Because herbicide dissipation rates are affected primarily by the chemistry of the individual herbicide and the environmental conditions, a tankmix will not exactly help extend the residual control beyond what we’d expect from the longest-lasting material. Or, to say it another way: if you mix a short residual herbicide with a long residual herbicide, one will last a short time and the other a long time but the mix will not last longer.

Higher rates: Many, but not all, preemergence herbicide labels have a range rates registered in a crop to account for differences in soils, required level of control, weed spectrums, etc. Within the labeled rate, it stands to reason that given similar dissipation processes, a higher rate will result in the soil concentrations of the herbicide remaining above the efficacy threshold for a longer time than a lower rate. This is generally true and is a common approach when we only have one opportunity to make a preemergence herbicide application. However, I think this is an indirect way to approach the problem of summer grasses in orchard crops.

Sequential approach: In the orchard cropping system, some growers may want to consider using a sequential approach to available preemergence herbicides to tackle problems with glyphosate-resistant summer annual grass weeds. Conceptually, this approach simply moves a portion of the winter preemergence herbicide program to a bit later in the year to late winter or early spring. A preemergence herbicide with activity on summer grasses would be applied along with the grower’s spring burndown herbicide program and, thus, would be present in the soil solution much closer to the timeframe when summer grasses begin to germinate and emerge. Importantly, I think this could be achieved in many situations with no significant changes in cost, number of field operations, or negative environmental impacts.

Illustration: An almond grower who typically uses an effective preemergence program (pick your favorite program) applied around the first of December followed by a March “cleanup” treatment with glyphosate may still have difficulty managing glyphosate-resistant grasses. The grower knows that herbicides like oryzalin or pendimethalin (eg. Surflan or Prowl H2O) could help with grasses. Using the higher rate approach, the grower could use a high label rate one of these materials in December with the idea that it will persist long enough to control summer grasses emerging six months later. Using the sequential approach, the grower could move all or part of the oryzalin or pendimethalin component of the program to the March timing to more directly target those summer germinating grasses, possibly at a the same or even lower total application rate.

Who might want to consider a sequential approach? This approach requires a bit of close management attention. First, because incorporation of preemergence herbicides is key to their performance, moving some of this product to late spring will require either timely rain or overhead irrigation capabilities. Growers with solid-set or micro sprinkler systems should have little problem with this, but single- or double-line drip irrigated orchards will need to get a rain and should not delay too late in the spring.

Second, moving all or part of the preemergence grass herbicide to late in the year requires that growers know their weed spectrum. If you know or suspect glyphosate-resistant summer weeds, this may be an approach to consider. You should also have an idea of what weeds you are managing during the winter season too and make sure that your winter program still addresses that part of the weed spectrum.

Weed management in orchard crops is complex and getting further complicated by new glyphosate-resistant weeds. Because of our relatively mild climate and seasonally variable temperature and moisture conditions, we encounter weed germination and emergence in every season. Strategies to manage one fraction of the weeds present in a given orchard may not work equally well for other species. Handling shifting weed problems may require different approaches in order to make the most effective use of existing weed management tools.

Development of a Novel Herbicide, Benzobicyclon + Halosulfuron, (BUTTE®), for California Rice Production. James R. Brazzle*[1], N. Alonso[1], K. Holmes[2], A. Takahashi[3]. [1]Gowan USA, [2]Gowan Company, [3]SDS Biotech K.K. *jbrazzle@gowanco.com

Benzobicyclon + halsulfuron, BUTTE® herbicide, is currently under development by Gowan Company & SDS Biotech K.K. for use in the California rice market. Beginning in 2008 thru 2015, field and laboratory studies have been conducted to evaluate crop safety, weed spectrum, use rates and guidelines, and fit in resistance management and integrated weed management programs in California.

At a use rate of 101 - 121 gm ai/A of benzobicyclon + 21 – 26 gm ai/A of halosulfuron, BUTTE herbicide provides excellent sedge and select broadleaf weed control. Strong activity on grasses requires more refined application timing. BUTTE has shown greater activity against, sprangletop (*Leptochloa* spp.) verses watergrass (*Echinochloa* spp.). Several resistant weed species have been tested under field and laboratory conditions highlighting the benefits of benzobicyclon's novel mode of action. In crop safety studies rates over 242 gm ai/A have shown a high degree of selectivity as measured in rice stand, growth & crop yield. Multiple varieties at several stages of crop growth have been tested. In 2013-2015, larger scale aerial application studies were conducted to confirm and compliment results observed in smaller scale studies.

BUTTE herbicide fits well into the water seeded production system employed in California. This new mode of action potentially provides rice growers a novel tool to combat the growing resistant weed patterns observed in California. Overall BUTTE has a strong fit as a foundation herbicide in California's integrated weed and resistance management programs.

Modeling Weed Growth in California Rice: Opportunities for Management.

Whitney Brim-DeForest, University of California, Davis

Due to the development of herbicide resistance in major weed species of rice in California, including *Cyperus difformis* L. (smallflower umbrella sedge) and *Echinochloa phyllopogon* (Stapf) Koss (late watergrass), it is has become necessary to use integrated pest management (IPM) techniques. IPM in rice includes cultural controls such as alternative tillage and irrigation methods, as well as stewardship of our remaining herbicides.

Predicting the emergence and growth patterns of major weed species under a variety of tillage and irrigation methods will enable us to effectively suppress weeds using these methods. Likewise, to prevent the evolution of resistance to the remaining herbicides, it is important to utilize these herbicides at the appropriate growth stage of each weed. We have been developing a model that will utilize soil temperature and moisture to accurately predict the emergence and growth of late watergrass and smallflower umbrella sedge. The model will be an effective tool for growers to utilize in the management and prevention of herbicide resistant weeds.

Target-Site Resistance to Propanil in Smallflower Umbrella Sedge and Ricefield Bulrush from California Rice: Implications for Management.

Albert J Fischer, Ibrahim Abdallah, Rocio Alarcón-Reverte, Kassim Al-Khatib, and Rafael M Pedroso, University of California, Davis

Smallflower umbrella sedge (*Cyperus difformis*; CYPDI) and ricefield bulrush (*Schoenoplectus mucronatus*; SCHMU) are major weeds of California rice which recently evolved resistance to propanil, an important photosystem II (PSII)-inhibiting herbicide. We conducted a series of experiments aimed at assessing levels of resistance present in newly-obtained biotypes obtained from field-collected CYPDI and SCHMU populations, as well as elucidating their propanil resistance mechanism. Such information is essential for proper management of resistant (R) populations in rice fields and for the design of applied prevention and management practices to delay the spread of resistance. Propanil-R CYPDI and SCPMU lines studied displayed at least a 14-fold level of propanil resistance. Our results indicate that, unlike all previous cases of propanil resistance in plants, an amino acid alteration at propanil's target-site in CYPDI and SCHMU entails resistance to not only propanil but also diuron, metribuzin, and bromoxynil, which are also PSII inhibitors. Such modification, however, is here shown to possess a novel attribute for propanil-R lines displayed an increased susceptibility to the PSII inhibitor bentazon, another important herbicide used in rice worldwide. Tank-mixing bentazon and propanil can thus be seen as an interesting option to manage and prevent the spread of the resistant phenotype, but seems unlikely due to the current ban on bentazon usage in California. One can expect propanil resistance to spread by the movement of seeds rather than carried by pollen due to the mutated gene being part of the chloroplast genome. Therefore, efforts to minimize seed movement across fields - such as proper equipment sanitation and leaving resistant fields as last harvest - might play a major role in slowing down the spread of propanil-R CYPDI and SCHMU within California's rice-growing areas.

Optimizing Weed Management Program in Rice: Challenges and Opportunities. Kassim Al-Khatib, University of California, Davis

Weeds are considered a serious problem in California rice fields. Decades of using a continuously-flooded rice cropping system in California have selected specific weed species that display similar ecological requirements and growing patterns to rice. Although effective preplanting weed control and proper cultural practices including water management is used in weed management program in rice, herbicides continue to be the most important component of any weed management program in rice. With the excessive reliance on a few herbicides and lack of crop rotation, however, several weeds in rice fields have evolved resistance to herbicides including California Arrowhead, Smallflower Umbrella Sedge, Ricefield Bulrush, Late Watergrass, Redstem, Barnyardgrass, Early Watergrass, and Junglerice. In California, rice has more herbicide-resistant weeds than any other crop or region in the United States which result in more complex and expensive weed management program. Proper identification of weed species and understanding their susceptibility/resistance to herbicides are essential to any successful weed management in rice. In addition, knowledge of the species and its competitive ability are critical to target the most important and potentially damaging weeds. Most California rice fields have between 10 to 15 weed species, however, not all of these species have similar damaging effects on rice. To develop effective weed control practices, it is not enough only to identify a particular species, but whether or not it exhibits herbicide resistance. Selection of any herbicide program in rice is difficult. Weed pressure, herbicide resistance, water management practices, weather conditions, herbicide formulation, and nearby nontarget susceptible plants influence the any decision to select herbicide programs. The ideal and most effective weed management program integrated prevention, good cultural and water management practices, and herbicides.

Esplanade™ Herbicide for Invasive Annual Grass Control. Harry Quicke, Western Region Stewardship and Development Manager, Bayer Vegetation Management. harry.quicke@bayer.com

Managing invasive winter annual grasses is a challenge in many regions of the US. During the winter and early spring, these species exploit moisture and nutrients before native plant communities break dormancy. This results in dense stands of winter annual grasses invading roadsides and other disturbed areas and significant reductions or elimination of desirable perennial grass, forb, and shrub species. Currently, there are limited management options for controlling winter annual grasses that work consistently, provide multiple years of control, and do not injure desirable plant communities. This presentation covers research conducted at Colorado State University demonstrating that Esplanade herbicide provides long-term residual control of winter annual grasses allowing for the release or re-establishment of desirable species. Field studies compared downy brome and feral rye control with Esplanade to currently recommended herbicides. A greenhouse study compared Esplanade and Plateau® herbicide for pre-emergence control of downy brome, feral rye, jointed goatgrass, Japanese brome, medusahead and ventenata. This research provides the first evidence of a new option for residual invasive winter annual grass control.

Impacts of Deficit Irrigation on Weed Spectrum in Turf. Cheryl Wilen, Area IPM Advisor, University of California Cooperative Extension/UC IPM 9335 Hazard Way, Ste. 201, San Diego, CA 92123 cawilen@ucanr.edu

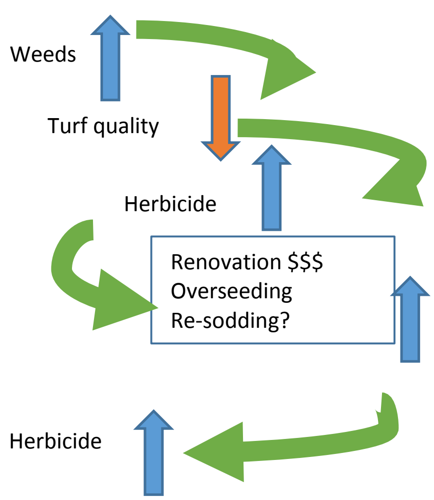
In April 2015, Governor Brown announced that there will be an enforced 25% water use reduction for the entire state of California. In response to the to this executive order, many landscape managers severely cut back on irrigation in turf areas, often exceeding the mandated 25%. This was likely done so that other areas such as playing fields or other public areas can be maintained in high quality for both safety and aesthetics.

Nevertheless, the complete shutdown or severe reduction of irrigation at previously well-watered sites resulted in turf death as would be expected but also in the growth of weeds that could survive under this level of deficit irrigation. The following are my personal observations at various locations in southern California during the summer and fall of 2015.

- Residential lawn that was sodded with tall fescue; no supplemental irrigation applied - fescue died out and the lawn is being invaded with kikuyugrass. Another lawn under similar conditions was strongly invaded by woodsorrel after the tall fescue died.
- City park used primarily for youth soccer and picnicking; tall fescue and ryegrass; irrigation reduced about 25% in playing field and more in the turf surrounding the field – playing field has small patches of kikyugrass, surrounding area is nearly all kikuyugrass; picnic areas are kikuyugrass, tall fescue, and annual broadleaf weeds. Interestingly, fairy rings are common in the deficit irrigated picnic areas
- Sidewalk medians that had tall fescue – most of fescue died; weeds in site were common chickweed, black medic, cheeseweed, spotted spurge, common purslane, and dandelion
- In many sites, dallisgrass proliferated

As expected, weeds which became established under deficit irrigation were those that had an adaptive mechanism which facilitated growth and development under conditions that are generally stressful for the tall fescue, a common turf species used in southern California. These weeds tended to have deep tap roots or rhizomes, e.g. cheeseweed, dandelion, dallisgrass, spotted spurge, kikuyugrass. Additionally, when the turf thinned out, there was considerably less competition and annual weeds were able to establish.

The impacts of deficit irrigation are going to have an impact on turf management even if the executive order is lifted or rainfall increases. As shown in the figure below, as turf irrigation is reduced to the point where the turf is no longer competitive, the weeds increase and turf quality declines. It is likely that herbicide use will increase to manage weeds that would normally be suppressed and in extreme situations, the site will needs to be completely renovated, also often resulting in additional herbicide use.



Drip Irrigation and Weed Control. John T Law Jr., Ph.D., ValleyCrest Companies

This discussion is about weed control on commercial landscapes, or what is called the *built environment*. The term built environment refers to landscapes that are built to provide a setting for people to live, work, shop, move around and other activities. The built environment includes infrastructure like electricity, water for irrigation and drainage structures. The soil in the built environment is extensively modified by compaction to provide support for structures and the infrastructure. Compacted soil in the built environment has a high bulk density which means very few pores large enough for water to move. Consequently, the landscape soil has a low water infiltration rate and water percolation rate. The water infiltration rate is typically much slower than water is applied by irrigation systems. Water tends to run off. Amending the soil to improve structure typically results in only a short lived improvement. Organic amendment added to soil during landscape installation breaks down quickly and is usually gone in a few months or less. Once installed, a commercial landscape cannot be tilled or amended as is done with agriculture and garden soil. Consequently, irrigation water tends to run along the soil surface to lower areas. Water collecting in lower areas, combined with generally uneven irrigation provides good moisture for weed growth. If the water constantly displaces air in the soil, roots of ornamentals cannot grow well, making the ornamentals less competitive to the weeds. Weeds basically only need light and water, so managing irrigation and soil moisture is important. Of course, there are other weed control challenges in the "built environment.

The recent GMO - cancer - glyphosate narrative has resulted in some clients not allowing glyphosate use. Clients often propose "alternative" burn back or contact herbicides, but they have been poor performers. It is important to recognize that there is a huge gap in scientist vs. citizen beliefs about the hazards of herbicides and other chemicals. Social science research says this gap cannot be closed by education or facts. Some clients insist on natural organic fertilizer. Natural organic fertilizer contains significant amount of phosphorous (P), which is basically a "starter" fertilizer for weed seeds. Landscape ornamentals typically do not need P. Besides favoring weeds, natural organics have a high carbon footprint compared to polymer coated urea, and if the P goes off site it can be a pollutant.

