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Introduction

Richard Smith, Editor

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This issue of the California Weed Science Society Journal deals with weed control issues in the urban landscape. The article by Martin Guereña is an example of a weed manager balancing the demands of the public for low toxicity weed control solutions with efficacy and cost considerations. Working with the City of Davis, Department of Public works he has implemented an IPM program to manage weeds. He provides education to the public through a variety of innovative means and controls weeds with a variety of approaches. Working in urban areas can be challenging as there is usually little understanding of the difficulties involved in controlling weeds as well as anxiety over the use of pesticides. With those issues in mind, we have included articles that help address some of the technical issues that urban weed control managers confront, as well as an interesting article by Dr. Steven Duke, who was a Key Note speaker at the January CWSS conference, on the relationship between pharmaceuticals and herbicides.

This is the last paper issue of the CWSS Journal. All subsequent issues will be sent via email. If you think that we may not have your email address, please send it to Celeste Elliott and she will add you to the email list: manager@cwss.org.

Be sure to mark your calendars for the CWSS annual meeting in Monterey on January 19-21, 2011 (for information visit the website at <http://www.cwss.org>). If you have questions or comments about the CWSS Journal, contact me at 831-759-7357 or rifsmith@ucdavis.edu.

Organic Herbicides – Do they work?

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In recent years, several organic herbicide products have appeared on the market. These include Weed Pharm (20% acetic acid), C-Cide (5% citric acid), GreenMatch (55% d-limonene), Matratec (50% clove oil), WeedZap (45% clove oil + 45% cinnamon oil), and GreenMatch EX (50% lemongrass oil), among others.

These products are all contact-type herbicides and will damage any green vegetation they contact, though they are safe as directed sprays against woody stems and trunks. These herbicides kill weeds that have emerged, but have no residual activity on those emerging subsequently. Additionally, these herbicides can burn back the tops of perennial weeds, but perennial weeds recover quickly.

These products are effective in controlling weeds when the weeds are small and the environmental conditions are optimum. In a recent study, we found that weeds in the cotyledon or first true leaf stage were much easier to control than older weeds (Tables 1 and 2). Broadleaf weeds were also found to be easier

to control than grasses, possibly due to the location of the growing point (at or below the soil surface for grasses), or the orientation of the leaves (horizontal for most broadleaf weeds) (Tables 1 and 2).

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

Adding an organically acceptable adjuvant has resulted in improved control. Among the organic adjuvants tested thus far, Natural wet, Nu Film P, Nu Film 17, and Silwet ECO spreader have performed the best. The Silwet ECO spreader is an organic

silicone adjuvant which works very well on most broadleaf weeds, but tends to roll off of grass weeds. The Natural wet, Nu Film 17 and Nu Film P work well for both broadleaf and grass weeds. Although the recommended rates of these adjuvants is 0.25 % v/v, we have found that increasing the adjuvant concentration up to 1% v/v often leads to improved weed control, possibly due to better coverage. Work continues in this area, as manufacturers continue to develop more organic adjuvants. Because organic herbicides lack residual activity, repeat applications will be needed to control new flushes of weeds.

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

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

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

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

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

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

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

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

Organic herbicides are expensive at this time and may not be affordable for commercial crop production. Because these materials lack residual activity, repeat applications will be needed to control perennial weeds or new flushes of weed seedlings. Finally, approval by one's organic certifier should also be checked in advance as use of such alternative herbicides is not cleared by all agencies.



Winter weeds injured by a Weed Pharm (20% acetic acid) application but regrowing 15 days after application. Weed control from winter applications was found to be less effective.



Nutsedge is burned back by an application of GreenMatch applied at a 15% concentration plus 1% Natural Wet

Nutsedge Management (or lack of) in Turf

Cheryl Wilen, Area IPM Advisor, UC Statewide IPM Program and UC Cooperative Extension.

Why don't turf managers get consistently good control of nutsedge? There are probably three good reasons. First, the plant has to be at a growth stage where the herbicide can most easily be translocated to the growing tips. Late season applications will probably not have much an effect as the aboveground part of plants will be dying back. Applications targeting early growth stages will be most effective because at this stage, the plants are just emerging and have not yet developed new tubers. The second best time is prior to the plant developing 5 leaves. In general, tuber production is starting to be initiated at this time and applications to the foliage will rapidly move to young tubers and tips of rhizomes. Follow-up applications will improve control over a single application. Secondly, the targeted weed must be well watered both before and within 24 hours after application to assure good uptake. Stressed plants will not translocate the herbicides as well as well-watered ones.

