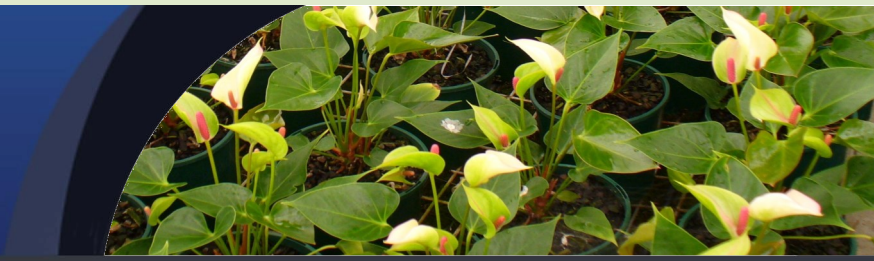


University of California UCNFA News



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Steaming and Other Management Practices for Pre-Plant Weed Control in Nurseries

by *Steven A. Fennimore*

Weed seed are the means by which annual weeds reproduce and disperse. The seed buried in the soil is referred to as the seedbank. Most seed in the soil seedbank were produced in the same field or greenhouse. Some of the seed in the seedbank moved there through the actions of wind, water, animals or the activities of man. Annual weeds usually regenerate from seed stored in the soil seedbank. The seedbank reflects the effectiveness of recent weed management practices in the field or greenhouse and will determine future weed infestations. This article will outline some of the factors that influence weed seedbanks and how to use steam to kill weed seeds.

Weed Seedbanks

Harper (1977) viewed the soil seedbank much as a bank account to which deposits and withdrawals can be made (fig. 1). Deposits occur as weed seed enter the seedbank from local production or dispersal. Withdrawals occur by germination, death and consumption by birds or insects. Only a small fraction of the seedbank is capable of germinating at any given time.

When we discuss greenhouses we are not talking about “weed seedbanks” as they exist in an agricultural field, but weed seed that are anywhere in the greenhouse — under the bench, in the gravel under pots and in the soil or potting mix. The ecosystem in a greenhouse is much less variable than in an open field, but many of the

Editor’s Note

This issue focuses on weeds and weed management for nursery and floricultural operations. Our featured articles were written by researchers who usually work in other agricultural crops, but the weed management information they present is all applicable to your nursery operations. Also included are weed-control related articles in “Regional Reports,” “Science to the Grower,” and “Get Cultured.”

We acknowledge the importance of disease and insect pest management issues to all nursery operators and, in our last issue, introduced a new column “Disease Focus.” With this issue, we begin another new column “Insect Hot Topics,” with regular contributions from Farm Advisor Jim Bethke.

◆ Steve Tjosvold and Julie Newman

PRE-PLANT WEED CONTROL:

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concepts that weed ecologists have developed to talk about weed seedbanks in the field hold true for greenhouses. Generally seedbanks are composed of a few weed species that make up 70% to 90% of the total. A second group of species comprises 10% to 20% of the seedbank, but is not adapted to the current production system. The final group of seed consists of newly introduced species and seed from previous crops (Wilson 1988).

Soil seedbanks are what we target when we use soil fumigants or steam to disinfest soil. We use steam to eradicate the seedbank in the soil mix. However, after steaming or fumigation, the potting mix can become reinfested with weed seed. Many weed species are well suited for dispersal into greenhouses by wind from uncontrolled weeds surrounding the greenhouse, or by human-aided dispersal such as muddy work boots or tires. If we utilize cultural practices that minimize introduction of weed seed into the greenhouse by using preventative practices such as controlling weeds in and around the greenhouse, we practice preventative weed management rather than reactive weed control. A grower who does not tolerate weed seed set in and around the greenhouse minimizes the risks of higher production costs due to higher handweeding costs. For example a grower with a relatively weed-free greenhouse may have lower production costs due to lower hand-weeding bills.

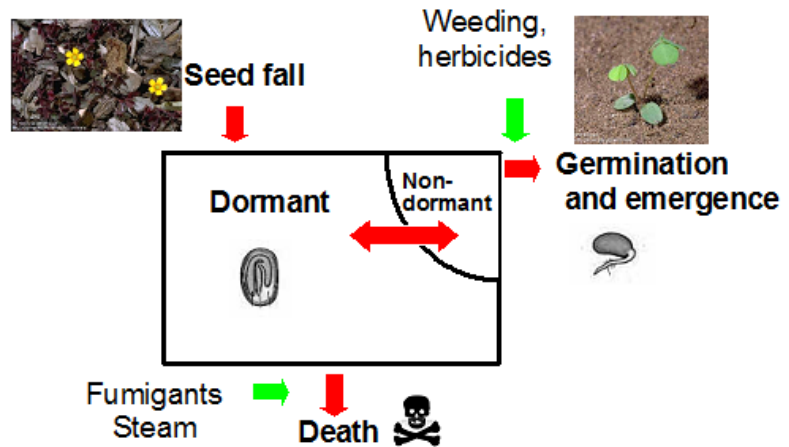


Fig. 1. Flow chart for the dynamics of weed seeds in the soil (Harper 1977).

Additions to the Seedbank

Seed can enter the seedbank by many means, though the largest sources are weeds producing seed within the field (Cavers 1983). Most seed in the seedbanks of farmland came from annual weeds growing on that same land (Hume and Archibold 1986). Just as in open agricultural fields, most weeds that infest greenhouses likely come from seed that were produced in the same greenhouse. Individual weeds can produce large numbers of seed when grown without competition (table 1). I do not have the data for greenhouse weeds, but the concepts are the same — if weeds are given the chance to set seed they will.

Weed seed can enter a field from external sources such as mud on equipment or shoes, contaminated crop seed, animals, wind, and manure. Many weed seeds have special attachments that allow them to be dispersed by wind, water or animals (fig. 2). Wind dispersal (fig. 2 a-d) allows a few seed to move great distances, however, most seed remain close to the mother plant. Wind-

blown seed such as common groundsel can easily blow into the greenhouse from surrounding fields. The introduction and dispersal of noxious weeds is the greatest threat from dispersed seed.