Drip irrigation is typically an agency or municipal requirement for new landscape installations. It is not unusual to see claims that drip is 95% efficient to support these mandates. That is impossible on landscapes, and probably anywhere. Even to give landscape water use design numbers is misleading. Irrigation output calculations can be difficult for drip systems and the numbers typically have a lot of false precision. Nevertheless, drip or other low pressure irrigation is the way to irrigate narrow bed areas. Also, recycled water is best delivered by drip to minimize exposure to air born from the recycled water. However, stream rotors are usually just as efficient as drip, in spite of the frequently misleading numbers. The main limitation is stream rotors work best in beds wider than 15 feet, and 20 feet is better. Designing a landscape with perhaps fewer, but larger planting areas has other benefits. Trees grow better and stormwater can be managed better in bigger beds. However, what is usually important for landscape design is flow and site lines. This often leads to narrow and/or small ornamental beds along the flow.

Overhead sprays can be used on narrower beds, and are useful for watering preemergent herbicide, keeping down dust, and wetting mulch. However, spray heads are not as efficient as drip. Some consideration should be given to having both drip and spray irrigation. The drip can be used most of the time and the spray heads used when overhead water is needed such as a preemergent application to prevent annual weeds. Overhead irrigation is a consideration for perennial weeds as well.

An important part of establishing a landscape is the initial control of existing perennial weeds such as Bermudagrass, Kikuyugrass, Oxalis, bindweed, nutsedge etc. The best way to do this is "grow and kill". The landscape site is irrigated to stimulate growth of dormant rhizomes, as well as weed seeds. It is much more difficult to soak the soil with drip irrigation than with overhead irrigation. The stimulated weed growth and active underground growth are then killed by glyphosate or other systemic herbicides. The stimulated weeds can also be killed by smothering them, but that typically takes too long for typical construction schedules, and may result in underground portions going dormant rather than dying. Tilling is usually not practical unless done before site development begins. The advantage of glyphosate is that it can be applied to planned landscape areas after all the infrastructure has been installed.

Weeds can easily grow back into a new landscape, especially when plants are not established. Plants that have not established a root system have to be irrigated more often, favoring weeds. And the plants don't grow significantly to shade the soil, which also favors weeds. So, the quicker the landscape plants establish the easier it will be to control weeds. Keeping root balls moist on new plants is always a challenge, especially for container grown plants. Water needs to be applied directly over the root ball until roots grow into the surrounding soil. Overhead irrigation provides water somewhat better than typical inline drip installations. However, using emitters on flexible PVC pipe is the best. The flexible PVC pipe can be moved from the rootball to beside the root ball, and then farther out as the tree or shrub grows. There is a limit to how much area the drip system can be expanded to cover. So if the goal is complete plant cover of well-established woody plants then overhead rotors will get you there faster. Overhead irrigation also has another advantage.

Roots and water often find the same cracks and pores, but drip placement might not be where these cracks and pores are. Overhead irrigation is more likely to flow into these "voids". So overhead rotors can achieve the much desired goal of "targeted delivery" of the water where it is needed. The roots essentially target themselves for water via interacting with soil voids that water can flow into and drain out of. This is why modern installation specs call for fracturing soil (http://www.urbantree.org/details_specs.shtml). Fracturing follows natural weaknesses in the compacted soil so the cracks tend to be longer and more connected than just tilling, rototilling or mixing. If the goal is *not* complete cover, then weeds will be much more likely, since weeds basically just need light and water. As discussed earlier there are usually parts of a landscape that stay wet a significant amount of time. Water is applied unevenly on most ornamental beds, and a lot of turf. So to keep the driest areas from drying out, some of the wettest areas stay wet. A 3X difference in water application would not be unusual. And, remember that the soil is compacted, so water does not readily soak in, and tends to run. Most roots are near the soil surface where they can get air. It takes at least several years and usually longer for roots to grow down into the soil with the result that the plants can be irrigated less often. Again, fracturing the soil will speed this deeper root growth by creating cracks for roots to grow into. Mulching with chips from pruning operations also helps roots grow. Mulch of course shades the soil to inhibit weeds, but as the mulch breaks down it helps achieve less frequent irrigation which keeps weed seeds from successfully germinating. When mulch decays it creates a spongy layer on top of the soil, basically an O horizon. This layer can detain the irrigation water, giving it more time to soak in. The decaying mulch also creates an ecosystem of invertebrates, some of which burrow in to the soil creating pores for water infiltration. Mulch decay depends on moisture and the decay process will be much slower with drip under mulch than with overhead irrigation. There are also other considerations of drip vs. overhead irrigation.

More and more irrigation water contains a significant amount of salts. Recycled water contains more salt than potable water. This salt will accumulate unless it is leached below the root zone. Leaching is much more efficient with overhead irrigation than with drip irrigation. Salts, as well as biological activity from the nutrients in recycled water typically cause more clogging problems for drip irrigation than for overhead rotors. Monitoring and maintenance of drip systems is more demanding because the system is usually buried or under mulch. Leaks can be hard to find.

Weeds are the best adapted plant in the landscape and they are much more of a problem when soil stays moist. When designing a landscape consider weed control. One of these consideration is drip vs overhead rotors on areas wider than 15 feet. Drip is sometime mandated even where it will not make any more efficient use of water than rotors and can make weed control more difficult.

Irrigation Cutbacks for Conservation, Less Water, More Weeds, Dead Trees.

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Following four years of drought, the Governor mandated a statewide 25% reduction in water use in 2015. In single family homes, about half of the household water use is for outdoor purposes, including irrigation. Indoor conservation measures tend to be previously implemented, but this is usually not the case for outdoor uses. Most of the outdoor use is for irrigation and turf has been labeled as a high water user. But, it is okay to reduce irrigation to the turf and let quality diminish. However, there has been a range of responses from reductions in applications to completely shutting off all irrigation. The issue is that when irrigation to turf is reduced, trees that are planted in or near the turf and have become dependent on irrigation become stressed or are killed. This is because turf irrigation tends to be done improperly with short, frequent applications that result in shallow roots. Proper irrigations should wet the soil deeply, to a depth of 12" for turf, but most applications are much shallower. Because of this the irrigation reductions have resulted in poorly performing turf, sometimes exposing soil that facilitates weed invasions, and stresses trees.

It is important to recognize water stress symptoms and provide water to trees before their health is compromised. Water stressed trees are susceptible to infestation by insects, such as borers, and diseases, such as root rots. When providing irrigation to trees, properly placing irrigation is important to facilitate water uptake. Applications should be near the drip line of the tree canopy where most of the roots that absorb water are located and not at the base of the tree near its trunk, which can compromise tree health. Water should be applied slowly and should wet the soil to a depth of 2-3 feet depending on the tree species, age, soil type, and other factors.

Evaluation of Products for Control of Rogue Bentgrass (Agrostis spp.) and Annual Bluegrass (*Poa annua*) in Fine Fescue Fairways.

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Introduction

The ongoing six-year drought in California continues to emphasize the importance of water conservation and the thoughtful use of all natural resources in the maintenance of turfgrass systems.

The fine fescue species including hard fescue (*Festuca longifolia* or *duriuscula*), Chewings fescue (*Festuca rubra* subp. commutata), (blue) sheep fescue (*Festuca ovina*), creeping red fescue (*Festuca rubra* subp. rubra), and slender creeping red fescue (*Festuca rubra* subp. litoralis) exhibit some of the lowest water use rates of all cool season grasses. This fine textured turfgrass is well adapted to cool Mediterranean microclimates in the coastal areas of Central Coast and Northern California. Fine fescues are often blended and used successfully as a stand-alone turf type where traffic is moderate or can be utilized in mixtures with other cool season grasses such as perennial ryegrass and Kentucky bluegrass.

Unfortunately, rogue bentgrass types and annual bluegrass (*Poa annua*) are frequent contaminants of fine fescue resulting in small and large patches of aggressively growing turf types that differ greatly in color, texture and visual appearance. If left unchecked, these rapidly growing patches of rogue bentgrass and *Poa annua* will persist and over time expand in size, greatly reducing visual uniformity, aesthetics, playability and surface quality of fine fescue fairways and rough areas.

The objectives of this replicated field trial were as follows:

1. to evaluate products for enhanced suppression and control of rogue bentgrass and *Poa annua*, and safe use on fine fescue fairways, when applied as multiple sequential applications, and

2. to utilize this information in the development of a practical agronomic program for the suppression and control of rogue bentgrass and *Poa annua* in fine fescue turf stands.

Materials & Methods

The field study was conducted from July 2 to December 22, 2014 in a fairway area on the seventeenth hole at the California Golf Club located in South San Francisco, California. The fine fescue grass stand consisted of a well-maintained three-way mixture of SR5250 creeping red fescue, SR5130 chewings fescue and SeaLink slender creeping red fescue with a plot average of 19.6% bentgrass and 23.5% *Poa annua* cover.

The site was mowed two to three times per week depending on the season at a cutting height of 0.400 inches and irrigated to avoid moisture stress. Soil was classified as sand to loamy sand. This area is characterized as a true Mediterranean climate with moderate summers and moderate to cool winters.

Treatments were deployed as presented in Table 1. The first application was deployed on July 2, 2014. The spray interval for sequential applications was treatment specific and deployed at 21, 28 or 42-day intervals. At 12:08 pm on the afternoon of the first application, the soil temperature registered 73.3° F at a depth of three inches with an air temperature of 70.8° F.

Plots measured 10’ x 10’ with 5’ x 10’ treatment plots directly adjacent to 5’ x 10’ in-plot check plots. This plot orientation allows for side-by-side comparison of treated versus untreated areas and aids in the identification of subtle treatment effects. Treatments were replicated four times.

A calibrated CO_2 propelled spray system pressurized to 28 psi and equipped with four 11008LP Tee-Jet nozzles applied liquid treatments at a spray volume of 1.5 gallons per thousand square feet (1000 ft^2). A pacing watch was used for spray applications to ensure uniform and accurate delivery. The field plot was not mowed for 24 hours prior to application and was not mowed for 48 hours after application.

Fine fescue injury, percent bentgrass and *Poa annua* cover, and calculated percent bentgrass and *Poa annua* control were evaluated. Fine fescue injury was rated on a 0-100 scale with 0 representing no injury, 30 a maximum level of acceptable injury and 100 dead turf.

Percent creeping bentgrass and *Poa annua* cover were visually estimated on a 0-100% scale. Percent creeping bentgrass and *Poa annua* control were statistically calculated based on the change in percent cover of treatments versus the untreated check plot. Data were summarized and statistically analyzed. Differences between means were determined via LSD.

Table 1. Treatment application schedule at the California Golf Club. S. San Francisco, CA. Mahady & Assoc., Inc.

Treatments		Rate	Application Frequency & Interval	Application Schedule
1)	Untreated Check	*	*	*
2)	Tenacity[1] + NIS[2]	5 oz/A + 0.25% v/v	3x: 21-day interval	7/2, 7/23, 8/13/14
3)	Tenacity + Turflon[3] + NIS	5 oz/A + 8 oz/A + 0.25% v/v	3x: 21-day interval	7/2, 7/23, 8/13/14
4)	Tenacity + Turflon + NIS	5 oz/A + 16 oz/A + 0.25% v/v	3x: 21-day interval	7/2, 7/23, 8/13/14
5)	Xonerate 4SC[4]	2.8 oz/A	3x: 21-day interval	7/2, 7/23, 8/13/14
6)	Tenacity + Xonerate	5 oz/A + 1.4 oz/A	3x: 21-day interval	7/2, 7/23, 8/13/14
7)	Tenacity + Xonerate	5 oz/A + 2.8 oz/A	3x: 21-day interval	7/2, 7/23, 8/13/14
8)	SZ Southern[5] + QuickSilver[6]	5 pt/A + 2.7 oz/A	3x: 21-day interval	7/2, 7/23, 8/13/14
9)	SZS + QuickSilver + Turflon	5 pt/A + 2.7 oz/A + 8 oz/A	3x: 21-day interval	7/2, 7/23, 8/13/14
10)	Grass-Getter[7]	0.2 oz/M	3x: 21-day interval	7/2, 7/23, 8/13/14
11)	Fusilade[8] + NIS	16 oz/A + 0.5% v/v	2x: 28-day interval	9/24, 10/22/14
12)	GF-142 + MSO[9]	0.044 lb/A + 24 oz/A	3x: 6-week intervals	7/2, 8/13, 9/24/14
13)	GF-142 + MSO	0.066 b/A + 24 oz/A	3x: 6-week intervals	7/2, 8/13, 9/24/14
14)	GF-142 + MSO	0.088 lb/A + 24 oz/A	3x: 6-week intervals	7/2, 8/13, 9/24/14
15)	Roundup Pro[10]	3 oz/A	3x: 21-day interval	7/9, 7/30, 8/20/14

[1] Mesotrione
[2] Activator 90
[3] Triclopyr
[4] Amicarbazone
[5] 2,4-D, MCPP, Dicamba, Carfentrazone
[6] Carfentrazone
[7] Sethoxydim
[8] Fluazifop
[9] Methylated Seed Oil
[10] Glyphosate

Key Results and Discussion

◆ ***Treatment Effects on Fine Fescue Injury (Table 2)***

- The most severe and highly unacceptable injury was observed with Treatment 7, Tenacity 5 oz/A + Xonerate 2.8 oz/A, Treatment 6, Tenacity 5 oz/A + Xonerate 1.4 oz/A, Treatment 5, Xonerate 2.8 oz/A and Treatment 4, Tenacity 5 oz/A + Turflon 16 oz/A. Differences were statistically significant when compared to the untreated check. It is hypothesized that within these tank mix combinations, Xonerate (amicarbazone) and Turflon (triclopyr) were the individual active ingredients which contributed most significantly to this increasing injury.

- The severity of the fine fescue injury in Treatments 4, 5, 6 and 7 would completely negate the potential use of these treatments in fine fescue fairways, regardless of their potential to control bentgrass or *Poa annua*.

Table 2. Treatment effects on fine fescue injury. California Golf Club. 2014. Mark M. Mahady & Associates, Inc.