Halosulfuron-methyl, formally Manage from Monsanto and currently sold as Sedgehammer by Gowen, was the first of a new generation of postemergence herbicides marketed to selectively control yellow purple nutsedge and green kyllinga in turfgrass. The active ingredient is in the sulfonyleurea (SU) chemical class and these have been shown to inhibit acetolactate synthase (ALS), an enzyme needed to synthesize three essential amino acids in plants. The mechanism of selectivity is thought to be that the herbicide is rapidly metabolized into non-phytotoxic metabolites in tolerant plants. Halosulfuron is safe to use over a wide spectrum of both cool and warm season turfgrass species commonly grown in California including Bermudagrass, St. Augustinegrass, Kikuyugrass, seashore paspalum, zoysiagrass, Kentucky bluegrass, perennial ryegrass, fine fescue, tall fescue, and creeping bentgrass.

Following the introduction of halosulfuron methyl, other herbicides which affect the ALS enzyme were launched into the turf market that had slightly improved activity. These include Monument (trifloxysulfuron-sodium), Certainty (sulfosulfuron), both in the sulfonyleurea chemical class, and Image (imazaquin) in the imidazolinone chemical class.

Interestingly, the herbicides with the trade name "Image" in California are not the same. Depending on the label and use, the active ingredient in those products can be MSMA, atrazine, triclopyr, dichlobenil and there are no registered products with the active ingredient imazaquin listed in the California Department of Pesticide Regulation's active product database at the time of this publication.

Of the registered products in California, Monument has the most limited use as it is labeled only for application Bermudagrass and zoysiagrass. Certainty is registered for use on a number of warm season species including Bermudagrass, St. Augustinegrass, Kikuyugrass, seashore paspalum, zoysiagrass, buffalograss. With both herbicides, there may be some temporary discoloration of the turf.

Finally, the choice of surfactant can have a great effect on these herbicides' activities. While none recommend a specific (i.e. a trade name) surfactant on the label, they do recommend that a non-ionic surfactant be used and both Certainty and Monument labels state that using another type of surfactant may increase the likelihood of turf discoloration. In a paper by McDaniel et al. (1999), they found that methylated soybean oil (Scoil) and methylated sunflower oil (Sun-It II) improved yellow nutsedge control of halosulfuron over the non-ionic surfactants they tested (Action "99" and X-77). In a later paper, McDaniel et al. (2001) again compared various surfactants but this time they tested them on purple nutsedge. They again found that the addition of Scoil and Sun-It II to halosulfuron provided superior control to that of X-77 but also reported that Action "99", an organosilicone nonionic surfactant, provided excellent control when evaluated 8 weeks after treatment. They also found that there was only a slight improvement in control at the high rate (27g a.i./ha) versus the a lower rate (18g a.i./ha) when using methylated seed oil

(MSO). Additionally, when evaluated 2 years after treatment they found that both MSO treatments reduced the number of viable tubers by at least 97% over that in the untreated containers. Nevertheless, caution should be taken when using MSO adjuvants as they may increase turf injury at the expense of improved nutsedge control.

References

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McDaniel, G. L., W. E. Klingeman, W. T. Witte, and P. C. Flanagan. 2001. Choice of adjuvant with halosulfuron affects purple nutsedge control and nursery crop tolerance. *HortScience* 36:1085-1088.

Alternative Weed Control Methods in Davis California.

*Martin Guerena, Integrated Pest Management Specialist,
City of Davis, California 95616*

In the 1980s the City of Davis pesticide use was similar to other cities and agricultural operations. Much of the maintenance of park, greenbelts, landscaping, bike paths, streetscapes and open space consisted of scheduled applications of fertilizers and pesticides. The pesticides used were a mixture of Category I (Danger), II (Warning) and III (Caution) compounds.