Seed Losses

Although seed of many weed species have the potential for long-term survival in the seedbank, most seed have a short life (Murdoch and Ellis 1992).

Table 1. Seed production and seed survival (Wilson 1988).

Weed species	No. of seed produced per plant (Stevens 1954, 1957)
Common lambsquarters	72,450
Common purslane	52,300
Common ragweed	3,380
Pennsylvania smartweed	19,300
Prickly lettuce	27,900
Redroot pigweed	117,400
Shepherd's-purse	38,500
Wild oat	250
Yellow foxtail	6,420

PRE-PLANT WEED CONTROL:

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Factors accounting for the loss of weed seed in the soil include germination, decay and predation. The relative importance of each factor varies with species and environmental conditions (Buhler et al. 1997). Fumigation and steam are also means of accelerating the loss of viable seeds in the seedbank (fig. 1).

In a weed management program we are primarily interested in those seed that germinate and seedlings that emerge. Germinated weed seed can result in new plants that may reduce crop yields and require control. Most weed seed in the soil seedbank are dormant with a small fraction of nondormant seed capable of germination at any one time. Several types of dormancy exist and most weeds possess one or more types.

From the moment a seed is shed its dormancy status is one of the key factors that determine when the seed will germinate. Seed dormancy is a means by which a plant species enhances its probability for successful reproduction in a changing environment. Dormancy is relieved by appropriate environmental conditions such as chilling, afterripening, light or scarification. Embryo dormancy (dormancy imposed by the embryo itself) is often reversible and represents a flexible system that allows a weed seed to adapt to its environment. The induction of secondary dormancy is the response of many weeds species to unfavorable environmental conditions. Secondary

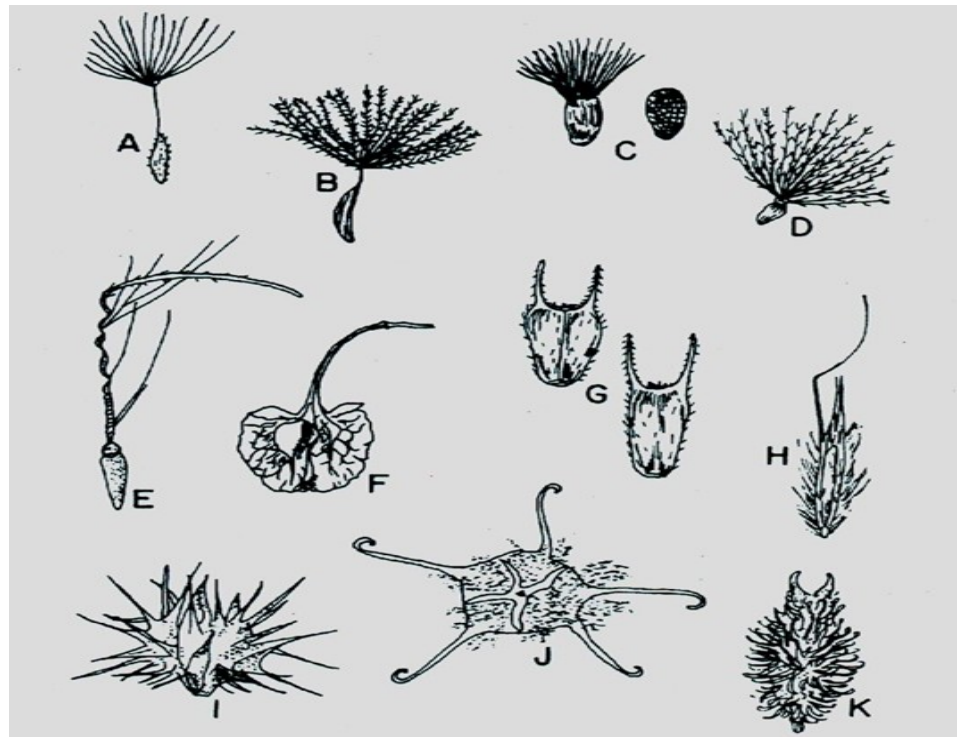


Fig. 2. Characteristics that aid dispersal of weed seed (Robbins et al. 1941).

dormancy and weather conditions are responsible for much of the variation in weed germination from year to year.

Weed Management

Weed seed densities can be greatly reduced by eliminating seed production for a few years; conversely, soils with low seed densities can be quickly reinfested with weed seed if plants are allowed to produce seed. Burnside et al. (1986) found that broadleaf and grass seed density declined 95% after five weed-free years. In the sixth year, herbicide use was discontinued and seedbank density rebounded to within 90% of the original density. Although seed production from most weed species can be reduced by management factors, seed production will likely remain high enough to maintain or increase the seedbank with low to moderate weed infestations. Hartz-

ler found that velvetleaf grown at densities of 2 and 4 plants per 100 square feet and allowed to set seed in year 0 resulted in as many as 1,800 plants per 100 square feet during years 1 to 4, even though no velvetleaf plants were allowed to set seed during that period (Hartzler 1990).

Weeds can survive in a greenhouse either by using seed dormancy or seed dispersal to allow some individuals to escape control and produce seed. In a weed species that has seed dormancy, weed seed germinate at a low rate over long periods of time, increasing the chance that a few individuals elude control and reproduce — thus replenishing the seedbank. With the dispersal strategy, some viable seeds find a safe place to reproduce. Management of weeds with seed dormancy requires reducing the seedbank population to low levels, such as with fumigants or steam steri-

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lization, and then maintaining strict weed control measures indefinitely to prevent reestablishment of the weed population. With weeds that have seed that disperse widely, the seed population in the greenhouse seedbank must be reduced and survivors controlled. At the same time the surrounding area must be kept as weed-free as possible to reduce the incidence of new weed seed dispersing into the greenhouse.