Treatments	Fescue Injury[1] 7/9/14 7DAA1[2]	Fescue Injury 7/23/14 21DAA1	Fescue Injury 8/13/14 21DAA2	Fescue Injury 8/20/14 7DAA3	Fescue Injury 9/3/14 21DAA3	Fescue Injury 9/24/14 42DAA3	Fescue Injury 10/1/14 49DAA3	Fescue Injury 10/22/14 70DAA3	Fescue Injury 11/21/14 100DAA3	Fescue Injury 12/22/14 131DAA3
1 Untreated Check	0.0 b[3]	0.0 b	0.0 c	0.0 f	0.0 d	0.0 d	0.0 c	0.0 b	0.0 b	0.0 a
2 Tenacity 5 oz/A	0.0 b	0.0 b	16.3 bc	23.3 de	11.3 d	0.0 d	0.0 c	0.0 b	0.0 b	0.0 a
3 Tenacity+Turflon 5+8 oz/A	0.0 b	0.0 b	10.5 bc	19.5 def	34.8 c	11.3 d	1.3 c	7.5 b	6.3 b	0.0 a
4 Tenacity+Turflon 5+16 oz/A	0.0 b	14.5 a	33.5 b	39.5 bc	49.0 bc	27.5 c	13.8 c	10.8 b	8.5 b	0.0 a
5 Xonerate 2.8 oz/A	1.3 b	6.3 b	21.8 bc	31.0 cd	44.3 bc	32.5 c	17.3 c	10.0 b	5.0 b	0.0 a
6 Tenacity+Xon 5+ 1.4 oz/A	0.0 b	6.0 b	30.0 bc	47.8 d	60.0 b	61.3 b	41.3 b	17.5 b	9.3 b	0.0 a
7 Tenacity+Xon 5+ 2.8 oz/A	5.5 a	14.0 a	56.0 a	82.5 a	90.0 a	87.8 a	83.0 a	72.8 a	71.3 a	5.0 a
8 SZS+QS 5 pt+2.7 oz/A	1.3 b	0.0 b	0.0 c	0.0 f	0.0 d	0.0 d	0.0 c	0.0 b	0.0 b	0.0 a
9 SZS+QS+Tf 5 pt+2.7+8 oz/A	0.8 b	1.3 b	3.8 bc	10.0 ef	7.5 d	0.0 d	5.0 c	6.3 b	5.0 b	0.0 a
10 Grass-Getter 0.2 oz/M	1.3 b	1.3 b	5.0 bc	1.5 f	0.0 d	0.0 d	0.0 c	0.0 b	0.0 b	0.0 a
Treatments	********	********	********	********	********	**DOA1**	**7DAA1**	**DOA2**	**30DAA2**	**61DAA2**
11 Fusilade 16 oz/A	0.0 b	0.0 b	0.0 c	0.0 f	0.0 d	0.0 d	0.0 c	0.0 b	0.0 b	0.0 a
Treatments	**7DAA1[2]**	**21DAA1**	**DOA2**	**7DAA2**	**21DAA2**	**DOA3**	**7DAA3**	**28DAA3**	**58DAA3**	**89DAA3**
12 GF-142 0.044 lb/A	0.0 b	0.0 b	14.5 bc	0.0 f	0.0 d	0.0 d	2.5 c	0.0 b	0.0 b	0.0 a
13 GF-142 0.066 lb/A	0.0 b	0.0 b	11.0 bc	0.0 f	0.0 d	0.0 d	3.8 c	0.0 b	0.0 b	0.0 a
14 GF-142 0.088 lb/A	0.0 b	0.0 b	8.8 bc	0.0 f	0.0 d	0.0 d	3.8 c	0.0 b	0.0 b	0.0 a
Treatments	**DOA1**	**14DAA1**	**14DAA2**	**DOA3**	**14DAA3**	**35DAA3**	**42DAA3**	**63DAA3**	**93DAA3**	**124DAA3**
15 Roundup Pro 3 oz/A	0.0 b	0.0 b	0.0 c	0.0 f	7.0 d	5.0 d	3.8 c	0.0 b	0.0 b	0.0 a
LSD (P=.05)	2.89	4.84	18.01	12.67	14.26	14.62	14.08	13.87	9.69	3.69
Standard Dev.	2.02	3.39	12.60	8.87	9.98	10.23	9.85	9.71	6.78	2.58
CV	303.67	117.43	89.58	52.16	49.27	68.12	84.31	116.72	96.64	774.6

[1] Fine fescue injury: 0-100 scale with 0 representing no injury, 30 a maximum level of acceptable injury and 100 dead turf.
[2] Days after application one.
[3] Means followed by the same letter do not differ significantly (P=0.05, Student-Newman-Keuls).

- Treatment 2, Tenacity 5 oz/A also exhibited low levels of fine fescue injury 21 days after application two (DAA2) and 21 DAA3, with marginally acceptable fine fescue injury levels 7 DAA3. Differences were statistically significant 7 DAA3 when compared to the untreated check.

- While several of the remaining treatments including Treatments 12-14, GF-142, Treatment 10, Grass-Getter and Treatment 9, SpeedZone Southern + QuickSilver + Turflon showed subtle and short term turfgrass color effects, none exhibited fine fescue injury levels that would cause concern to golf course superintendents. Treatment 11, Fusilade exhibited no visual injury to fine fescue on any evaluation date over a 12-week period.

◆ ***Treatment Effects on Percent Bentgrass Cover and Control (Table 3)***

- Table 3 shows the influence of key treatment effects on percent bentgrass cover and statistically calculated percent bentgrass control.

Table 3. Treatment effects on percent bentgrass cover and percent bentgrass control. California Golf Club. 2014.

Treatments	Bent %Cover **** 7/2/14 DOA1	Bent %Cover (%Control) 8/20/14 7DAA3	Bent %Cover (%Control) 9/3/14 21DAA3	Bent %Cover (%Control) 9/24/14 42DAA3	Bent %Cover (%Control) 10/22/14 70DAA3	Bent %Cover (%Control) 11/21/14 100DAA3	Bent %Cover (%Control) 12/22/14 131DAA3	Bent % Control Ranking 1-15 12/22/14 131DAA3
1 Untreated Check	19.0 a	19.5 a	22.5 a	22.5 a	22.5 a	23.8 a	27.5 a	15
	****	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)
2 Tenacity 5 oz/A	19.3 a	6.5 b	10.0 ab	5.0 cd	4.5 bc	4.8 bc	6.0 bcd	9
	****	(66.7%)	(55.6%)	(77.8%)	(80.0%)	(80.0%)	(78.2%)	(78.2%)
3 Tenacity+Turflon 5+8 oz/A	20.3 a	1.0 b	2.8 b	2.3 d	2.3 c	1.8 c	2.5 cd	6
	****	(94.9%)	(87.8%)	(90.0%)	(90.0%)	(92.6%)	(90.9%)	(90.9%)
4 Tenacity+Turflon 5+16 oz/A	19.5 a	0.0 b	1.0 b	1.0 d	1.0 c	0.8 c	1.5 cd	4
	****	(100.0%)	(95.6%)	(95.6%)	(95.6%)	(96.8%)	(94.5%)	(94.5%)
5 Xonerate 2.8 oz/A	19.5 a	19.5 a	21.3 a	20.0 ab	19.3 ab	23.0 a	23.8 ab	12
	****	(0.0%)	(5.6%)	(11.1%)	(14.4%)	(3.2%)	(13.6%)	(13.6%)
6 Tenacity+Xonerate 5+1.4 oz/A	19.8 a	0.8 b	1.0 b	1.5 d	1.3 c	1.0 c	2.0 cd	5
	****	(96.2%)	(95.6%)	(93.3%)	(94.4%)	(95.8%)	(92.7%)	(92.7%)
7 Tenacity+Xonerate 5+2.8 oz/A	18.8 a	0.0 b	0.8 b	0.3 d	0.3 c	0.0 c	3.0 cd	7
	****	(100.0%)	(96.7%)	(98.9%)	(98.9%)	(100.0%)	(89.1%)	(89.1%)
8 SZS+QS 5 pt+2.7 oz/A	19.5 a	19.5 a	19.5 a	19.5 abc	19.5 ab	23.3 a	24.5 ab	13
	****	(0.0%)	(13.3%)	(13.3%)	(13.3%)	(2.1%)	(10.9%)	(10.9%)
9 SZS+QS+Turf 5 pt+2.7+8 oz/A	19.8 a	19.0 a	19.0 a	19.3 abc	19.3 ab	19.5 ab	20.0 abc	11
	****	(2.6%)	(15.6%)	(14.4%)	(14.4%)	(17.9%)	(27.3%)	(27.3%)
10 Grass-Getter 0.2 oz/M	18.8 a	10.8 ab	8.0 ab	7.0 bcd	8.3 abc	8.0 abc	9.3 a-d	10
	****	(44.9%)	(64.4%)	(68.9%)	(63.3%)	(66.3%)	(66.4%)	(66.4%)
Treatments	Bent %Cover **** 7/2/14 ****	Bent %Cover (%Control) 8/20/14 ****	Bent %Cover (%Control) 9/3/14 ****	Bent %Cover (%Control) 9/24/14 DOA1	Bent %Cover (%Control) 10/22/14 DOA2	Bent %Cover (%Control) 11/21/14 30DAA2	Bent %Cover (%Control) 12/22/14 61DAA2	Bent % Control Ranking 1-15 12/22/14 61DAA2
11 Fusilade 16 oz/A	19.8 a	19.8 a	20.3 a	20.3 ab	1.0 c	0.5 c	4.3 cd	8
	****	****	****	****	(95.6%)	(97.9%)	(84.5%)	(84.5%)
Treatments	Bent %Cover **** 7/2/14 DOA1	Bent %Cover (%Control) 8/20/14 7DAA2	Bent %Cover (%Control) 9/3/14 21DAA2	Bent %Cover (%Control) 9/24/14 DOA3	Bent %Cover (%Control) 10/22/14 28DAA3	Bent %Cover (%Control) 11/21/14 58DAA3	Bent %Cover (%Control) 12/22/14 89DAA3	Bent % Control Ranking 1-15 12/22/14 89DAA3
12 GF-142 0.044 lb/A	19.8 a	1.5 b	0.3 b	0.3 d	0.0 c	0.0 c	0.0 d	1 (tie)
	****	(92.3%)	(98.9%)	(98.9%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)
13 GF-142 0.066 lb/A	21.0 a	2.0 b	0.0 b	0.8 d	0.0 c	0.0 c	0.5 cd	3
	****	(89.7%)	(100.0%)	(96.7%)	(100.0%)	(100.0%)	(98.2%)	(98.2%)
14 GF-142 0.088 lb/A	20.5 a	0.8 b	0.0 b	0.0 d	0.0 c	0.0 c	0.0 d	1 (tie)
	****	(96.2%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)
Treatments	Bent %Cover **** 7/2/14 DOA1	Bent %Cover (%Control) 8/20/14 DOA3	Bent %Cover (%Control) 9/3/14 14DAA3	Bent %Cover (%Control) 9/24/14 35DAA3	Bent %Cover (%Control) 10/22/14 63DAA3	Bent %Cover (%Control) 11/21/14 93DAA3	Bent %Cover (%Control) 12/22/14 124DAA3	Bent % Control Ranking 1-15 12/22/14 124DAA3
15 Roundup Pro 3 oz/A	18.5 a	3.5 b	18.5 a	17.5 abc	20.0 a	23.5 a	24.8 ab	14
	****	(82.1%)	(17.8%)	(22.2%)	(11.1%)	(1.1%)	(10.0%)	(10.0%)
LSD (P=.05)	18.72	10.56	13.39	13.26	13.66	15.55	16.88	
Standard Dev.	13.10	7.39	9.37	9.28	9.56	10.88	11.81	
CV	66.94	89.41	97.1	101.62	120.49	125.79	118.51	

- The highest levels of bentgrass control were observed with the following treatments:

  - Treatment 12, GF-142 0.044 lb/A: 131 DAA3 — 100.0% Control
  - Treatments 14, GF-142 0.088 lb/A: 131 DAA3 — 100.0% Control
  - Treatments 13, GF-142 0.066 lb/A: 131 DAA3 — 98.2% Control
  - Treatment 4, Tenacity 5 oz/A + Turflon 16 oz/A: 131 DAA3 — 94.5% Control
  - Treatment 6, Tenacity 5 oz/A + Xonerate 1.4 oz/A: 131 DAA3 — 92.7% Control
  - Treatment 3, Tenacity 5 oz/A + Turflon 16 oz/A: 131 DAA3 — 90.9% Control
  - Treatment 7, Tenacity 5 oz/A + Xonerate 2.8 oz/A: 131 DAA3 — 89.1% Control
  - Treatment 11, Fusilade 16 oz/A: 61 DAA2 — 84.5% Control

- Although all three GF-142 treatments exhibited the highest bentgrass control following three sequential applications at six-week intervals and was very safe for use on fine fescue fairways, this experimental product is not yet registered in California or the United States.

- Unfortunately, several of the other treatments that showed some of the highest levels of bentgrass control also exhibited severe and highly unacceptable fine fescue injury and could never be recommended for use on fine fescue fairways. These treatments included Treatment 7, Tenacity 5 oz/A + Xonerate 2.8 oz/A (89.1% bentgrass control), Treatment 6, Tenacity 5 oz/A + Xonerate 1.4 oz/A (92.7% bentgrass control), Treatment 4, Tenacity 5 oz/A + Turflon 16 oz/A (94.5% bentgrass control), and Treatment 3, Tenacity 5 oz/A + Turflon 16 oz/A (90.9% control).

- Of the registered products and treatments evaluated, two sequential applications of Treatment 11, Fusilade deployed at a rate of 16 oz/A at four-week intervals exhibited the highest level of bentgrass control (84.5%) of all treatments that showed no potential to injure fine fescue.

◆ ***Treatment Effects on Percent Poa annua Cover and Control (Table 4)***

- Table 4 shows the influence of key treatment effects on percent *Poa annua* cover and statistically calculated percent *Poa annua* control.

- Treatment 14, GF-142 0.088 lb/A was the only treatment to exhibit an actual reduction in percent *Poa annua* cover (-9.1%) from the day of application one, July 2, 2014, to December 22, 2014.

Table 4. Treatment effects on percent *Poa annua* cover and percent *Poa annua* control. California Golf Club. 2014.