In 1989 the city established an Integrated Pest Management (IPM) program where new methods of managing public landscapes were imposed. The program included:

- First IPM Policy developed by the Parks and Community Services department.
- First IPM specialist hired by the City of Davis.
- Issuing written pesticide recommendations.
- Consolidating and centralizing pesticide storage in upgraded facilities.
- Cooperating with UC Davis in experimenting, utilizing beneficial insects and other practices.
- Minimizing toxic pesticide use.
- Increasing staff training and education on IPM.

Since then the city has fine-tuned the program, resulting in an IPM and pesticide use policy for all city departments. Parks maintenance personnel as well as contractors are involved in pest control activities—mostly weed control throughout the parks, greenbelts, open space, and landscaped street medians. Public Works has three divisions involved in pest control activities. The Wastewater Treatment Plant (WWTP) personnel maintain the grounds around the plant, lagoons, overland flow (bioremediation process using perennial grasses), associated open space, and treatment wetlands. The Transportation Division maintains streets, roadsides, bike paths, and the old landfill/pistol range site. Some of its weed control is done by a contractor who treats problem roadsides and non-landscaped traffic medians with herbicides in the late fall. The Collections Division is in charge of maintaining stormwater flow within drainage channels, right-of-way access and the sanitary sewer system.

Current pest control response is dictated by the results of pest-population monitoring by field staff. Monitoring results are compared to action thresholds. Action thresholds include functional impairment, fire hazard, and aesthetic degradation. Functional impairments are infestations that impair the operation of a City facility, program, and/ or objective. Dense weed growth on City property, adjacent to private or public structures, creates a fire hazard. Weed infestations that occur in parks, bike or sidewalk paths, and road medians are considered hazardous and of poor aesthetic value.

Several alternative pest control methods are performed to reduce reliance on conventional pesticides and meet IPM objectives. Weed management techniques include:

- **Mechanical Removal:** Mowing, weed trimming, and tilling.
- **Hand Removal:** Seasonal employees and volunteers were utilized at the WWTP, Wetlands, and community garden sites to pull weeds from around landscaping and native plant restoration areas.

- **Flooding:** Water level management continued to be effective at controlling weeds and Canada goose nest density at the local stormwater detention basins and the Wetlands.
- **Rx Burning:** Prescribed fire was used at the Wetlands to stimulate native grasses and reduce weed seed production.
- **Grazing:** Livestock grazing is utilized at the Mace Ranch Community Park habitat area and Yolo County Grasslands burrowing owl preserve to meet burrowing owl habitat objectives (Goat and Sheep are used for)
- **Use of Native Vegetation in New Landscaping Projects:** The City continues to utilize native trees, shrubs, and grasses in municipal landscape projects.
- **Use of Wood Chip Mulch and Sheet Mulching Techniques:** Landscape contractors and park field staff continues to maintain mulch around landscaped areas. Some areas are sheet mulched with cardboard and weed cloth. Mulch helps to smother weeds and reduces the need for fertilization and water.
- **Green Herbicide:** Trials with these products continues to be tested and are showing promising results. Acetic acid (vinegar) along with soap based and herbal oil based herbicides have shown promise in burning down annual broadleaves. This is encouraging for areas that are sensitive to conventional pesticide use due to human and pet exposure or wildlife habitat. Work will continue in other areas as well, especially those that relate to water quality issues.
- **Weed Flaming:** Propane flammers are utilized when conditions of high humidity reduce the options for other forms of weed control.
- **Irrigation Management:** Central irrigation system provides water when and where it is needed.



The City of Davis IPM policy incorporates the Pesticide Hazard and Exposure Reduction (PHAER) zones program. This strategy gives structure to the implementation process of the IPM policy in parks and greenbelts by allowing supervisors the needed flexibility in their management options and informing the citizens about the general level of pesticide hazard on a site-by-site basis. These zones are designated as Green, Yellow and Special Circumstance Zones, with Green Zones providing the lowest potential for pesticide hazard and exposure. Each Zone has a corresponding pesticide list determined by existing toxicological data. For more information contact: <http://www.home.earthlink.net/~phaerzones/PHAER%20Color%20V.%201.2.pdf>

Public outreach and education is one of the major goals of the program. The City of Davis comprises 6,353 acres: 1,028 acres are parks, greenbelts, open space and streetscapes which fall under the IPM policy. The remaining 5,325 acres are managed by the citizens, who can choose how to manage their pest problems. Outreach efforts include:

- Development of City of Davis' IPM website. (<http://cityofdavis.org/pgs/ipm/index.cfm>)
- Development of IPM comic "The Exterminator." (<http://cityofdavis.org/pgs/ipm/extinator.cfm>)
- Notification of City herbicide application activities in parks and greenbelts via the Pesticide Hotline.
- Encouraging local pesticide vendors to participate in the Our Water Our World (OWOW) program. This program provides "Less Toxic" fact sheets and shelf tags set adjacent to pesticides sold in stores. In addition to the written materials, store employees are given training regarding what products are environmentally conscious alternatives for pest control. For more information on the OWOW program visit: <http://www.ourwaterourworld.org>

- Tips and alternatives to pesticide use provided in the annual Public Works sponsored "Utility Connections" and citywide "Focus" newsletters.
- Distribution of IPM educational literature at community events partnering with the Master Gardener Program and Tree Davis. Tables feature the OWOW program, bat and owl boxes, as well as pamphlets and handouts on our pest control programs, etc.
- Periodic presentations at local schools regarding stormwater quality including tips and alternatives to pesticide use.
- Presentations on least-toxic pest control at the community gardens, Central Park garden and the Mace Channel Herb Garden.
- City-sponsored annual Horticulture Pest Control Seminar, where continuing education units are available to city staff and other pest control professionals from the school district and surrounding communities.
- Pesticide safety training for City field staff.
- Attendance at IPM conferences by departmental staff involved with IPM coordination.
- Annual presentations to the city council and citizen advisory commissions.
- Use of positive posting at locations where alternatives to chemical pest control are in use.

Overall pesticide use by the City of Davis has declined in the past two years due in part to some of these alternative practices. Pest control strategies are dictated by weather, pest persistence and staff availability to implement management techniques. Persistence of infestations and budgetary constraints may hinder some alternative control methods. The IPM program continues to keep staff and management informed on pesticide regulation updates and safety. It will maintain field trials to demonstrate alternatives, their effectiveness, limitations and costs.

Herbicide and Pharmaceutical Relationships - Closer Than You Think*

*Stephen O. Duke, Research Leader and Plant Physiologist
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Few people would think that there are significant and interesting ties between pharmaceuticals and herbicides. Can such a relationship be any more than superficial? In this short review, the author would like to be clear that he is in no way suggesting that any commercial herbicide be used by the public for any pharmaceutical use.

Pharmaceuticals and herbicides are both designed to target particular biological functions. In some cases these targeted functions for pharmaceutical and herbicides have similar molecular target sites. This link was one reason that pharmaceutical companies until recently had pesticide divisions. Most or all compounds generated by one division of the company were evaluated for biological activity by the other division. Lead herbicides sometimes became pharmaceuticals and vice versa. Little of this type of information was published and must usually be surmised from patent literature.

The chemical parameters used by industry as rough estimates of the probability of a molecule being a good pharmaceutical or pesticide are similar. The 20 most common chemical side chains of pharmaceutical

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The chemical parameters used by industry as rough estimates of the probability of a molecule being a good pharmaceutical or pesticide are similar. The 20 most common chemical side chains of pharmaceutical

molecules are the same as those for herbicides and are found in about the same relative frequency. This remarkable overlap enhanced the synergy between the two discovery areas.

Occasionally, certain analogs of a particular chemical class have been found to be good pharmaceuticals, while others are used as herbicides. The molecular target sites can be the same and in other cases different. For example, a triketone pharmaceutical, NBTC, is structurally very similar to the triketone herbicide mesotrione. Both compounds target the enzyme *p*-hydroxyphenylpyruvate dioxygenase (HPPD), although the enzyme has very different functions in plants and humans. In other cases, such as the sulfonylureas, the chemical structures are similar, but the pharmaceutical and herbicide molecular targets are quite different.

One could consider pharmaceuticals used to kill disease organisms to be pesticides, in that they kill unwanted organisms. Examples of such pharmaceuticals include anti-malarials, antivirals, antibiotics, and medicinal fungicides. One of the first antibiotic classes was the sulfa drugs, including sulfanilamide. Sulfanilamide and the structurally related herbicide asulam both target an enzyme required for folic acid synthesis. Folic acid is required to sustain the target organisms in both cases.