Preemergence herbicides kill germinating seeds and therefore act on only a small portion of the soil seedbank. Similarly, postemergence herbicides and tillage can only kill emerged weeds. Therefore, most of our weed control tools do not affect the dormant weed seeds in the soil seedbank. There are some exceptions: soil fumigants and steam can act on the entire seedbank including dormant and nondormant seed (fig. 1).

Steaming. Steam heating uses heat to kill weed seeds. In this process, conventionally used in greenhouse beds and in soilless media for container production, steam is mixed with air and injected into the media to heat it to 180°F for 30 minutes (Baker 1957). Length of time and temperature are critical if weed seeds are to be controlled. The pile or bed must be covered with a tarp so that the entire area, including the outer edges, reaches 180°F (Wilén and Elmore

2009; Baker 1957). The moisture of the media to be steam sterilized is also important — uniform heating is necessary if we are to kill weed seed throughout the media batch, and moist media conducts heat more readily than dry media. Further, weed seed are more easily killed when imbibed with moisture. This includes ungerminated weed seed that are swollen with high water content, which facilitates heat conduction from the seed surface to the embryo, and imbibed weed seed that germinate in the moist media.

There has been increased interest in the use of steam in field applications due to the phase out of methyl bromide. My research has shown that heating to 158°F for 20 minutes is effective in killing weed seeds in the field. As with steaming greenhouse beds and container media, proper moisture levels are important. Further, soil clods should be avoided as it is difficult for steam to penetrate the clods.

In trials conducted near Salinas and Watsonville in 2007 to 2009, we demonstrated that steaming in the field was comparable to fumigation treatments (methyl bromide/chloropicrin or chloropicrin/1,3-dichloropropene). However steaming with traditional pipe and hose methods of distribution is too expensive for commercial use. One strategy to reduce costs is to use an automatic applicator to increase steam application efficiency. Because there are no automatic

steam applicators that are commercially available for raised beds, which are utilized by California strawberry and cut flower growers, we developed an “alpha” prototype (Clayton Steam Generator) in September 2011. This prototype was successful in heating the top 24 inches of the soil profile in beds for 20 minutes above 158°F. Although less expensive than traditional steaming methods, the operating cost of the alpha prototype is still too high (\$5472 per acre). We plan to take what we have learned from the “alpha” prototype and design a more efficient commercial “beta” prototype in 2012. Our objective is to make field steaming as comparable in cost to methyl bromide fumigation as possible (\$3500 per acre in California).

Crop Rotation. Crop rotation is effective for weed management because changing patterns of disturbance diversifies selection pressure. This diversification prevents the proliferation of weed species well suited to the practices associated with a single crop. To better manage weeds one needs to change practices regularly. For example, if you are growing a container plant that requires two years to prepare for the market, this is plenty of time for weeds to become adapted. It is convenient to leave the long-cycle crop in the same greenhouse, but a better strategy is to move a short- and long-cycle crop around so that the production cycle in a greenhouse is varied. Short crops provide frequent

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tions in the greenhouse between crops that will kill weeds, and the empty greenhouse space between each crop cycle will allow the use of nonselective herbicides to kill weeds.

Conclusions

- Seedbanks are the source of most annual weed species.
- Most seedbanks are dominated by one or two species.
- Most weed seeds in the seedbank were produced in the same greenhouse.
- The greatest threat from weed seed dispersal is the introduction and spread of noxious weed species.
- Seed losses occur from germination, decay and predation.
- Dormancy is a key factor that determines when a seed will germinate and allows weeds to persist in the environment.
- A small number of weeds can produce many seeds and given the opportunity can restore the weed seedbank to high levels in a short time.
- Steam heating of soil or potting mix can kill dormant and nondormant weed seed.
- Steam for soil disinfestation in the field is as effective as fumigants — although it is more expensive than fumigants.
- Crop rotation minimizes the opportunities for one weed species to dominate a field or greenhouse.

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Evaluation of Herbicides for Weed Control Efficacy and Crop Safety in Field Production of Nursery Fruit and Nut Trees

by *Joi Abit and Brad Hanson*

Weed control is an ongoing management problem facing nursery growers of field-grown fruit and nut trees. Competition from weeds can decrease crop productivity and interfere with field and harvest operations. Control strategies currently rely on methyl bromide, pre-emergence herbicides, hand labor and multiple tillage operations. Soil fumigation alone often does not provide and maintain a consistently high level of weed control over the entire 1- to 3-year nursery tree-cropping cycle. Some weed species are not well controlled by fumigants due to their biology (impermeable seed coat, dormancy), ecology (airborne invasion, large seed bank), or response to environmental conditions (dry soil). This problem likely will be compounded by use of fumigants other than methyl bromide which is being phased out due to environmental concerns. Hand labor can effectively control weeds within rows of nursery stock but can result in mechanical crop damage, requires access to a large labor force, and is becoming more expensive and subject to greater worker safety regulations.

Therefore, weed control chemicals and techniques will likely become an important part of an integrated pest management strategy in nursery crops as methyl bromide is phased out and fuel and labor cost increase. Several herbicides are labeled for use in tree and vine nurseries but during the critical rootstock emergence and early-season growth period, residual herbicide choices are limited by number of registered materials and by crop safety concerns. Some herbicides can injure either perennial crop root growth (stunting or malformations) or above-ground growth (meristem damage, stem malformations, stunting, chlorosis, or death). Because nursery-grown tree and vines that are produced in the ground are dug up and sold, e.g., as bareroot stock, any root or stem damage is not acceptable to the buyers and these plants are not marketable. Several new herbicides have been registered in orchard

crops for control of a broad spectrum of weeds; however, these herbicides are not currently labeled for tree nursery production.

The goals of these field trials were to evaluate weed control efficacy of several pre-emergence and post-directed herbicide treatments, evaluate nursery root-stock safety of the herbicide treatments, and determine the effect of treatments on the health, vigor and productivity of the field-grown fruit and nut trees at harvest. Ultimately these experiments will provide growers and researchers information on weed control efficacy and crop safety with these herbicides.