Treatments	Poa %Cover **** 7/2/14 DOA1	Poa %Cover (%Control) 8/20/14 7DAA3	Poa %Cover (%Control) 9/3/14 21DAA3	Poa %Cover (%Control) 9/24/14 42DAA3	Poa %Cover (%Control) 10/22/14 70DAA3	Poa %Cover (%Control) 11/21/14 100DAA3	Poa %Cover (%Control) 12/22/14 131DAA3	Actual % Δ Poa Cover 7/2/14 to 12/22/14 Ranking 1-15 1 is Best
1 Untreated Check	30.0 a	30.5 a	30.0 abc	30.5 abc	35.0 a-e	36.5 a-d	43.8 a-d	+46.0%
	****	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	4
2 Tenacity 5 oz/A	37.8 a	37.3 a	37.8 ab	38.5 ab	54.0 ab	58.3 ab	72.5 ab	+91.8%
	****	(-22.1%)	(-25.8%)	(-26.2%)	(-54.3%)	(-59.6%)	(-65.7%)	6
3 Tenacity+Turflon 5+8 oz/A	22.0 a	22.5 a	30.3 abc	32.3 abc	47.0 abc	56.3 abc	66.5 a-d	+202.3%
	****	(26.2%)	(-0.8%)	(-5.7%)	(-34.3%)	(-54.1%)	(-52.0%)	13
4 Tenacity+Turflon 5+16 oz/A	27.3 a	28.0 a	40.5 a	46.5 a	57.5 a	63.5 a	74.5 a	+172.9%
	****	(8.2%)	(-35.0%)	(-52.5%)	(-64.3%)	(-74.0%)	(-70.3%)	12
5 Xonerate 2.8 oz/A	12.8 a	10.0 a	4.8 c	8.3 c	16.0 cde	17.3 d	25.8 d	+101.6%
	****	(67.2%)	(84.2%)	(73.0%)	(54.3%)	(52.7%)	(41.1%)	7
6 Tenacity+Xonerate 5+ 1.4 oz/A	19.0 a	17.8 a	6.5 c	17.0 bc	35.8 a-e	39.5 a-d	63.5 a-d	+234.2%
	****	(41.8%)	(78.3%)	(44.3%)	(-2.1%)	(-8.2%)	(-45.1%)	14
7 Tenacity+Xonerate 5+ 2.8 oz/A	16.3 a	9.0 a	3.8 c	11.0 c	44.5 a-d	64.3 a	72.0 abc	+341.7%
	****	(70.5%)	(87.5%)	(63.9%)	(-27.1%)	(-76.0%)	(-64.6%)	15
8 SZS+QS 5 pt+2.7/A	14.0 a	14.0 a	14.0 bc	14.8 bc	18.8 cde	20.3 cd	30.8 d	+120.0%
	****	(54.1%)	(53.3%)	(51.6%)	(46.4%)	(44.5%)	(29.7%)	10
9 SZS+QS+Turf 5 pt+2.7+8 oz/A	27.0 a	27.0 a	27.0 abc	26.5 abc	27.5 a-e	32.8 a-d	35.0 a-d	+29.6%
	****	(11.5%)	(10.0%)	(13.1%)	(21.4%)	(10.3%)	(20.0%)	3
10 Grass-Getter 0.2 oz/M	34.0 a	34.0 a	34.8 ab	38.5 ab	45.3 a-d	48.0 a-d	58.8 a-d	+72.9%
	****	(-11.5%)	(-15.8%)	(-26.2%)	(-29.3%)	(-31.5%)	(-34.3%)	5

Treatments	Poa %Cover **** 7/2/14 ****	Poa %Cover (%Control) 8/20/14 ****	Poa %Cover (%Control) 9/3/14 ****	Poa %Cover (%Control) 9/24/14 DOA1	Poa %Cover (%Control) 10/22/14 DOA2	Poa %Cover (%Control) 11/21/14 30DAA2	Poa %Cover (%Control) 12/22/14 61DAA2	Actual % Δ Poa Cover 7/2/14 to 12/22/14 Ranking 1-15 1 is Best
11 Fusilade 16 oz/A	15.0 a	16.8 a	18.0 abc	21.0 abc	22.3 cde	29.8 a-d	32.8 bcd	+118.7%
	****	****	****	****	(36.4%)	(18.5%)	(25.1%)	9

Treatments	Poa %Cover **** 7/2/14 DOA1[2]	Poa %Cover (%Control) 8/20/14 7DAA2	Poa %Cover (%Control) 9/3/14 21DAA2	Poa %Cover (%Control) 9/24/14 DOA3	Poa %Cover (%Control) 10/22/14 28DAA3	Poa %Cover (%Control) 11/21/14 58DAA3	Poa %Cover (%Control) 12/22/14 89DAA3	Actual % Δ Poa Cover 7/2/14 to 12/22/14 Ranking 1-15 1 is Best
12 GF-142 0.044 lb/A	23.3 a	25.8 a	21.8 abc	21.5 abc	29.3 a-e	42.5 a-d	52.3 a-d	+124.5
	****	(15.6%)	(27.5%)	(29.5%)	(16.4%)	(-16.4%)	(-19.4%)	11
13 GF-142 0.066 lb/A	28.0 a	28.0 a	12.5 bc	12.5 bc	23.0 b-e	26.8 bcd	34.3 a-d	+22.4%
	****	(8.2%)	(58.3%)	(59.0%)	(34.3%)	(26.7%)	(21.7%)	2
14 GF-142 0.088 lb/A	30.8 a	30.8 a	7.5 c	8.5 c	12.3 e	17.8 d	28.0 d	-9.1%
	****	(-0.8%)	(75.0%)	(72.1%)	(65.0%)	(51.4%)	(36.0%)	1

Treatments	Poa %Cover **** 7/2/14 DOA1	Poa %Cover (%Control) 8/20/14 DOA3	Poa %Cover (%Control) 9/3/14 14DAA3	Poa %Cover (%Control) 9/24/14 35DAA3	Poa %Cover (%Control) 10/22/14 63DAA3	Poa %Cover (%Control) 11/21/14 93DAA3	Poa %Cover (%Control) 12/22/14 124DAA3	Actual % Δ Poa Cover 7/2/14 to 12/22/14 Ranking 1-15 1 is Best
15 Roundup Pro 3 oz/A	15.0 a	13.8 a	11.8 bc	10.3 c	14.5 de	21.5 cd	31.3 cd	+108.7%
	****	(54.9%)	(60.8%)	(66.4%)	(58.6%)	(41.1%)	(28.6%)	8
LSD (P=.05)	25.68	25.31	22.60	22.65	26.78	31.16	34.86	
Standard Dev.	17.97	17.71	15.82	15.85	18.74	21.81	24.39	
CV	76.59	77.0	78.89	70.45	58.25	56.91	50.71	

- From these data it would appear that GF-142 at 0.088 lb/A exhibits some degree of postemergent activity on *Poa annua*. GF-142 is an experimental product and is not yet registered in California or the United States. No other treatment exhibited acceptable levels of *Poa annua* control.

- Those treatments that exhibited the greatest degree of fine fescue injury over the course of the 25-week trial (Treatments 3, 4, 6 and 7), also showed the greatest increases in percent *Poa annua* cover. It is hypothesized that these injury effects reduced fine fescue vigor and shifted the competitive balance in the stand from fine fescue to *Poa annua*.

<u>Summary and Practical Perspectives</u>

- There was a wide range of variance in fine fescue safety among the treatments and active ingredients evaluated in this replicated field trial.

- Unfortunately, several treatments that showed high levels of bentgrass control also exhibited severe and highly unacceptable fine fescue injury and should never be used on fine fescue fairways. Those treatments that exhibited unacceptable fine fescue injury included the following: Tenacity 5 oz/A + Xonerate 2.8 oz/A, Tenacity 5 oz/A + Xonerate 1.4 oz/A, Tenacity 5 oz/A + Turflon 16 oz/A and Xonerate 2.8 oz/A.

- GF-142 deployed at 0.044, 0.066 and 0.088 lb/A, exhibited the highest bentgrass control of all treatments following three sequential applications at six-week intervals and was very safe for use on fine fescue fairways. However, this experimental product is not yet registered in California or the United States.

- Of the registered products and treatments evaluated, two sequential applications of Fusilade deployed at a rate of 16 oz/A at four-week intervals exhibited the highest level of bentgrass control (84.5%). Fusilade was very safe for use on fine fescue fairways at the 16 oz/A rate and showed absolutely no observed visual fine fescue injury during any of four evaluation dates over an eight-week period.

- GF-142 deployed at 0.088 lb/A was the only treatment to exhibit an actual reduction in percent *Poa annua* cover (-9.1%) from the day of application one, July 2, 2014, to December 22, 2014. From these data it would appear that GF-142 at 0.088 lb/A exhibits some degree of postemergent activity on *Poa annua*.

- Those treatments that exhibited the greatest degree of fine fescue injury over the course of the 25-week trial also showed the greatest increases in percent *Poa annua* cover. It is hypothesized that these injury effects reduced fine fescue vigor and shifted the competitive balance in the stand from fine fescue to *Poa annua*. For this reason, selecting products and programs that are very safe for use on fine fescue is a critically essential component of a sound agronomic program for both bentgrass control and *Poa annua* suppression.

Is Glyphosate Injury to Roundup Ready Alfalfa Possible? Steve Orloff*[1] and Rob Wilson[2]. [1]University of California Cooperative Extension, Siskiyou County, CA, USA, [2]University of California Intermountain Research and Extension Center, Tulelake, CA, USA. *Corresponding author: sborloff@ucanr.edu

Roundup Ready (RR) alfalfa has become a popular weed management strategy for alfalfa producers in western states. Considerable research was conducted before and shortly after its commercial release to evaluate its value in terms of weed control and crop safety. The research showed properly timed applications of glyphosate provided excellent weed control with essentially no perceptible crop injury, which was further confirmed by grower experience in commercial fields. However, during the spring of 2014 and 2015, we observed significant crop injury in RR alfalfa fields in the Scott Valley (Intermountain area of Northern California). Logical potential causes for the poor growth such as spray-tank contamination, a bad batch of glyphosate, or non-herbicide related management practices were systematically ruled out, and the theory was developed that cold temperatures after an application of glyphosate was the cause. Yield was monitored in three commercial fields in the Scott Valley in 2015 by harvesting three treated and untreated areas in the affected RR alfalfa fields with a plot harvester and averaging the yield. A first cutting yield reduction up to 0.8 tons/acre was observed (alfalfa recovered by second cutting). Replicated field experiments were conducted in the spring and fall of 2015 to further evaluate the theory that cold temperatures following an application of glyphosate to RR alfalfa can cause injury. Alfalfa was treated with 22 and 44 ounces of Roundup PowerMax per acre prior to cold temperatures. In the spring trial a reduction in height was observed as well as a yield reduction of 0.3 and 0.4 tons/acre for the 22 and 44 ounce rates of Roundup, respectively. Injury did not carry over into second cutting. Four additional trials were conducted in the fall of 2015 where alfalfa was treated on weekly intervals at the same rates as above from mid-September through October. Within a week after treatment, the same injury symptoms that were observed in the spring were found in some of the trials. The tips of affected shoots drooped in a typical "shepherd's crook" and eventually turned neurotic. Later as the temperatures dropped further, some of the plants in treated plots turned chlorotic.

Research results and field observations to date suggests that the injury is related to the degree and number of frosts after application, the height of the alfalfa (taller alfalfa being more prone to injury), and stand age (injury was has not been observed in seedling alfalfa and fields established for over a year appear to be more prone to injury). Research is ongoing and will be expanded to better understand the conditions that lead to injury so that it can be avoided in the future and to understand the biochemical mechanism responsible for cell injury. These results do not question the value of the RR technology in cold climates, but rather demonstrate the need for further research to identify management practices (such as application timing) that should be employed to avoid damage in the future.

Influence of Environmental Factors on the Efficacy of Postemergence Herbicides. Anil Shrestha, California State University, Fresno, CA

The Weed Science Society of America has classified herbicides into 29 groups based on their mode of action. Most of these herbicides fall under one of the following eight major physiological modes of action: cell membrane disrupters, growth regulators, amino acid synthesis inhibitors, lipid synthesis inhibitors, glutamine synthesis inhibitors, photosynthesis inhibitors, pigment inhibitors, and seedling growth inhibitors. Among these, the first five modes of action listed are mostly found in post-emergence herbicides, whereas the last three are mostly found in pre-emergence herbicides.

Factors that strongly influence post-emergence herbicide efficacy include characteristics of the plant (leaf orientation, leaf area, pubescence, cuticular wax, growth stage etc.), characteristics of the spray (surface tension, droplet size, spray volume etc.), and environmental conditions during spray application (temperature, moisture, relative humidity, light etc.). Of the post-emergence herbicides, some are contact type while others are systemic. Contact herbicides only directly kill plant parts on which the chemical is deposited, and thus are most effective against small weed seedlings and annual weeds. Therefore, plant and spray solution characteristics may affect efficacy of contact herbicides more strongly than environmental factors. Systemic herbicides are absorbed either by roots or foliar parts of a plant and are then translocated to other parts of the plant system. This suggests that characteristics of the plant, spray solution, and environmental factors may have equally important influence on the efficacy of systemic herbicides. Environmental factors (both physical and chemical) influence the amount of herbicidal penetration and translocation, and ultimate toxicity. Thus, not only short-term but long-term effects induced by environmental factors are important for herbicide efficacy.

Photosynthesis and respiration are temperature dependent and higher temperatures generally enhance herbicide penetration and translocation within plants. However, certain herbicides are less effective at high temperatures and some herbicides (e.g. dicamba) can volatilize at temperatures >77°F. Generally, under warmer temperatures the waxy cuticle is more permeable which allows herbicides to penetrate through this layer more easily and enter plant cells. Lower temperatures can reduce cuticle permeability and also reduce herbicide translocation. For herbicides to translocate more rapidly, the plants must be actively growing for the herbicide to inhibit the targeted process. However, very high temperatures can result in reduction in herbicide activity due to lack of metabolic activity in the plants. Generally, contact herbicides are less influenced by cool air temperatures than systemic ones because they do not need to be translocated. In the case of glyphosate efficacy on hairy fleabane (*Conyza bonariensis*), it was reported that the herbicide provided better control of the plants when it was applied on plants that were grown in 60/50 and 78/68°F day/night temperature than plants that were grown in 95/85°F. Under the low temperatures some of the glyphosate- and paraquat-resistant hairy fleabane plants were also controlled (Dennis et al. 2016).

Similarly, relative humidity can also influence the efficacy of post-emergence herbicides. Plants growing under low relative humidity tend to have thicker cuticles and thus herbicide penetration would be reduced under such conditions. Low relative humidity combined with high air temperatures can make the cuticle thicker and less penetrable.

Light (both quantity and quality) is another important environmental factor that influences the effectiveness of post-emergence herbicides. Plant response to foliar applied herbicides is usually more rapid on sunny days. Light intensity will directly and indirectly effect herbicide performance through many processes. For example, high light intensity directly improves herbicide penetration into leaves and promote systemic movement of herbicide in the phloem. Furthermore, light influences leaf shape and plant architecture. For example, under high light intensity plants tend to have short internodes, smaller, and thicker leaves with a waxier cuticle than plants growing under low light intensity which have larger, thinner leaves with thinner cuticles and less wax. These factors will influence the amount of herbicide that penetrates and thus their efficacy. Light is an essential factor for the activity of some herbicides such as paraquat and PPO inhibitors. A study by Dennis et al. (2016) reported that glyphosate provided better control of hairy fleabane plants when applied in fall than in spring indicating the role of light intensity even for glyphosate. Similarly, a study by Cox et al. (2016) reported that junglerice (*Echinochloa colona*) control by sethoxydim was reduced under shade compared to full sun conditions.

Along with the environmental factors discussed above, soil moisture is another factor influencing weed control with postemergence herbicides. Dry conditions can cause the plants to develop thicker cuticles, reduce absorption, retention, and translocation of the herbicides, and alter plant metabolisms, ultimately influencing the efficacy of postemergence herbicides. Recommendations from Purdue University (Legleiter and Johnson, 2012) for weed control under drought conditions suggest using maximum label rates, making herbicide applications in the morning when weeds are most active and before leaves begin to curl and roll, applying contact herbicides at higher carrier volumes and in the morning when leaf surface exposure is most favorable for contact, and maximizing adjuvant rates. Cox et al. (2016) reported that the efficacy of glyphosate on junglerice was affected by soil moisture levels. The efficacy was generally greater under shade than under full sun conditions and mortality was greater at 100% and 75% Field Capacity (FC) than at 50% FC. However, control of junglerice with sethoxydim was lower under shaded and low moisture conditions. Therefore, this study suggested that both shade and soil moisture conditions should be taken into consideration when selecting postemergence herbicides for control of junglerice.