Herbicides have significant activity against apicomplexan parasites such as those associated with malaria, toxoplasma, and leishmania. This class of protozoan human disease organisms contains an organelle, the apicoplast, that is considered to have originated from an ancestor with an endosymbiotic photosynthetic blue-green alga. Chloroplasts of plants are thought to have originated and evolved in higher plants in a similar manner. Since most herbicides target plastid processes, herbicides have been evaluated as pharmaceuticals for apicomplexan diseases. Herbicides are also of particular interest for such pharmaceutical leads because of the assumption that the molecular target site may not be found or, if present, be affected in humans. So far, no antimalarial drugs have resulted from studies of herbicides.

Aryloxyphenoxypropionate herbicides (e.g., diclofop) that inhibit acetyl-CoA carboxylase (ACCase) are effective against the disease *Toxoplasma gondii*. ACCase of this apicomplexan is localized in the plastid.

Dinitroaniline herbicides are perhaps the most studied herbicides for potential use as pharmaceuticals. Trifluralin and oryzalin are active against the malaria microbe *Plasmodium falciparum*, as is aminophos-methyl, and glyphosate. Both trifluralin and oryzalin are active against *T. gondii*. The selectivity factor between *T. gondii* and human cells is about 1000X, suggesting a high level of safety at

therapeutic doses. Several non-apicomplexan protozoan parasites are sensitive to trifluralin, including trypanosomal diseases such as caused by *Leishmania* spp. and *Trypanosoma cruzi*. Some researchers have concluded that antimitotic herbicides are very promising leads for treating infections with protozoal parasites.

The biochemical pathway leading to carotenoids in plants and other critical compounds in some bacterial and protozoan human pathogens is a target for both herbicides and pharmaceuticals. Triazines have been studied as antimalarials, and sulfonylureas and imidazolinones have been used to target the same enzyme in the tuberculosis bacterium that they target in weeds.

Herbicides also have pharmaceutical activity against several non-transmittable diseases. I mentioned earlier the pharmaceutical NTBC for treatment of a metabolic disorder and closely related triketone herbicides such as mesotrione. Both target HPPD. HPPD inhibitors have also been patented for treatment of depression and/or drug withdrawal symptoms.

The herbicide endothall and its natural product analogue cantharidin (the active component of Spanish fly) have been studied as anti-cancer drugs. Endothall has also been used in the study of diabetes-associated atherosclerosis. Research results suggest that some of the biological effects of the 'fop' type of grass herbicides (e.g., diclofop) and some antiinflammatory drugs in animals may be due to the inhibition of ACCase, the target site of fop herbicides.

PPO-inhibiting herbicides have been patented for use in photodynamic cancer therapy. Results were similar to those with a conventional photodynamic therapy dye. Bifenox, a PPO inhibiting herbicide, was found to be a potent inhibitor of hormone-sensitive lipase, with potential in the treatment of diabetes.

Some triazine compounds are directly effective against cancer due to their cytotoxicity to cancer cells. Non herbicidal triazines have been studied for inhibition of cholesterol synthesis and treatment of cardiovascular disease, ulcers, and Parkinson's disease. Certain sulfonylureas are used in the treatment of type II diabetes by stimulation of insulin production. Some sulfonylureas are also anti-cancer drugs. Certain imidazolinone compounds are effective against hypertension through their effects as angiotensin II receptor antagonists.

The use of a compound for one category (herbicide or pharmaceutical) would likely preclude it from use in the other for economic, public perception, and regulatory reasons. But, from a scientific standpoint there are clearly many parallels between pharmaceutical and herbicide chemistries and target sites, as well as approaches to discovery.

In 2006, Delaney et al. stated in the journal *Drug Discovery Today* (vol 11, pages 839-845) that "The potential for unanticipated side (pharmaceutical) activity is clearest with herbicides that also tend to have lead-like properties. The *Silent Spring* image of pesticides is an anachronism that serves to obscure the pharmaceutical potential lurking within agrochemical collections. An opportunity missed?"

*This is a synopsis of a full paper with literature citations published in the journal *Weed Science*. A copy can be obtained from Stephen.Duke@ars.usda.gov

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