Methodology

Field trials were conducted from 2009 to 2010 and 2010 to 2011 at commercial nurseries with Nemaguard peach (seeded) and Krymsk86 plum/peach hybrid (cuttings) rootstocks. Prior to planting, nursery blocks were fumigated with either methyl bromide or a dual application of Telone II. Each experiment was arranged in a randomized complete block design with four replications and individual herbicide plots were 3 feet by 25 feet containing a single

Table 1. Herbicide products used.

2009-2010		2010-2011	
Common name	Trade name	Common name	Trade name
carfentrazone	Shark	indaziflam	Alion
dithiopyr	Dimension	oryzalin	Surflan
flumioxazin	Chateau	rimsulfuron	Matrix
isoxaben	Gallery T&V	penoxsulam	Tangent
oryzalin	Surflan	oxyfluorfen	Goaltender
oxyfluorfen	Goaltender	penoxsulam + oxyfluorfen	Pindar GT
paraquat	Gramoxone Inteon	dithiopyr	Dimension
pendimethalin	Prowl H ₂ O	foramsulfuron	Option
rimsulfuron	Matrix		
thiazopyr	Visor		

EVALUATION OF HERBICIDES:

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Table 2. Effects of POST directed herbicide applications on Krymsk86 plum/peach cuttings in a tree nursery trial in 2009–2010.

Herbicide treatment ^a	Rate	Crop injury ^b	Grass control ^b	Broadleaf control ^b	Trunk diameter ^c
	lbs ai/acre		%		mm
untreated	-	0	0	0	15.3
isoxaben	1.0	5	63	28	17.1
isoxaben	1.3	1	82	71	15.8
dithiopyr	1.0	14	98	96	16.9
dithiopyr	2.0	6	97	97	17.4
pendimethalin	1.0	0	88	62	16.6
pendimethalin	2.0	0	94	84	16.0
oxyfluorfen	0.5	6	71	79	17.0
oxyfluorfen	1.0	28	97	91	18.0
thiazopyr	0.5	0	99	84	16.7
thiazopyr	1.0	8	99	97	16.7
pendimethalin + oxyfluorfen	2.0 + 0.5	0	97	89	16.4
pendimethalin + oxyfluorfen	2.0 + 1.0	15	99	98	18.3
rimsulfuron	0.016	5	99	92	15.4
LSD (0.05)		15	19	24	NS

^a Treatments applied:
March 5, 2009

^b Evaluated:
May 24, 2009

^c Measured:
October 30, 2009

tree row. Several pre-(PRE) and post-emergence (POST) applications of registered and unregistered herbicides were applied (table 1). PRE treatments were applied after seeding the rootstock but before emergence using a CO₂-pressurized backpack sprayer calibrated to deliver 25 to 50 gallons per acre in a 3-foot band. In the POST trials, herbicides were applied using a directed or shielded spray boom as appropriate to minimize crop exposure to the treatment.

Crop injury and weed control were monitored throughout the 14-month growing season. Prior to harvest, established trees were counted and trunk caliper was measured.

Results and Discussion

In 2009 to 2010, low weed populations were observed due to either effective fumigation or handweeding operations in all sites. Control of grasses was effective in all treatments except those treated with isoxaben or the low rate of oxyfluorfen, while broadleaf weed control was generally poor with low rates of pendimethalin and

oxyfluorfen and both rates of isoxaben (table 2). All treatments resulted in similar Krymsk86 rootstock trunk diameter and demonstrated excellent safety except the high rate of oxyfluorfen which caused significant visual injury. Overall, the most promising materials from a crop safety and weed control standpoint were thiazopyr, dithiopyr, rimsulfuron, and pendimethalin + oxyfluorfen.

From 2010 to 2011, all PRE treatments except oryzalin and low rates of indazaflam and penoxsulam provided good to excellent control of broadleaf weeds (table 3). Among the herbicide treatments, foramsulam at all rates caused the least injury to Nemaguard peach seedlings (fig. 1). One month after PRE applications, significant stunting and malformation were observed in plots treated with dithiopyr, penoxsulam + oxyfluorfen, and high rates of indaziflam and penoxsulam. Low seedling establishment was observed in plots treated with rimsulfuron and in plots treated with the highest rates of indaziflam and penoxsulam. Due to large variability in tree estab-

EVALUATION OF HERBICIDES:

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ishment throughout this field, no differences in final tree trunk measurements were observed.

The study showed that application of PRE and POST herbicides provided good to excellent weed control in tree nurseries and caused little injury to rootstocks planted as cuttings but safety was lower in seeded rootstock. However, considerable work on herbicide rates, timing and method of application are needed before these materials can be safely applied to newly planted rootstock on a more broad scale.

M. Joy Abit is Post Doctoral Scholar and Brad Hanson is Cooperative Extension Weed Specialist, Department of Plant Sciences, UC Davis.

Table 3. Effects of PRE herbicide applications on Nemaguard peach seedlings in a tree nursery trial in 2010–2011.

Herbicide treatment ^a	Rate	Broadleaf control ^b	Seedling injury ^b	Established trees ^c	Trunk diameter ^d
	lbs ai/A	no./plot	%	no./10 ft	mm
Untreated	-	13	-	17	15
indaziflam	0.032	10	9	15	15
indaziflam	0.065	3	48	13	17
indaziflam	0.085	2	43	14	15
indaziflam	0.17	1	71	4	20
oryzalin	2.0	11	13	18	16
rimsulfuron	0.016	5	53	7	17
penoxsulam	0.015	9	49	12	15
penoxsulam	0.03	3	48	5	16
penoxsulam	0.06	4	74	1	16
oxyfluorfen	0.25	4	20	16	17
penoxsulam + oxyfluorfen	0.03 + 0.25	4	53	10	14
dithiopyr	2.20	3	55	14	14
foramsulfuron	0.022	4	0	18	14
foramsulfuron	0.044	2	0	19	14
Foramsulfuron	0.088	1	3	18	15
LSD (0.05)		4	24	5	NS

^a Treatments applied: January 8, 2011

^b Evaluated: April 8, 2011

^c Plot size: 3 feet by 25 feet

^d Measured: October 18, 2011



Fig 1. Seedling establishment and weed control in a plot treated with (A) indaziflam at 0.032 pounds active ingredient per acre (lb. a.i./acre) for the lowest rate and (B) foramsulfuron at 0.044 lb. a.i./acre two months after treatment.