In summary, environmental conditions along with the type of weed species present have to be taken into consideration while selecting postemergence herbicides. Although it is difficult to make specific recommendations, as a general rule for best weed control with postemergence herbicides, they have to be applied under ideal temperatures (65 to 85°F), when the weeds are actively growing, and the relative humidity is higher. The soil moisture needs to be adequate for active growth of the weed for successful translocation of systemic herbicides.

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Scotch Broom Gall Mite: A New Natural Enemy to California. Scott Oneto, University of California Cooperative Extension

The broom gall mite has recently taken residence on the invasive plant Scotch broom (*Cytisus scoparius*) in California. Scotch broom was first introduced into North America as an ornamental and for erosion control back in the mid 1800's. The bright yellow flowers and rapid growth made it a desirable ornamental; however its ability to out-compete native plants and form dense stands has also made it one of California's worst wildland weeds.

Controlling Scotch broom hasn't been an easy task. The shrubs can form dense monotypic stands that make it difficult for hand removal. The shrubs also grow on steep terrain making accessibility difficult for either chemical or non-chemical control. As a mostly wildland weed, chemical control is not always an option especially in sensitive areas and on sometimes on federal lands. Previous attempts at biological control have been only partially effective.

Native to Europe, the Scotch broom gall mite was first found on Scotch broom in the Tacoma, Washington and Portland, Oregon regions in 2005. Since that time the mite has become established throughout western Washington and Oregon and even into parts of British Columbia. Up until 2013, the mite had been found as far south as Ashland, Oregon with no occurrences in California. In 2014, the mite was found in the central portion of the Sierra Nevada range in El Dorado County, California.

The mite forms small growths on the plants buds, greatly reducing Scotch broom's ability to grow and reproduce. The mite is considered to be an ideal biological control agent due its largely specialized feeding habits and the debilitating damage they cause to plants. In some areas, the gall mite has even killed large stands of broom.

Further research is being conducted to understand the potential impact the mite might have on Scotch broom populations throughout the state. For more information on the mite, visit; http://cecentralsierra.ucanr.edu

Weed Management in Potatoes and Onions in Tulelake. Rob G. Wilson*, Darrin Culp, Skyler Peterson, & Kevin Nicholson. University of California Intermountain Research & Extension Center, 2816 Havlina Rd. Tulelake, CA. 96134 *rgwilson@ucdavis.edu

Weeds are a perennial pest in potatoes and onions grown in Tulelake, CA. Historically, growers have tried to avoid planting vegetables in fields with a history of high weed populations, but limited water availability and wide-spread disease and nematode problems have restricted suitable vegetable acreage to a point where growers are obligated to plant in certain fields regardless of weed pressure. Weed control in onions is particularly difficult due to the early emergence of weeds and the slow emergence and growth of onions. Herbicide screening studies were conducted in Tulelake, CA from 2011 to 2014 with funding support from the California Garlic and Onion Research Advisory Board, California Potato Research Board, and private industry. Studies were designed to evaluate preemergence and postemergence herbicides applied at several rates and application times on two distinct soil types, silty clay loam and sandy loam. Weed density, crop stand, crop injury, and crop yield were measured to determine treatments' influence weeds and crop yield.

In potatoes, treatments with the highest control of hairy nightshade (*Solanum physalifolium*), common lambsquarters (*Chenopodium album*), redroot pigweed (*Amaranthus retroflexus*), and redstem filaree (*Erodium cicutarium*) included EPTC (Eptam), dimethenamid (Outlook), dimethenamid + pendimethalin (Prowl H_20), rimsulfuron (Matrix) + metribuzin (Sencor), and fomesafen (Reflex) applied preemergence at hilling followed by rimsulfuron early postemergence. One postemergence application of rimsulfuron + methylated seed oil (MSO) applied early or late did not provide greater than 90% control of all weed species. Rimsulfuron split-applied early and late postemergence provided good control of hairy nightshade and lambsquarters on silty clay loam soil, but this treatment did not provide a high level of hairy nightshade control on sandy loam soil.

Top-performing herbicide treatments shared the common theme of combining a preemergence herbicide(s) with rimsulfuron + MSO applied early postemergence. Treatments that relied solely on postemergence applications failed to provide greater than 90% control of all weed species. All preemergence treatments failed to provide greater than 90% weed control at potato emergence suggesting rimsulfuron applied postemergence was critical to achieving 90% weed control regardless of the preemergence program. Metribuzin remains a popular herbicide used in potatoes because it controls several weeds that rimsulfuron does not. In these trials, metribuzin improved control of common mallow (*Malva neglecta*), redstem filaree, and common lambsquarters compared to applying rimsulfuron early postemergence alone.

Herbicide treatments did not cause visual injury or a reduction in potato stand compared to the untreated control on multiple soil types. At sites with silty clay loam soil, all herbicide treatments had similar total yield and US # 1 yield compared to the control. At sites with sandy loam soil, all herbicide treatments except fomesafen had similar total yield and US # 1 yield compared to the control.

In onions, DCPA (Dacthal) applied post-plant and pendimethalin (Prowl H_20) applied at or before the loop stage reduced kochia (*Kochia scoparia*), lambsquarters, and hairy nightshade density compared to the untreated control. There was an additive effect when these two herbicide treatments were used in combination especially for kochia control. DCPA and pendimethalin at labeled rates did not reduce onion stand or onion yield compared to hand-weeded plots in multiple trials on multiple soil types. Tulelake growers have long thought that DCPA was not effective on Tulelake soils believing that the herbicide was tied up due to the fine soil texture and high organic matter content. This research refutes this previously held belief and demonstrates that DCPA applied after planting can be effective and economical when used at low rates and combined with pendimethalin. Herbicide programs incorporating both preemergence and postemergence herbicide treatments were capable of reducing weed density by more than 90% compared to the untreated control. Unfortunately no single herbicide or herbicide combination treatment provided 100% weed control at multiple sites, suggesting hand-weeding may be necessary for follow-up weed control in fields with high weed seedbanks.

Management of Weeds in Cool Season Vegetables. Richard Smith, Vegetable Crop and Weed Science Farm Advisor, University of California Cooperative Extension, Monterey County

The summer-time cool season vegetable production areas of California include the coastal production districts of the Salinas, Santa Maria and Oxnard valleys. Cool season vegetable production in these areas is characterized by short-season crops with short turn around intervals. The high-value nature of these crops allows for excellent production practices such as precise cultivation and rotations with crops that generally also have good weed control. As a result, weed populations in these areas tend to be relatively lower than other areas dominated by long-season crops which are subject to multiple flushes of weeds that often set seeds. Weed seed populations tend to be lowest in cropping systems that specialize in production of high density vegetables such as spinach, baby lettuces and spring mix crops. These crops mature before many weeds set viable seed. The end result is a reduction in weed seed populations in the soil seed banks. Other rotations with crops such as broccoli allow for more weed seed set and soil seed banks will be tend to be higher where this crop is common in rotations. In spite of the generally lower weed populations in the cool season vegetable production areas, there is a continuous need of effective weed control strategies to maintain the economic viability of these crops.

There have been few new herbicides registered in the last 10 years for use on cool season vegetables. Exceptions include flumioxazin on artichokes, asparagus, celery and garlic, and carfentrazone for use in thinning lettuce. New uses of older chemistries such as linuron and prometryn for use on crops like cilantro and other carrot family crops have been approved. Retaining registrations for key herbicides such as pronamide on leaf lettuce which was lost in 2009 has been a struggle; however, much progress has been accomplished by Dow AgroSciences and it looks like pronamide will soon be reregistered.

New production practices such as the potential for expanded use of transplants in lettuce production may affect weed control practices in this crop. Currently transplanting lettuce costs approximately $397 more than direct seeded romaine lettuce on 80-inch wide beds with 6 seedlines. Recently developed automated transplanters such as Plant Tape® and the AutoPlanter® transplanters, have the potential to reduce the cost of transplanting lettuce and thus make it a more realistic option for general lettuce production. Pendimethalin and *S*-metolachlor are both in the registration process for use on transplanted lettuce. The combination of the shorter season for transplanted lettuce and the use of these herbicides has the potential to nearly eliminate the need for hand weeding in transplanted lettuce.

The following are two examples of weed control research that is underway in cool season vegetables. Phenmedipham is currently registered for use on freezer and seed spinach, but not for fresh market spinach. The fresh market spinach industry is completely intolerant of phytotoxicity on the leaves; in addition, there are not enough days in the production cycle to allow the plants to grow out of any damage. However, research indicates that applying phenmedipham in the evening can reduce phytotoxicity. We evaluated 0.5 and 1.0 pint rates of phenmedipham in trials conducted in commercial spinach production fields with cooperating growers in 2015. Both 0.5

and 1.0 pint/A of phenmedipham controlled purslane and black nightshade. The 1.0 pint/A treatment reduced the yield of spinach in one trial. No necrosis or other signs of phytotoxicity were observed in either trial even in the morning applications. Given the value and sensitivity of this crop more evaluations will need to be conducted to confirm the safety of phenmedipham on fresh market spinach and if evening applications can improve its safety.

Two automated weeders that are capable of cultivating the seedline were available for the first time in the Salinas Valley in 2105. Both machines use cameras to detect plants, and a computer to process the image and calculate which plants to keep and which to remove. The computer activates split knives which close between the crop plants and open up to go around the crop plants. The two machines used in these studies were the Robovator, Frank Poulsen Engineering: http://www.visionweeding.com/Products/Intra%20Row%20Weeding/ROBOVATOR.htm , Denmark and Steketee IC Weeder, the Netherlands: http://portal.steketee.com/ . On average there is a trend that indicates that the automated weeders reduced the stand of lettuce by 5.6%. This may be due to incidental damage from the knives opening or closing at the wrong time. This type of damage can be managed by adjustments on the machine that affect the aggressiveness of the blades. On average, mechanical weeders removed 51.4% of the weeds in the seedlines and reduced follow up hand weeding in the fields by 37.1%. These machines did not completely eliminate the need for hand weeding, but they did reduce the time to hand weed the crop in these evaluations over hand weeding alone.

Evaluation of Pyroxasulfone in Cool-Season Vegetables on the Central Coast.

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Pyroxasulfone (Zidua) was evaluated in green bunching and bulb onion, as well as celery during 2015 at Salinas, CA. Green bunching onion 'White Spear' and bulb onion 'Wala Wala' were direct-seeded February 23, 2015. Celery 'White Spear' was transplanted May 12, 2015. **Green onion** treatments were: Zidua at 0.5, 1.0 and 2.0 oz. ai/A PRE and DCPA (Dacthal) at 8 pts/A PRE and split treatments of Zidua PRE followed by (fb) POST were: 0.5 fb 0.5 and 1.0 fb 1.0 oz. ai/A. **Bulb onion** treatments were: Zidua at 2.0 and 3.0 oz. ai/A PRE, and POST on 1st leaf, 2-3 leaf and 4-6 leaf stage; and Dacthal PRE at 8 pts fb bromoxynil (Buctril) at 1.5 pts/A + oxyfluorfen (GoalTender) at 0.5 pts POST on 2-3 leaf onion. Zidua was applied as a split treatment on bulb onion at 1.5 fb 1.5 oz. ai/A POST on 2-3 fb 4-6 leaf stage. **Celery** treatments were: Zidua at 2.0 and 3.0 oz. ai/A, 1-day, 2 weeks and 4 weeks POST and prometryn (Caparol 4F) at 3.2 pt./A, 2-weeks POST. Zidua was also applied at 2.0 fb 2.0 oz. ai/A, at 1-day fb 2-weeks POST, and at 2-weeks fb 4-weeks POST. Treatments were spray applied at 40 GPA using a single nozzle CO_2 backpack sprayer. Treatments were replicated four times and arranged in a randomized complete block design. Data collected were weed densities, crop injury estimates, 0 = safe, 10 = dead, crop height and yield. Green onion was harvested May 19, 2015 and celery was harvested August 12, 2015. Bulb onions were harvested August 20, 2015 and field cured for a week. The onions were graded: prepack (<2¼" diameter), medium (2¼-3"), jumbo (3-3¾"), colossal (3¾-4¼"), super colossal (>4¼") and culls. Data were subjected to analysis of variance, and mean separation was performed using LSD's (P=0.05).

Green onion results. None of the Zidua treatments controlled bur clover but did control purslane and hairy nightshade. Zidua at 0.5 oz. ai/A PRE is safe on green onion; causing only minor injury and no significant yield loss. Zidua at 0.5 fb 0.5 oz. ai/A PRE fb POST was safe on green onion; having caused slight injury which the crop outgrew and there was no significant yield loss. All other Zidua treatments caused moderate to severe injury and yield loss.

Bulb onion results. Primary weeds were bur clover (*Medicago polymorpha*) and hairy nightshade (*Solanum physalifolium*). Zidua PRE and 1st leaf POST provided the best weed control. Zidua POST at the 4-6 leaf onion stage provided poor weed control. However, Zidua POST applications to 4-6 leaf bulb onions were the only Zidua treatments that were safe to onion. All other Zidua treatments caused moderate to severe leaf stunting, twisting and distortion. The discussion on yield will focus on the super colossal grade which we assume is the most sensitive to herbicide injury. All Zidua treatments produced super colossal bulb weights and individual bulb weights equal to the Dacthal PRE fb GoalTender + Buctril POST treatment or the nontreated. Zidua at 3 oz./A appears to be too injurious to onion at the early growth stages. Consider use of lower rates of Zidua such as 1 to 1.5 oz. Onion tolerates Zidua best at late growth stages e.g. 4-6 leaf POST, but the weeds are too large to wait this late. Sequential applications of a PRE or early POST material fb Zidua at the 4-6 leaf stage should be considered.

Celery results. Weeds present were burning nettle (*Urtica urens*) common purslane (*Portulaca oleracea*), little mallow (*Malva parvaflora*), and shepherd's-purse (*Capsella bursa-pastoris*). All

Zidua treatments partially controlled burning nettle; however, Caparol provided excellent control of burning nettle. Zidua at 2.0 and 3.0 oz. ai/A 1 day POST and 2.0 fb 2.0 oz. ai/A 1 day POST fb 2 weeks POST controlled purslane at levels similar to Caparol. Zidua applied 4 weeks POST did not control purslane. Zidua applied at 2.0 fb 2.0 oz. ai/A at 1 day fb 2 weeks POST and Caparol reduced mallow compared to the nontreated. Zidua applied at 2.0 and 3.0 oz. ai/A 1 day POST and at 2.0 fb 2.0 oz. ai/A at 1 day fb 2 weeks POST caused minor injury to celery that it later outgrew. All other Zidua treatments were safe on transplanted celery, and all Zidua treatments produced celery yields similar to Caparol.