Machine-Guided Cultivation to Control Weeds in Field-Grown Cut Flowers

by Richard Smith, Steve Fennimore and Laura Tourte

Growers strive to improve crop production and harvest efficiency as well as crop yield and quality. Barriers to achieving these goals include the availability of registered herbicides and the accessibility and cost of labor for weed control. The accessibility and cost of labor is greatly affected by State or Federal immigration policy and the economy; the availability of registered herbicides is affected by the chemical registrants' expected sales revenues (which may be low for specialty crops and may not offset registration costs) and projected liability to the registrant if the crop is injured by the herbicides, as well as environmental issues. Immigration policy, the economy and pesticide registration decisions are factors that are difficult or impossible for growers to control or influence. Fortunately, labor issues and the availability of herbicides are less of a hindrance to weed control when growers adopt new technologies that can increase labor-use efficiency.

The application of computer technology to row crop production has been an active area of research and development, and has made significant progress with respect to weed control. Mechanical weed control machines are becoming available that utilize cameras to detect crop plants on a bed. The camera then sends an image of the bed to a computer, which analyzes the data and records the location of crop plants on each bed. Present technology relies on size differences between the crop and the weeds. Computer-assisted mechanical weed control machines are therefore more effective when used on transplanted crops than direct-seeded because transplanted crops are initially larger than the weeds that emerge after planting. Once crop plants are recognized, the machines use a variety of techniques to remove the weeds from the seed line: swinging, spinning, or opening and closing blades,

or other techniques such as flaming and the use of timed chemical sprays. All of these mechanisms are designed to avoid crop plants and remove weeds between the crop plants in the seed line. Currently, there are two notable computer-assisted mechanical weed control machines either on the market or close to being commercialized for row crop production. In the following two examples, we describe these machines and our efforts to evaluate efficacy or provide a demonstration opportunity for growers.

Example 1

In 2009 and 2010 we evaluated a commercially available unit, the Tillet Weeder, which is fabricated in England (Garford Corp, <http://garford.com/>). This computer-assisted mechanical weed machine uses a spinning blade with a notched cut-out on one side. The blade travels in the seed line removing weeds, but when it encounters a crop plant, it spins around it by placing the plant in the notch (fig. 1). We evaluated the efficacy of this machine for weed control, crop safety and impact on hand weeding in trials on leafy green vegetables and tomatoes as compared to



Fig. 1. The Tillet Weeder is a commercially available mechanical weed control machine that uses computer technology and a spinning blade to remove weeds. Note the disc-shaped cultivation blade with a notched cut-out to allow the blade to spin around transplanted cabbage.

MACHINE-GUIDED CULTIVATION:

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Table 1. Effect of the Tillet Weeder on weed control, hand-weeding time and crop yield in transplanted radicchio in 2009. Weed counts pre- and post- cultivation were made in the seed line only — the standard cultivation does not remove weeds in the seed line.

Treatment	Pre-cultivation weed counts Aug 5	Post-cultivation weed counts Aug 7	Percent weed control	Hand weeding Aug 7	Hand weeding Aug 14	Total weeding time	Stand count Aug 7	Stand count Oct 7	Yield mean head Oct 7	Yield total weight Oct 7
	Total Weeds	Total Weeds	%	hr/A	hr/A	hr/A	Plant/A	Plant/A	lbs/head	tons/A
Standard	40.3	NA	NA	8.4	6.9	15.3	31,245	29,628	0.84	12.4
Tillet	47.6	16.9	64	5.9	5.7	11.6	30,721	29,119	0.88	12.7
Pr>F treat	0.242	NA	NA	<0.001	0.005	<0.001	0.318	0.278	0.448	0.657
Pr>F block	0.06	NA	NA	0.616	0.061	0.156	0.221	0.073	0.251	0.447
LSD 0.05	NS	NA	NA	0.7	0.8	1.3	NS	NS	NS	NS

standard cultivation with knives and sweeps, which do not remove weeds from the band that is left around the seed line. In one trial with transplanted radicchio, the Tillet removed 64% of the weeds in the seed line and reduced subsequent hand-weeding time by 3.7 hours per acre (table 1). The mechanical action of the Tillet in this trial did not reduce the stand or the yield of radicchio. In contrast, in direct-seeded lettuce, although the Tillet Weeder reduced weed densities by 69% and hand-thinning times by 24% compared to the standard cultivator, the crop yield in the Tillet cultivator treatments were 11.7% less than the standard cultivator treatments. The Tillet cultivator worked much better in transplanted lettuce, where hand-weeding times were only 10% less than in the standard cultivator treatments, but lettuce yields were not affected by cultivator type (data for lettuce are not shown).

In most of our trials for direct-seeded and transplanted lettuce and tomatoes, the Tillet was able to reduce thinning and hand-weeding costs per acre between 15 and 30% over standard cultivation. However, as previously mentioned, the Tillet also reduced yields in a

number of trials, resulting in lower net returns to growers. Some fine-tuning of this technology would be helpful in minimizing yield reductions, which in turn may improve net returns to growers. Comparable savings in thinning and hand-weeding costs observed in these trials may be achieved in field-grown flowers if they are planted in bed configurations that are similar to the plant spacing used in the evaluated vegetable crops (double rows on 40-inch beds with 10 to 12 inches between plants in the seed line). Attention to total yield and net returns must be factored into any decision for use of this technology.

Example 2

In May, 2011 we held a field day demonstrating a second type of technology that is soon to be commercially available which is a prototype of an automated weeder/thinner developed by the University of Arizona and Mule Deer Automation (New Mexico). Instead of using a blade to remove weeds as in the Tillet cultivator example, this machine sprays a chemical in a band application to remove unwanted plants. Various chemicals can be used in this machine such as acid or salt-based fertilizers (e.g., phosphoric acid or ammonium nitrate [see fig. 2]) or herbicides such as para-

MACHINE-GUIDED CULTIVATION:

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Fig. 2. Lettuce thinned and weeded with the University of Arizona/Mule Deer Automation prototype. The unwanted plants were treated with ammonium nitrate (AN20) fertilizer (in dark gray rectangular areas) and will die in a matter of days.



quat or pelargonic acid (Scythe); organic herbicides can also be used. A number of growers at the field day expressed interest in testing and buying this machine when it becomes commercially available.

Conclusion

In general, computer-assisted mechanical weed control machines will continue to develop and improve in the coming years. This technology has been shown to be useful to vegetable crops and could be used in field-grown cut flower production as well because many of the production practices (e.g., bed configuration and spacing, plant density per acre) are similar. Computer-assisted mechanical weed control machines can provide an alternative option for weed control that reduces the need and cost for labor, as well as help growers cope with the limited availability and loss of effective herbicides due to regulation constraints and issues.

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Organic Herbicides — Do They Work?

by *W. Thomas Lanini*

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). These organic products can be effective in controlling weeds, but there are limitations. In this article, I will summarize the information that we have learned from trials on the efficacy of these herbicides and economic considerations for commercial use. Although these products are of interest for use in sustainable production systems, organic growers should always check with their organic certifier in advance of the intended application as such use of the alternative herbicide may not be cleared by all agencies.

Weed Control and Selectivity

Organic herbicides kill weeds that have emerged but have no residual activity on those emerging subsequently. Further, while these herbicides can burn back the tops of perennial weeds, perennial weeds recover quickly. These organic products are effective in controlling weeds when the weeds are small but are less effective on older plants. In a recent study, we found that weeds in the cotyledon or first true leaf stage were much easier to control than

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older weeds (tables 1 and 2). The control ranged from better than 60% to 100% if these weeds received high volumes of these materials when they were just 12 days old. When broadleaf weeds were 26 days old, even high volumes of these materials gave at best less than 40% control.

We also found that broadleaf weeds were easier to control than grassy weeds — the best control on even young, 12-day-old grass weeds was only around 40 percent. This may possibly be 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).

All of these materials are contact-type herbicides and will damage any green vegetation they contact. However, they are safe as directed sprays against woody stems and trunks. For turfgrass sod production, organic herbicides could be applied when preparing the seedbed and then again with the first flush of weeds. Grass seed could be planted a bit deeper (1/4 to 1/2 inch deeper) to delay turfgrass emergence, so that the organic herbicide could control the broadleaf flush without adversely affecting the turfgrass.

Application

Organic herbicides kill only contacted tissue so good spray coverage is essential. For example, a large, flat nozzle (e.g., 8006) would be preferable in turfgrass production. In tests comparing various spray volumes and product concentrations, high concentrations at low spray volumes (20% concentration in 35 gal-

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

lons per acre) were less effective than lower concentrations at high spray volumes (10% concentration in 70 gallons per acre). Because organic herbicides lack residual activity, repeat applications will be needed to control new flushes of weeds.

In addition to high volume, we found that adding an organically acceptable adjuvant 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 well. Although the recommended rate of these adjuvants is 0.25 % volume per volume (v/v), 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.

Environmental Conditions

Optimum environmental conditions are required when applying these organic products for good control of weeds. Temperature and sunlight

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Table 3. Plantain and annual bluegrass control (%) at 4 and 9 days after treatment (DAT). Applications made on January 6, 2011 during cool conditions (40°F). All treatments included Eco Silwet 0.5% v/v.

Treatment	Plantain control		Annual bluegrass control	
	4 DAT	9DAT	4DAT	9DAT
Biolink 3% v/v	52	48	15	35
Biolink 6% v/v	63	80	40	63
MOI-005 5% v/v	2	13	0	2
MOI-005 10% v/v	10	20	0	3
GreenMatch 7.5% v/v	12	13	3	5
GreenMatch 15% v/v	23	38	10	52
Matran 7.5% v/v	5	8	2	3
Matran 15% v/v	20	17	5	30
Weed Zap 7.5% v/v	18	28	10	42
Weed Zap 15% v/v	52	78	23	78
Weed Pharm 100%	82	90	53	87

Table 4. Weed control with WeedZap (10% v/v) in relation to adjuvant, spray volume and light levels. Plants grown in the greenhouse in either open conditions or under shade cloth, which reduced light by 70%.

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

have both been suggested as factors affecting organic herbicide efficacy. In several field studies, we observed that organic herbicides work better when temperatures are above 75° F, so applications in the winter may be less effective than summer applications. However, recent experiments have assessed winter weed control during cool conditions (table 3), and in spite of cold temperatures, plan-

tain control was very good with Weed Pharm, or the high rates of Weed Zap or Biolink. Annual bluegrass control was also good with these same materials during cool conditions.

Sunlight has also been suggested as an important factor, and anecdotal reports indicate that control is better in full sunlight. However, in a greenhouse test using shade cloth to

block 70% of the light, we found that weed control with WeedZap improved in shaded conditions (table 4). The greenhouse temperature was around 80° F, so it may be that sunlight is less of a factor under warm temperatures.

Economic Considerations

Organic herbicides all work if you have enough volume and concentration to directly contact the weeds. However, these herbicides are expensive and may not be affordable for commercial crop production at this time. Cost in 2010 was about \$400 to \$600 an acre for broadcast application, which may be considerably more expensive than hand weeding. Moreover, because these materials lack residual activity, repeat applications will be needed to control perennial weeds or new flushes of weed seedlings. We see these herbicides eventually being used commercially with camera-based precision applicators that “see” weeds and deliver herbicides only to the weeds, not to the crop or bare ground.