Egyptian Broomrape: First Discovery in United States (aka: Damn this Parasitic Weed)! Gene M. Miyao, University of California Cooperative Extension, Yolo, Solano & Sacramento Counties, 70 Cottonwood Street, Woodland, CA, USA. 95695 emmiyao@ucanr.edu

A July 2014 discovery of an infestation of broomrape in a local processing tomato field (in Solano County, California) is a stark example of unknowingly introducing a harmful parasitic weed pest. In this case, the consequence of this discovery was a CDFA/USDA quarantine resulting in crop destruction of the host tomato crop without harvest. Supportively, the processing tomato industry through California Tomato Growers Association, the California Tomato Research Institute and California tomato processors organized with CDFA to fund a control effort to eradicate the first reported introduction of this broomrape species, *Orobanche aegyptiaca,* into the United States. Fumigation is costly at ~$4K per acre. Subsequently, in order to remove the quarantine, the grower must plant susceptible host crops to monitor broomrape emergence as escapes. There are limited economic crop choices until the grower demonstrates successful eradication. How would anyone know ahead of time that a field was infested with the tiny speck of a broomrape seed? And before these parasitic weeds emerged as a foreign-looking plant to trigger an alert, how many tractors and people passed through the field as unaware potential carriers to spread the seeds?

Bottom Line: Vigilance with sanitation may reduce the introduction of unwanted pests. Perhaps field sanitation should be an adopted routine when leaving a field. This might apply to all of us as field personnel scouting fields as well as equipment operators and irrigators. An ounce of prevention is worth…

The Industry Response? What will be the tact if additional fields are infested in the future? Can we move as an industry to accept the presence of broomrape without quarantine? The Australian and the Israeli tomato industries approach is to control the pest much like another weed within the season because eradication attempts failed. The question remains for us in California: left unchecked and without government quarantine, how big of an agronomic problem will broomrape become? If the new species outbreak in the Solano field represents the norm, the problem is serious and would likely worsen without a unified eradication effort. A quarantine program without an economic means to eradicate the pest is not a solution. If the problem becomes worse, the industry needs to rally.

Below are links to broomrape information.

http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/orobanche-aegyptiaca-factsheet.pdf

http://www.ipm.ucdavis.edu/EXOTIC/egyptianbroomrape.html

Breaking Bindweed: Have We Met Our Match? Lynn M. Sosnoskie, Ph.D. Project Scientist, UC-Davis, Plant Sciences, MS-4, One Shields Avenue, Davis, CA 95616 @LynnSosnoskie on Twitter Phone: 229-326-2676

Processing tomato production in California has changed, dramatically, over the last half-century. Improved cultivars, conversion from seeded to transplanted production, commercialization of the mechanical harvester, and the steady adoption of drip irrigation have helped to expand the size and economic value of the industry. In 2013, California led the nation in the production of processing tomatoes in terms of hectares planted and harvested (105,000 ha), total yield (10 million metric tons), and total value of production ($918 million). The adoption of drip irrigation also reduced in-crop weed densities (small-seeded annual species) and the need for subsequent cultivation. One weed that has been less impacted by the swith to drip systems is field bindweed (*Convovulous arvensis*), a deep-rooted and drought-tolerant perennial that can be difficult to control once it has become established.

Field studies were conducted in 2013 and 2014 to evaluate the efficacy of currently registered PPI, PRE and POST herbicides for field bindweed management in processing tomatoes in California**.** Results show that bindweed cover was reduced >50% in early-planted tomatoes, relative to the control (0 to 30% cover up to 6 WAT), when using trifluralin, alone, or in combination with rimsulfuron, *S*-metolachlor or sulfentrazone (0 to 10% cover up to 6 WAT). Similar trends were observed with respect to field bindweed density. Pre-plant applications of glyphosate to emerged bindweed in late-planted tomatoes, coupled with PPI/PRE herbicide applications, reduced weed cover (1 to 13% up to 6 WAT) by more than half when compared to plots treated with residual herbicides, alone (1 to 43% up to 6 WAT). Similar trends were also observed for weed density in late-planted tomatoes. Herbicide tank-mixes and sequential herbicide treatments can broaden the spectrum of weeds controlled in processing tomato, including field bindweed emerging from seed. However, the most simple and cost-effective approach for managing field bindweed emerging from perennial structures may be to combine glyphosate treatments before final bed preparation and later transplanting dates in tomato fields with heavy field bindweed infestations.

The successful control of deep-rooted perennials, such as field bindweed, is dependent upon herbicides reaching latent root and shoot buds. The majority of root/rhizome biomass for field bindweed is located within the top 2 feet of the soil profile, although some vertical roots can reach depths of more than 10 feet. Conversely, Treflan and other residual herbicides registered for use in processing tomatoes are usually incorporated into the top 2 to 3 inches of the soil profile. Because of their shallow placement, these herbicides may not suppress bindweed vines that are emerging from deeply buried rhizomes. In 2015, we undertook a similar study in processing tomatoes. Specifically, our research was focused on describing how sub-surface applications of trifluralin interacted with surface applied herbicides (trifluralin, *S*-metolachlor, and sulfentrazone with respect to field bindweed control. Results from our study show that broadcast (trifluralin to the entire width of the bed) sub-surface herbicide applications can significantly reduce field bindweed cover relative to the untreated check (no sub-surface trifluralin) or banded (trifluralin applied, sub-surface, only to the outermost 6 inches of the bed) treatments. When averaged over PPI and PRE herbicides, field bindweed cover in the broadcast treatment ranged from 7 to 36%, whereas bindweed cover in the banded and the trifluralin-free (sub-surface) plots ranged from 10 to 50%. An evaluation of the data achieved from these trials suggests that we do have herbicides that are able to suppress field bindweed in processing tomato systems, however, the efficacy of these products are likely to vary with respect to both placement and activation strategy.

Continuing research is being conducted to evaluate the how the type and timing of herbicide applications affect in-crop perennial bindweed control.

Best Practices to Keep Pesticides out of Water. Sam S. Sandoval Professor and Cooperative Extension Specialist in Water Resources, UC Davis and UC Agriculture and Natural Resources, 1 Shields Ave. Dept. LAWR, Bldg. PES 1111, Daivs, CA, 95616 samsandoval@ucdavis.edu

What is Hydrology? How can we keep pesticides out of water? This presentation describes basic concepts of hydrology, from main climatic drivers such as Atmospheric Rivers, to how water moves in the landscape, as well as surface water and groundwater interactions. This presentation provides best management practices on how to keep any contaminant (including pesticides) out of our water, such as storing, loading and manipulating any pesticide over an impermeable layer and 100 feet away from any stream or well. The objective of this presentation is to make available the fundamental knowledge regarding Hydrology and how to keep our water free of contaminants.

Pesticides Detected in Ground Water and Surface Water. Nels C. Ruud, Environmental Scientist and Michael P. Ensminger, Senior Environmental Scientist (Specialist), California Department of Pesticide Regulation, 1001 I Street, P.O. Box 4015, Sacramento, CA 95812. Nels.Ruud@cdpr.ca.gov, Michael.Ensminger@cdpr.ca.gov

The California Department of Pesticide Regulation (DPR) includes the Ground Water Protection Program (GWPP) and the Surface Water Protection Program (SWPP) within its Environmental Monitoring Branch. The GWPP began addressing pesticide contamination of groundwater in the early 1980s, spurred by the discovery of contamination of groundwater from the legal applications of the fumigant DBCP. Reports of additional pesticides in groundwater led to the passage of the Pesticide Contamination Prevention Act (PCPA) in 1985. The purpose of the PCPA is to prevent further pollution by agricultural pesticides of groundwater used for drinking water supplies. It established a program to identify pesticides that have the potential to pollute groundwater, requires sampling to determine if those pesticides are present in groundwater, directs DPR to maintain a database of all wells sampled by all agencies for pesticides, and requires DPR to conduct a formal review to determine whether the use of the detected pesticides can be modified to protect groundwater. During 2013 and 2014, more than 6,600 unique wells in California were sampled between DPR and other agencies with 27 different agricultural chemicals (i.e., active ingredients or their degradation products) being found in groundwater. About 60% of the detected chemicals were active ingredients (or their degradation products) from DPR's Ground Water Protection List (3 CCR Sections 6800(a) and 6800(b)). Recent legislative changes to the PCPA will allow for formal review and possible re-regulation of certain parent active ingredients (alachlor, metolachlor, DCPA) based on the detection of their degradation products in groundwater.

SWPP conducts monitoring studies in several major urban and agricultural areas in the state. In addition, SWPP collects monitoring data from outside agencies, which is housed in the Surface Water Database (http://www.cdpr.ca.gov/docs/emon/surfwtr/surfcont.htm). Perusing this data, between 2010 and 2014, 90 studies by eight major organizations have monitored almost 200 chemicals. Differences exist between urban and agricultural (ag) monitoring programs. More pesticides have been monitored in ag areas (182 pesticides) than in urban areas (140 pesticides). Herbicides (57 urban; 67 ag) are most frequently monitored, followed by insecticides (46 urban; 61 ag), pesticide degradates (29 urban; 35 ag), and fungicides (6 urban; 14 ag). A few fumigants and synergists are also monitored (2 urban; 5 ag). Pesticides detected frequently are cause for concern, especially those with a higher potential for aquatic toxicity. Of herbicides, in ag monitoring, metolachlor, pendimethalin, oxyfluorfen, diuron, and trifluralin are frequently detected at concentrations that have potential toxicity to aquatic organisms. In urban areas, only diuron and pendimethalin meet these criteria. Synthetic auxin herbicides frequently detected in urban runoff do not pose a high aquatic toxicity potential. Of insecticides, imidacloprid and pyrethroids (ag, bifenthrin, lambda-cyhalothrin; urban, bifenthrin, cyfluthrin, permethrin) are frequently detected at levels potentially toxic to aquatic organisms. In ag monitoring, chlorpyrifos and methoxyfenozide are also a concern, but in urban monitoring, fipronil (and its degradates) are. Reducing or preventing runoff of these pesticides is prudent.

California Pesticide Residue Monitoring Program: How We Do It. Thom M. Cate*, M. Pappathakis, A. Hawatky, California Department of Pesticide Regulation, Enforcement Branch, Northern Regional Office. * Thomas.Cate@cdpr.ca.gov

California's Pesticide Residue Program provides a near real-time sample and response in the effort to detect illegal pesticide residues on fresh produce for human consumption in California. The program targets commodities preferentially consumed by children, various ethnic and cultural groups, and women aged 13-49, in an effort to prevent harmful pesticide residues reaching California consumers. Fourteen to eighteen different commodities are sampled up to six times per week throughout California, and submitted to analytic laboratories in Anaheim and Sacramento; results are typically available within 24-28 hours. This rapid turnaround allows the California Department of Pesticide Regulation (CDPR) to quarantine and remove from streams of trade any commodity with illegal or possibly harmful pesticide residues before it reaches the consumer. Violative findings may either be an excess of a permitted residue, or any amount of a residue for which no Federal tolerance has been established.

The CDPR Residue program samples only fresh, unprocessed plant products destined for human consumption. Approximately 3.5 tons of produce was sampled in 2014, the most recent year for which data are available. These pesticide screens determined that of 2,255 domestic samples, only 57 (~2.5%) were carrying illegal levels of pesticide residue; for imported commodities, 171 of 1,155 samples (~15%) were similarly violative. Commodities with frequent rates of violation included spinach, kale, nectarines, limes, ginger, snow peas and cactus pads and fruit.

Healthy Schools Act 101 For Landscape. Eric Denemark, Environmental Scientist, Department of Pesticide Regulation. 1001 I St. Sacramento CA 95814. Eric.Denemark@cdpr.ca.gov

This presentation focuses on the California Healthy Schools Act (HSA). First I will answer the question I am asked the most: can we use Glyphosate at a California school site? Yes, it can be used because it is not on the list of Pesticide Products Prohibited from use on California Schoolsites. Any product containing glyphosate is subject to all of the requirements of the HSA. Then, I will discuss the new training and reporting requirements from the perspective of school staff and contractors. The requirements include: identifying a School IPM Coordinator; developing an IPM plan; providing annual written notification; posting warning signs; keeping records of pesticide applications; submitting pesticide use reports, and completing a school IPM training. Next, I will present a simple case study to demonstrate a legal herbicide application at a California school site. In accordance with the HSA, I will promote low risk integrated pest management methods. I will use flame weeding as an example of how the HSA relates to non-chemical pest management strategies. I will also present new information from the School Pesticide Use Report database on the number of applications targeting gophers, and use that as an opportunity to promote gopher trapping as a low risk control method.

Chemical Resistant Glove Selection. Lisa A. Blecker, Pesticide Safety Education Program Coordinator, University of California Agriculture and Natural Resources Statewide IPM Program, 2801 Second Street #157, Davis, CA 95618-7774, lblecker@ucanr.edu

Chemical resistant gloves are commonly used personal protective equipment (PPE) worn by pesticide handlers – those who mix, load and apply pesticides. The U.S. Environmental Protection Agency (U.S. EPA) Chemical Resistance Category Selection Chart for Gloves is used to determine the type of gloves to be listed on pesticide labels, based on glove material resistance to solvents used in pesticide formulations. Agricultural pesticide product labels are required to reference the different glove materials on labels, and they do so either by specifying by name (e.g., nitrile, butyl, etc.) or by code (A through H). California regulations require employees to wear chemical resistant gloves for most pesticide handling tasks, even if the label does not require them. The consequences of not wearing gloves and other required PPE can be great. For example, a query of the California Pesticide Illness surveillance Program (PISP) database from 1992-2011 showed that 33% of reported handler pesticide illnesses that involved skin or systemic symptoms corresponded to a failure to wear required PPE. Participants in this session were asked to identify 10 different gloves – each made of one of the eight resistant materials. We displayed photos of each glove, in addition to distributing example gloves to some participants. The majority of the gloves were miss-identified. This activity highlighted some of the impediments to selecting and wearing the appropriate chemical-resistant gloves, which include: unclear or missing pesticide label statements, difficulty in distinguishing among different glove materials, and lack of identifying information on the actual gloves. Participants were instructed how to use the Glove Category Selection Key (California Department of Pesticide Regulation) to better understand label statements, and were shown how to use product information from glove distributers to make more informed decisions. Participants were reminded to keep themselves safe from pesticide exposure by following these practices: wear chemical resistant gloves for all handling activities; consult the label and California requirements for the appropriate glove material, and check manufacturers' specifications for thickness, uses, lining type, and other details that may affect the safety of the glove.