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SCIENCE TO THE GROWER: How much would you pay for a plant out of place?

by Richard Evans

My worst performance in all my years of schooling, except perhaps for the time I played Ilderim in a kindergarten production of Ben-Hur, was in Weed Science. Maybe that's why I went astray after I was asked to write an article summarizing recent weed research. I began writing about a study at the University of Utah, where researchers compared the carbon and nitrogen isotope ratios of leaves and flowers of marijuana to see if they could distinguish between indoor- and outdoor-grown crops, and to see if they could identify the geographic location of production (West et al. 2009). It turns out that's not what I was supposed to write about at all. By the way, the Utah group did find that the isotope ratio of outdoor-grown plants differed from that of indoor-grown plants, but they were less successful at figuring out where the plants were grown. Perhaps the Emerald Triangle growers can keep their business secrets for a while, after all.

A weed is a plant out of place. That's almost all I learned in my Weed Science class. So let's examine some plants out of place — ornamental plants that have become invasive weeds. An article about horticulture as a vector for invasive species stated that over half of the invasive plant species in North America were introduced as ornamentals (Reichard and White 2001). As ornamental crop production increases its share of the total value of agriculture, the potential for introduction of invasive species grows. The number of cultivars in North America has increased nearly four-fold in the last 20 years, and commercial cultivars now greatly outnumber native plant species. The authors of a review of the horticulture industry's response to invasive species introductions noted that many of the desired characteristics in horticultural plants — large flowers, attractive seeds and fruits, long or repeat blooming seasons, low maintenance requirements and adaptability to diverse cli-

mates, stress tolerance, and novelty—are also characteristics that can promote invasiveness (Drew et al. 2010). Much of the review describes how characteristics of the horticultural crop distribution chain may contribute to invasive plant introduction. In addition, the authors discuss the relative ineffectiveness of legislation and regulatory efforts to stop or slow the spread of invasive species. They conclude that the industry needs to fund more breeding and research trials to combat invasive plant introductions, and enlist consumers in the fight by educating them and offering them alternatives to invasive species.

Prevention is the key to control of invasive plants. It is much cheaper to keep them out than it is to eradicate or control them. Legislated control of invasive plant introductions hasn't been effective, so people have turned to the idea of industry self-regulation. To this end, a large group of horticulturists and scientists met in 2001 and developed the St. Louis Declaration and Voluntary Codes of Conduct (<http://www.centerforplantconservation.org/invasives/CodesN.asp>). The Codes of Conduct for Nursery Professionals focused on assessing invasive potential before introduction, identifying invasive species within the nursery's region and promoting alternatives to invasive plants. But how effective has self-regulation been? A group of graduate students at UC Davis conducted a survey of Northern California nurseries (growers, wholesalers and retailers) to find out if they followed the Codes of Conduct (Burt et al. 2007). Only 7% of respondents had heard of the Codes of Conduct. Most had engaged in at least two preventive measures, but few had participated in a majority of the measures. They identified lack of information, limited personnel, and the cost and labor required as the major obstacles to adopting the preventive measures.

Self-regulation might be more attractive if it were profitable. One important study found that 98% of consumers would not buy plants labeled as invasive (Reichard and White 2001). A University of Minnesota group recently

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explored such consumer preferences by testing whether labeling plants as invasive decreases consumer demand, and whether labeling native plants decreases demand for invasive species (Yu et al. 2010). I have to warn you that the study was conducted in April, by which time Minnesotans can't remember what living plants look like. Nevertheless, the researchers found that consumers would pay an extra \$0.35 for plants labeled native and non-invasive. Their willingness to pay for invasive species decreased by up to \$1.66 when the plants were labeled as such. The authors conclude that this labeling could be a useful strategy for combatting the introduction of invasive species.

These studies offer some hope for better control of invasive plant introductions. Information and outreach are keys to success. Growers can be pointed to the Codes of Conduct, but they still need sufficient information about species invasiveness. Consumers may respond to labeling about invasiveness, but they need to know what alternative species are non-invasive. It looks like I'd better get back to studying weed science.

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GET CULTURED: Non-chemical prevention of weeds in containers

by Don Merhaut

Weeds in containers are not only aesthetically unappealing, weeds also compete with plants for water and nutrients, and may attract pests and diseases that would otherwise not be a problem. Pesticides can be used, but prevention is the first key to weed management. Weed growth in containers is encouraged by three environmental factors: (1) light, (2) moisture and (3) seed/spore source. Cultural management should revolve around these factors.

Light

Most weeds of containerized plants require light for seed/spore germination. By minimizing light on the surface of containers, weed germination is greatly reduced. Light levels on container surfaces are usually highest directly after planting or shifting to larger containers, when the canopy of plant liners, plugs or transplants are small relative to the container size. As crops become established and the canopy develops, the plants will often shade the media surface sufficiently to reduce the likelihood of weed seed germination.

If the plant canopy is not dense enough to shade the surface of the container medium, then one should consider a weed barrier. A mulch of bark, straw, or any product that allows water to flow through the mulch to the medium can be used as a light barrier. Consider materials that are available locally, since these products are usually less expensive — for example, in pecan-growing regions, pecan shells are sometimes used by nursery growers, and rice hulls are readily available for use in California nurseries. However, be careful that organic products do not carry toxic biochemicals (allelopathic chemicals) or high concentrations of salts that may cause crop injury. Likewise, if inorganic products are used, be sure that toxic residues such as heavy metals cannot leach from the products. Fabric discs are also available that are pre-cut to fit various sizes of containers. These discs may be expensive and

may blow out of containers if not secured into place. However, these fabrics can be removed and reused when the plants are sold.

Moisture

The drier the surface of the container media, the less likely weed seeds will have an opportunity to germinate. Selection of appropriate media and mulches and use of good irrigation management strategies are practices that can reduce container surface moisture and weed germination.