Updates to the Worker Protection Standards and Impacts on California. Leslie A. Crowl, Department of Pesticide Regulation, Worker Health and Safety Branch, 1001 I Street Sacramento CA, 95812. leslie.crowl@cdpr.ca.gov

In 1992 the United States Environmental Protection Agency (U.S. EPA) implemented a set of regulations known as the Worker Protection Standards (WPS) to address worker safety concerns in the agricultural industry. On November 2, 2015, EPA published revisions to the WPS to address continuing concerns for the safety of agricultural workers and bring the regulations up to other industry safety standards. Several revisions to the WPS will affect certain California regulations relating to: pesticide safety training for workers and handlers, notification, hazard communication, drift, age, displaying pesticide safety information, decontamination, and agricultural exemptions. Not all of the U.S. EPA's revisions to the WPS will impact California regulations however some adjustments will need to be made.

U.S. EPA is shortening the retraining interval for workers and handlers from once every five years to annually. California requires annual training for handlers and will now be requiring annual training for field workers. U.S. EPA will be requiring employers to keep and maintain records of pesticide safety training(s) for their workers and handlers for two years. California requires record keeping for handlers and will now be requiring recordkeeping for workers. U.S. EPA is expanding the pesticide safety topics that workers and handlers are required to be trained on to include topics such as: take home exposure, application exclusion zones, and minimum age requirements. California has most of these topics covered in their Pesticide Safety Information Series (PSIS) but will need to codify the topics into regulation.

U.S. EPA is requiring field posting of pesticide warning signs for all applications of pesticides with a Restricted Entry Interval (REI) greater than 48 hours. California will now require posting for REI's greater than 48 hours instead of the current seven-day requirement.

U.S. EPA is requiring the employer to display pesticide hazard information (Safety Data Sheets) at the central display along with application information. California will now require Safety Data Sheets to be available at the central display instead of being provided upon request. U.S. EPA is requiring employers to maintain pesticide application information and pesticide hazard information for two years (information still only needs to be at the central display for 30 days + REI). California already has this requirement but must now allow for "designated representatives" to formally request this information in writing.

U.S. EPA is expanding their requirements for "entry restricted areas" to include outdoor production areas and has renamed these areas "application exclusion zones." For outdoor production, these zones may extend up to 100 feet around the application equipment during the application. California will incorporate U.S. EPA's exclusion zones into California regulations.

U.S. EPA is requiring all pesticide handlers and early entry workers, working in an agricultural setting, to be at least 18 years old. California will expand their current age requirements to require agricultural handlers and early entry workers to be at least 18 years old.

U.S. EPA is requiring employers to post pesticide safety information at all decontamination sites servicing 11 or more workers in addition to their current requirement for the information to be at a central location. California will now require employers to post an A-8 and/or A-9 at each decontamination site servicing 11 or more workers.

U.S. EPA is codifying into their decontamination regulations required amounts of water to be provided to workers and handlers measured at the start of their workday. Workers must be supplied with at least 1 gallon of water per worker; early entry workers and handlers must be supplied with 3 gallons of water per early entry worker/handler. California will codify U.S. EPA's water requirements into regulation. U.S. EPA is requiring an ocular decontamination system, capable of flushing the eyes gently with water for 15 minutes, to be available at all mixing and loading sites when the handler is mixing/loading a pesticide that requires protective eyewear or operating a closed system. California will add this requirement to regulation.

U.S. EPA is removing their exemption that allows employees working under a Certified Crop Advisor, performing crop advising tasks, to be exempt from certain PPE and re-entry worker requirements. California will now no longer allow this exemption either. U.S. EPA is removing their exemption that allows applicators to forego respiratory protection in an "enclosed cab approved for respiratory protection." Handlers will be required to wear the label required respirator unless the only label-specified respiratory protection is a filtering facepiece respirator (NIOSH approval number prefix TC–84A) or dust/mist filtering respirator. California will mirror U.S. EPA's change and remove the exemption for "enclosed cabs approved for respiratory protection."

U.S. EPA's new WPS requirements will go into effect in two rounds. The first round will be implemented January 2017 and will include all changes except the requirement to train workers on the new pesticide safety topics. U.S. EPA is delaying implementing their required training topics until January 2018 to allow time for U.S. EPA to generate new training materials.

Pesticide Jeopardy. Sarah P. Risorto, Pesticide Safety Educator, University of California, Agriculture and Natural Resources Statewide IPM Program, 2801 Second Street, Davis CA 95618, sprisorto@ucanr.edu

To reemphasize information delivered in prior sessions, a game of Pesticide Jeopardy was played at the end of the Laws and Regulations Session. Questions were based on information presented earlier in the Session and sourced from all speakers that day. Questions were presented in the following categories: *School IPM* (based on Eric Denemark's presentation: Healthy Schools Act 101 for Landscape), *Pesticides and Hydrology* (based on Sam Sandoval's presentation: Best Practices to Keep Pesticides out of Water), *Pesticides in Ground and Surface Water* (based on Nels Ruud's and Michael Ensminger's Presentation: Pesticides Detected in Ground Water and Surface Water), *Residue Monitoring* (based on Thom Cate's presentation: California Pesticide Residue Monitoring: How We Do It and Cheryl Reynold's presentation: How to Avoid Illegal Residues), *Worker Protection Standards* (based on of Leslie Crowl's presentation: Updates to the Worker Protection Standards & Impacts on California) and a Final Category, Gloves (based on of Lisa Blecker's presentation: Pesticide Protective Gloves). All questions were reviewed and revised as appropriate.

There were 143 participating audience members. The participants were divided and assigned into four teams: *Monocots*, *Dicots*, *Systemic* and *Contact*. Every participant was given an audience response devise, or a "clicker", that they used to answer multiple choice and true/false formatted questions. The participants answered 73% of School IPM, 80% of Pesticide and Hydrology, 76% of Pesticides in Ground and Surface Water, 72% of Residue Monitoring and 76% of Worker Protection Standard questions correctly.

Team *Contact* won Pesticide Jeopardy and was rewarded with an English/Spanish bilingual UC IPM publication, "Understanding Pesticide Labels for Making Proper Applications". This booklet was reviewed during Cheryl Reynold's presentation on How to Avoid Illegal Residues.

Temperature-dependent Germination Rates Among Several California Accessions of *Echinochloa colona.* Alex Ceseski[1], Lynn Sosnoskie PhD[1], Sarah Morran PhD[1], Brad Hanson PhD[1] [1]University of California, Davis

The purpose of this study was to determine how temperature affects the germination of junglerice (*Echinochloa colona*) from the Central Valley of California. Seeds from six junglerice accessions (A3, A8, C6 all from the Sacramento Valley and H5, L2, SV2 from the San Joaquin Valley), were scarified in concentrated sulfuric acid for 30 minutes; 50 seeds of each biotype were placed in Petri dishes containing 7.0mL of 0.2% Captan fungicide solution. The trials were conducted in two growth chambers with temperatures ranging from 15°C to 40°C, and set to a 16/8-hour light/dark cycle and 50% RH. The Petri dishes were held in nested cardboard flats to exclude intense, direct light and minimize desiccation potential.

Seeds were monitored, daily, until germination slowed to <1 seedling in three days or until all seeds had germinated. A seed was considered germinated when the emerged radicle was as long as the seed coat, about 2mm; germinated seeds were counted and then discarded at each observation point. The 20°C trial was run concurrently with the 15°C trial, so it was not terminated until the 15°C trial was. The 25°C, 30°C, 35°C, and 40°C trials were terminated at 10 days after plating. Each biotype was replicated four times per temperature, with a total of 24 petri dishes per temperature.

The rate of germination increased with increased temperature. At 15°C, 50% germination was achieved in a timespan ranging from 5 days after plating (SV2) to 37 days after plating (L2). At 20°C, 50% germination was achieved 2 to 4 days after plating for all biotypes. At 25°C, 30°C, and 35°C, 50% germination had occurred by 2 days after plating. At 40°C, all biotypes but SV2 reached 50% germination by 3 days after plating; SV2 reached 50% at 4 days. With the exception of SV2 at 35°C and 40°C, and L2 at all temperatures, maximum germination percentages ranged from 84% to 98% and were achieved in as soon as 3 days after plating (30° & 35°C) and as long as 49 days after plating (15°C). The least amount of germination occurred with accession L2; maximum germination for L2 ranged from 59% to 76%. Total germination percentages for SV2 were 94%, 97%, 96%, 92%, 71% and 67% at 15°C, 20°C, 25°C, 30°C, 35°C, and 40°C, respectively. It is unknown if the reductions in germination in SV2 at higher temperatures were the result of maternal factors affecting seed development/maturation, differences in seed dormancy mechanisms, or seed injury in response to scarification.

All of the temperature treatments will be evaluated at least twice more. With future data and analysis we hope to provide an adequate profile on junglerice germination potentials under different environmental conditions, which will further our ability to describe the species' invasion potential.

Weed Community Dynamics and Agronomic Productivity in Alternative Irrigation Systems in California Rice. Whitney B. Brim-DeForest[1*], Bruce A. Linquist[1], Kassim Al-Khatib[1], and Albert J. Fischer[1]. [1]Department of Plant Sciences, University of California, Davis [*]wbrimdeforest@ucdavis.edu

The composition of weed communities and relative abundance of weed species in agricultural environments is affected by a number of factors, both abiotic and biotic. In rice, two of the primary abiotic factors are soil moisture and oxygen saturation. Flood irrigation favors species that tolerate anaerobic (low oxygen) environments, while flush irrigation and drain events favor species that are better adapted to aerobic (high oxygen) environments. Since 2000, California has experienced a series of ever-worsening droughts. Rice, a traditionally flooded crop, has come under increasing scrutiny. A number of alternative irrigation systems have been proposed, including continuous flushing and flooding with an early drain. For growers, weed competition is one of the most limiting factors to maintaining high yields, so understanding the shifts among species in weed communities under the proposed alternative irrigation systems is vital. The primary objectives of this research were: 1) to determine weed community composition in rice under alternative irrigation systems at canopy closure and at harvest and 2) to quantify differences in yields between irrigation systems in both the presence and absence of weed competition.

The experiment took place from 2013-2014 at the Rice Experiment Station in Biggs, CA. Three irrigation systems were compared: 1) Drill-Seeded Alternate Wet and Dry (DS-AWD); 2) Water-Seeded Alternate Wet and Dry (WS-AWD); and 3) Water-Seeded Conventional (WS-Control). The DS-AWD was seeded by drill into dry soil to a depth of approximately 2 cm. It was flushed for emergence, and again whenever Volumetric Water Content (VWC, in cm^3 cm^{-3}) reached 35%. The WS-AWD and WS-Control were broadcast-seeded onto dry soil, and flooded to 10 cm above the soil surface within 24 hours. The WS-AWD treatment remained flooded until canopy closure of the rice, at which point water was allowed to drain. After draining, the WS-AWD treatment was flushed again whenever soil VWC reached 35%. Dominant weed species were evaluated at canopy closure and at harvest: watergrass (*Echinochloa* (L.) Beauv. spp)., smallflower umbrella sedge (*Cyperus difformis* L.), sprangletop (*Leptochloa fusca* (L.) Kunth), ricefield bulrush (*Schoenoplectus mucronatus* (L.) Palla), ducksalad (*Heteranthera rotundifolia* (Kunth) Griseb.) and redstem (*Ammannia* L. spp.). Relative cover and dry biomass at harvest of each species were assessed in nine quadrats per treatment plot. Weedy and weed-free rice yields were harvested and adjusted to 14% moisture.

Over both years, weed-free yields were not significantly different across the three irrigation systems (ANOVA, $p > 0.05$). Weedy yields were significantly less in the DS-AWD than in the WS-AWD and WS-Control across both years (Tukey-Kramer HSD Mean Separation, $p < 0.05$). Ducksalad and watergrass were the predominant weed species present in the WS-AWD and WS-Control at canopy closure over both years. In the DS-AWD, watergrass and sprangletop were the only two species present at canopy closure. At harvest, ducksalad had completed its life cycle, so watergrass was the predominant species across all irrigation systems, though the relative biomass was significantly greater in the DS-AWD than in the other systems ($p < 0.05$). The only significant difference found in species composition between the WS-AWD and WS-Control was the significant increase in biomass of smallflower umbrella sedge in the WS-AWD at harvest in both 2013 and 2014 ($p < 0.05$). The increase may be due to the biphasic emergence pattern of smallflower umbrella sedge, which could be stimulated by the drain at canopy closure in the WS-AWD treatment.

Preliminary Evaluation of Suspected Paraquat-resistant Italian Ryegrass in a California Orchard. Caio Brunharo[1], Bradley Hanson[1] [1]University of California at Davis

Paraquat is widely used as a nonselective herbicide for the control of weeds in row, vegetable and orchard crops. This quaternary ammonium acts by siphoning electrons from the plant's photosystem I and donating them to O_2, generating toxic molecules that lead to rapid plant cell membrane disruption. The present experiment was carried out following reported failures in controlling Italian ryegrass with paraquat in a prune orchard near Hamilton City, California. The 15 treatments in the experiment were commonly used herbicides for pre- and post-emergence grass-weed control in California, and included: (1) Untreated control; (2) Roundup PowerMax; (3) Gramoxone SL (2.5 pt/A); (4) Gramoxone SL (4 pt/A); (5) Rely 280; (6) Roundup PowerMax + Poast; (7) Roundup PowerMax + Fusilade; (8) Roundup PowerMax + Envoy; (9) Roundup PowerMax + Matrix; (10) Rely 280 + Poast; (11) Rely 280 + Fusilade; (12) Rely 280 + Envoy; (13) Rely 280 + Matrix; (14) Rely 280 + Alion; and (15) Gramoxone 2 + Surflan AS. Treatments were applied on May 23rd, 2015, when the ryegrass was 10 inches tall. Visual evaluations were carried out at 7, 14, 21 and 28 days after treatment, based on a 0-100 scale, where 0 represents no visible injury and 100 represent complete plant death. Overall, Roundup PowerMax exhibited poor visual control of Italian ryegrass in all treatment combinations. The treatments that performed statistically best were Rely 280 + Envoy (56 fl oz/A + 16 fl oz/A), Rely 280 + Fusilade (56 fl oz/A + 12 fl oz/A), Rely 280 + Matrix (56 fl oz/A + 2 oz/A) and Rely 280 (56 fl oz/A). In this field study, paraquat only provided 68-73% control of ryegrass which strongly supports the previously reported concerns about glyphosate-paraquat resistance in Italian ryegrass in California orchards

A Comparison of Remote Sensing Methods for Estimating Summer Annual Plant Cover. Roxanne Foss, Department of Environmental Science, Policy & Management, University of California, Berkeley, CA

Yellow star-thistle (*Centaurea solstitialis*; YST) is a noxious weed invading California's grasslands statewide, outcompeting native grasses, native forbs, and non-native annual grass forage (Bradley et al 2009, Pitcairn et al 2006). A considerable amount of research and a number of integrated pest management (IPM) programs have sought to reduce the density and extent of YST by burning, grazing, applying herbicide, and mechanically removing individuals (DiTomaso et al. 2006). This case study examines the accuracy of multiple classification methods in identification of potential YST cover across Briones Regional Park, within Contra Costa County, CA. Late summer annual plant cover was estimated with 2014 National Agriculture Imagery Program (NAIP) imagery and Landsat 8 near-infrared data using unsupervised, supervised, machine learning, and decision tree classification methods. All methods initially had low overall accuracy (less than 63%), but accuracy improved when cover classes with similar spectral signatures were combined. The vector machine learning classification method had the highest overall accuracy of all tested classification schemes (84.66% overall accuracy). However, the supervised classification method had the highest user and producer accuracy in identifying herbaceous cover with a high infrared signature (79.67% user; 89.09% producer). The classification of plant cover with high NIR signatures corresponds to a suite of summer annual species of management concern at Briones Regional Park. This replicable approach is applicable to land managers across California that face similar invasions of YST and other summer-maturing invasive plants.

Effect of Green Waste Compost and Tomato Pomace Soil Amendments on Weed Seed Inactivation with Biosolarization. Kate Hernandez[1*], Dlinka G. McCurry[1], Ruth M. Dahlquist-Willard[1], and James J. Stapleton[2]. [1]University of California Cooperative Extension Fresno County, Fresno, CA; [2]Statewide Integrated Pest Management Program, UC Kearney Agricultural Research and Extension Center, Parlier, CA. *kt.hernandez@hotmail.com

Weed pests pose a formidable problem for farmers without the help of fumigants and herbicides. Biosolarization, or solarization with soil amendments such as compost or other sources of organic matter, has the potential to increase the utility of solarization for weed control by reducing the time and/or temperature regimen needed to achieve mortality of weed seeds and other soilborne pests. The effect of biosolarization on seeds of black mustard (*Brassica nigra*) and black nightshade (*Solanum nigrum*) was evaluated as a sustainable alternative to pesticides. A field trial was performed in Parlier, California, using solarized and nonsolarized soil amended with tomato pomace (2.5% or 5% w/w), and green waste compost (2% w/w) combined with tomato pomace (2.5% or 5% w/w) to test weed seed inactivation efficacy. Solarized treatments with both compost and pomace amendment, as well as pomace alone, had nearly 100% mortality after 7 days, as opposed to treatments without amendments and treatments that were not solarized. Tetrazolium testing confirmed that nongerminated weed seeds were dead and not dormant. These results indicate that control of certain weeds with biosolarization can be achieved in much less time than is normally required for solarization without soil amendments (usually 6-8 weeks).

Effects of Simulated Rice Herbicide Drift Rates on Walnuts.

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English walnut is one of the top commodities grown in California and its importance has been increasing in the last decade. Often walnut trees are fairly close to rice fields; thus herbicides used on rice may contact walnut trees by either drift or accidental direct application. There are many complains about yellow spotting observed on young walnut leaves that are alleged to be related to rice herbicide drifting following aerial application. In the walnut growing Sacramento Valley counties, the majority of the rice herbicides are sprayed between the end of May and early July. This timing coincides with a period of rapid growth for walnuts and flower bud initiation. Two field experiments were conducted at the UC Davis experimental station to evaluate simulated drift rates of selected rice herbicide on two years old chandler walnuts. On June 24, 2015, bispyribac sodium, bensulfuron and propanil were applied at four rates representing 0.5%, 1%, 3% and 10% of the use rate in rice. The use rate was 44.8, 70.2, and 6725.1 g ai/ha for bispyribac sodium, bensulfuron and propanil, respectively. All herbicides caused significant damage and delayed growth of the young walnut leaves and shoots. The severity of symptoms peaked 21 days after treatment then plants started to recover from injury symptoms. At the end of the growing season, however, herbicide symptoms were still evident. The effects of multiple bispyribac sodium exposure were evaluated in a separate study. Two years old walnut trees were treated with four sequential applications of two rates (0.5% and 3% of the rice use rate) of bispyribac sodium on a weekly interval, starting on June 11, 2015. Bispyribac sodium, at both rates caused significant damage to walnuts leaves and growth. Symptoms were still apparent four months after the last bispyribac sodium treatment.

Mortality of *Brassica nigra* Seeds At Temperatures in the Low Range of Biosolarization Conditions. Dlinka G. McCurry[1]*, Kate Hernandez[1], Ruth M. Dahlquist-Willard[1], and James J. Stapleton[2]. [1]University of California Cooperative Extension Fresno County, Fresno, CA; [2]Statewide Integrated Pest Management Program, UC Kearney Agricultural Research and Extension Center, Parlier, CA. *dlinka.mccurry@gmail.com

Soil solarization is an organically acceptable technique that helps reduce the weed seedbank without using fumigation or herbicides. Biosolarization (solarizing soil amended with green waste compost and/or tomato pomace) could help shorten the time required for solarization by increasing mortality of weed seeds. We exposed *Brassica nigra* (black mustard) seeds to two constant temperatures in three soil preparations (field soil, field soil plus tomato pomace, and field soil plus green waste compost and tomato pomace). The soil preparations were exposed to moderate temperatures of 39 C and 42 C for periods of 48 and 72 hours in replicated, laboratory microcosm experiments. Seed samples were removed from microcosms and incubated for 14 days in a growth chamber to determine germination percentage. Mortality was determined as (1 –germination %) and verified with tetrazolium staining. Both heat treatment and soil mixture type had an effect on weed seed mortality, with higher mortality in heat-treated soil mixtures and higher mortality in amended soil mixtures (*P*<0.01). Weed seed mortality in both pomace- and compost+pomace-amended soil reached 98-100% at 42 C in 72 hours, indicating that biosolarization for weed seed control would be effective within a few days of treatment and at temperatures lower than those required for solarization in non-amended soil.

Screening the San Joaquin Valley for Glyphosate-resistant Palmer amaranth in Perennial and Annual Cropping Systems. Eduardo Padilla[1], Sonia Rios[2], Steve Wright[3], and Anil Shrestha[1]: [1]California State University Fresno, [2]UCCE Riverside/San Diego Co., [3]UCCE Tulare/Kings Co., 5241 North Maple Avenue, Fresno, CA 93740
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Glyphosate has been a popular herbicide for weed management in agriculture cropping systems and non-crop areas for more than a decade. Heavy reliance on a single mode of action can increase the risk of weed species evolving resistance to the herbicide. Glyphosate-resistant (GR) populations of Palmer amaranth have been confirmed throughout the southeast United States since 2005. Since 2012, growers in California's San Joaquin Valley (SJV) have observed poor control of Palmer amaranth in glyphosate-tolerant corn (*Zea mays L*.) and cotton (*Gossypium hirsutum L*.). Palmer Amaranth (*Amaranthus palmeri*) is one of the most difficult weeds to control because of its competitive ability, C4 photosynthesis, high water use efficiency and drought tolerance, rapid growth rate, and prolific seed production. However, it is not known if these are cases of GR populations or application of glyphosate at more tolerant stages of the weed. Palmer amaranth seeds from 6 annual and biannual cropping systems from different locations of the SJV were collected for evaluation of glyphosate resistance. The SJV Palmer amaranth populations have been evaluated against a known GR and a glyphosate-susceptible (GS) population from New Mexico. The experimental design was a 4 by 9 factorial randomized complete block with four replications. The 4 populations and the 9 herbicide doses were the factors. Glyphosate treatments were administrated at the 5- to 8- leaf stage at 0.5x, 1x, 1.5x, 2x, 2.5x, 3x, 3.5x, and 4x rates with a control, where 1x= 840 g ae ha^{-1} (labeled rate). The study was repeated. All the SJV populations had 100% mortality at the 840 g ae ha^{-1} rate of glyphosate in both studies and therefore deemed to be GS. However there was a significant difference ($P< 0.05$) between the two studies in the biomass. Collectively, these studies will provide information on whether the reported lack of control in the SJV Palmer amaranth populations are cases of GR populations or due to tolerance to glyphosate at later growth stages.

Life Cycle of Fall- and Spring-planted Biotypes of *Conyza* spp. Described in Growing Degree Days. Katrina Steinhauer[1], Marie Jasieniuk[2], Brad Hanson[2], and Anil Shrestha[1] [1]Department of Plant Science, California State University, Fresno, CA
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Horseweed (*Conyza canadensis*) and hairy fleabane (*C. bonariensis*) are two common weeds in perennial cropping systems and non-crop areas of California. Glyphosate-resistant (GR) populations of these species were documented in 2005 and 2007, respectively. In the Central Valley, these species generally have two major times of emergence, in late fall and late winter. The fall-emerging plants overwinter as a rosette and start rapid growth in late winter. The spring-emerging plants start rapid growth soon after emergence but both the fall- and the spring-emerging plants flower and set seed in late summer. However, the difference in growth and phenological development of the plants emerging at these two times of the year has not been studied. Also, it is not known if emergence characteristics or phenological differences are different between the GR and glyphosate-susceptible (GS) biotypes of these two species. The use of growing degree days (GDDs) is common in describing phonological development of crops and insect pests. In the case of weeds, the development of some species have also been described in GDDs. Control measures with herbicides may be better if application timings were based on GDD rather than on growth stage. Therefore, a two-year study was conducted at Fresno, CA to compare the growth and development of fall- and spring-planted GR and GS horseweed and hairy fleabane. The time taken to reach various phenological stages (rosette, bolting, initial appearance of flower bud, initial flowering, and initial seeding) was recorded days after transplanting and converted to GDDs using a base temperature of 13° C and 4.2° C, for horseweed and hairy fleabane growth, respectively. Dry mass of the plants at initial seed set was also recorded. Results showed that, the GDDs required to reach various phenological stages was different between the fall- and spring-planted hairy fleabane. The fall-planted hairy fleabane plants required more GDDs to set seed than the spring-planted ones. However, there was no difference between the GR and the GS hairy fleabane for the number of GDDs required to reach the various phonological stages. In contrast, both the fall- and spring-planted horseweed required similar GDDs to reach the various phenological stages. Furthermore, the GR horseweed plants required fewer GDDs to reach the various phenological stages than the GS plants. Planting date had no effect on final aboveground hairy fleabane biomass but fall-planted horseweed amassed more dry matter than the spring-planted individuals. Studies have reported that postemergence herbicides control these species better when applied at or before the rosette stage. Once the plants bolt, they become somewhat tolerant to herbicides, in general. Biological information generated from this study could help in the management of horseweed and hairy fleabane, especially with postemergence herbicides under various winter and spring temperature conditions.

Allelochemical Pest Control in Strawberry Production. Eli M. Weissman*[1], Dr. Scott Steinmaus, Dr. Kelly Ivors, Dr. Steven Fennimore, Dr. Matt Ritter
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Strawberry (*Fragaria* x *ananassa*) production relies predominantly on synthetic pesticide applications to control pests. Due to mandated reductions in methyl bromide use, and the subsequent emergence of pests previously controlled by this fumigant, strawberry growers must find novel pest control options. Allelochemicals, compounds produced by one organism that suppress the growth and/or development of another, are an appealing solution because research suggests they have fewer environmental impacts than traditional pesticides. In water agar, we produced 1000, 500, 100, and 10 parts per million (ppm) concentrations of gallic acid, ferulic acid, p-Coumaric acid, and juglone. We tested the *in vitro* dose-response of little mallow (*Malva parviflora*), common groundsel (*Senecio vulgaris*), annual blue grass (*Poa annua*), and romaine lettuce (*Lactuca sativa* 'Inferno') to these four putative allelochemicals. We subjected seedling length and percent germination data to analysis of variance, Tukey's HSD tests, and nonlinear regressions. Juglone inhibited *M. parviflora* germination (EC_{50}: 87 ppm) whereas the other compounds did not. Seedling length was a more sensitive response variable (*M. parviflora* seedling length EC_{50s} for juglone, p-Coumaric acid, ferulic acid, and gallic acid were 71 ppm, 115 ppm, 267 ppm, and 165 ppm, respectively). Enhanced juglone phytotoxicity was likely due to the greater lipophilicity of quinones, such as juglone, relative to the three phenolic acids. Generally, the phytotoxicity of the compounds fell into the following order: juglone>p-Coumaric acid>ferulic acid>gallic acid (e.g. *S. vulgaris* germination EC_{50s} listed in the compound phyotoxicity order: 69 ppm, 147 ppm, 666 ppm, and no inhibition). To further assess the suitability of the four suspected allelochemicals as pre-plant pesticides in strawberry production, we are performing additional weed and fungal assays in field soil.

Competition Between a Glyphosate-resistant and Susceptible Biotype of junglerice (*Echinochloa colona*). Pahoua Yang, Larissa Larocca de Souza, and Anil Shrestha, Department of Plant Science, California State University, Fresno, CA 93740

Junglerice (*Echinochloa colona*) is a problematic weed in annual and perennial cropping systems as well as non-crop areas of California. This problem has been further aggravated by the discovery of glyphosate-resistant (GR) biotypes in the Central Valley. Development of effective management strategies for herbicide-resistant weeds requires an understanding of population dynamics and potential impacts of the resistant biotype. For example, some herbicide-resistant biotypes carry a fitness penalty and can have reduced competitive ability than the herbicide-susceptible biotypes. Therefore, study of the competitive ability of resistant and susceptible biotypes of weeds is of ecological significance and can impact weed management decisions. Some studies have found that the GR horseweed (*Conyza canadensis*) was more competitive than the glyphosate-susceptible (GS) biotype. However, it is not known if it is the same case with junglerice. This needs to be determined as the findings may have ecological significance to the population dynamics of these two biotypes of junglerice in the Central Valley. Therefore, a study was conducted in summer 2015 in Fresno to compare the competitive ability of GR and GS junglerice.

Two- to 3-leaf seedlings of a confirmed GR and a GS junglerice biotype were obtained from University of California, Davis and were transplanted into 15.1 l (4 gal) plastic pots containing field soil. In each pot, the GR and GS plants were planted at different ratios in a replacement series experiment style. The ratios were 4:0, 3:1, 2:2, 1:3, and 0:4 of GR and GS plants, respectively. Each plant was labelled with a small plastic stake for identification. Each treatment was replicated four times and the experiment was arranged as a randomized complete block. All the pots were irrigated with 1.1 l/pot (0.3 gal/pot) of water every two days. Each pot was also fertilized with 100 ml (0.1 qt) of a solution containing 4 g (0.14 oz) of commercial fertilizer (Miracle-Gro) twice during the growing season. The plants were grown for six weeks. At the early flowering stage, the plants from each pot were individually harvested at the soil surface. After harvest, the plants were individually stored in paper bags, oven dried at 60° C for 3 days and shoot dry weights was recorded. Data were analyzed using analysis of variance procedures in SAS at a 0.05 level of significance and graphs were prepared using SigmaPlot.

The total average aboveground biomass and total dry weight of the inflorescence was greater in the GS than in the GR type. However, the number of flower heads was greater in the GR than in the GS type. This indicated that the biomass allocation patterns to the reproductive structures and total seed production could be different in the GS and the GR junglerice. However, this cannot be ascertained as the experiment was terminated before seed set. The replacement series data showed that the GS junglerice was more competitive than the GR biotypes and produced more biomass at all densities. Therefore, this study indicated that the GS was more competitive than the GR junglerice biotypes tested. However, it cannot be generalized if this is the case with all GR and GS biotypes of junglerice in California. The study will be repeated in 2016.