Media. When preparing or selecting media, be sure the substrate has sufficient water-holding capacity so that irrigation frequency can be reduced. Even plants such as azaleas, camellias and daphnes, which require a consistent moisture supply, can be grown without infestation of moss lichens by providing a moisture-retentive, but well-drained medium.

Mulch. In addition to serving as a light barrier, coarse mulches, such as pine bark, dry out rapidly and can therefore be used to reduce germination of most weed seeds.

Irrigation. Irrigation system design and maintenance as well as irrigation practices all affect weed germination. Irrigation systems such as drip and flood can be used to moisten the container medium without wetting the surface of the medium. However, subsurface irrigation systems with recirculating water must be carefully managed to minimize the spread of pathogens in the water. Salt accumulation in containers may also be a problem in subsurface irrigation systems.

Irrigation systems in the production beds should be properly maintained to ensure that the irrigation nozzles are not leaking. When leaking irrigation heads drip onto containers, weed seeds will likely germinate, and weed infestations of production beds will begin in these areas. Weed growth will be encouraged in and around any wet areas where there are irrigation leaks.

Proper irrigation practices will also minimize the duration of soil surfaces staying moist. Infrequent, but deep irriga-

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tion should be conducted, if possible. Since most weeds develop with newly planted crops, drip irrigation to the rootball is favored. This will not only minimize weed seed germination, but also conserve water and nutrients by supplying water only to the root ball and not the entire container, where roots have not yet developed. As plants grow larger, they obviously require more frequent irrigation, but at this time canopies are usually large enough to block light on the soil surface.

Seed/Spore Sources

Eliminating weed seed sources will reduce the likelihood of weed infestations in containers.

Adjacent fields. The areas in proximity to nursery beds should be free of vegetation. If lawns and fields are maintained upwind of production beds, be sure that they are mowed or maintained so that weed seed production is minimized.

Infrastructure. Gravel, pavement, or fabrics used under containers in production beds will minimize weed growth outside of containers, especially if overhead irrigation is used (figs. 1 and 2).

Greenhouses and shadehouses. Lichens and mosses tend to be the problem in greenhouses and shadehouses. Make sure that all containers and media are sterilized. Also, fungus gnats may spread spores, so controlling these insects will minimize lichen and moss infestations.

Cleanliness of media and mulches. All media and mulches that are used in production should be weed-seed free. Some mulches may harbor weed seeds — for example, rice hulls may contain viable rice seeds that may germinate — so be sure that these products are sanitized to kill any seeds.

Summary

If proper sanitation and cultural practices are followed, weed infestations into production beds should be eliminated or at least minimized to a controllable



Fig. 1. A thick coat of gravel on beds prevents weed growth. Prior to gravel placement, the soil should be compacted so that the gravel does not “sink” into the soil. The placement of fabric or plastic underneath the gravel works even better than compaction.



Fig. 2. Weed-barrier fabric placed on production beds eliminates weed seed germination and growth around containers. It also reduces the incidence of diseases caused by pathogens that are splashed onto foliage from soil surfaces.

level. Weed control is an ideal IPM practice since absence of weeds will also reduce the incidence of pests and pathogens.

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DISEASE FOCUS: Weeds as a source of plant virus infections and bacterial leaf spot of poinsettia

by Deborah M. Mathews

Weeds are often an overlooked source of virus diseases of plants. They also harbor many insect species that help transmit viruses to field and nursery crops. Tobacco mosaic virus (TMV), cucumber mosaic virus (CMV), impatiens necrotic spot virus (INSV), tomato spotted wilt virus (TSWV) and members of the Potyvirus group are among the viruses found in weeds that are easily transmitted to many other plant species. TMV has no known feeding insect vector but vectors such as people, birds and insects that touch infected plant parts can easily mechanically transmit virus particles to new plants; CMV is aphid transmitted; INSV and TSWV are both thrips transmitted; and Potyviruses are aphid transmitted. Weeds such as little mallow (also called “cheeseweed” [*Malva parviflora*]), lambsquarters (*Chenopodium* spp.) and jimson weed (*Datura stramonium*) are commonly found reservoirs of viruses. Obvious symptoms of disease may not be visible on these weed hosts, which could lead you to believe that they are not infected.

Another common plant found in nature (especially in Southern California) that essentially grows as a weed and is listed as an invasive plant, is *Nicotiana glauca* or tree tobacco. It often grows along creek beds or culverts, on hillsides, along roadsides and areas where soil is disturbed and can be identified by its smooth blue-green leaves and bright yellow tube-shaped flowers (fig.1 A, B). I studied this plant during my Ph.D. research by placing 240 healthy seedlings out at the field station at UC Riverside and testing for viruses every 6 months for 2 years. By the end of the trial all surviving trees contained at least 1 to 5 different viruses, primarily TMV, CMV and Potyviruses. This shows how easily these viruses can get around in nature and that tree tobacco can act as an important perennial reservoir. Prevention and eradication of weed species within and surrounding greenhouses as well as near field crops are the best management methods.

Bacterial Leaf Spot of Poinsettia

I'll try to give a little equal time to something other than viruses this month: One disease that seems to have become more prevalent the last couple of years across the United States is bacterial leaf spot of poinsettia caused by *Xanthomonas axonopodis* pv. *poinsettiiicola*. Spots start out on the undersides of leaves and are grayish brown in color. As the spots enlarge, they become visible on the upper side of the leaf and will be tan to brown. Eventually they become necrotic (dead spots) surrounded by a water-soaked area of lighter green or yellow (fig. 2). As many spots merge together, lesions will become angular in shape. Symptoms are similar to the leaf spots caused by the fungi *Sphaceloma poinsettiae* (scab=spot anthracnose) and *Alternaria euphorbiicola*, so a proper diagnosis should be obtained prior to control applications.

Prevention is the best management strategy, primarily by avoiding overhead watering which allows splashing of bacteria to adjacent plants. Once present, affected plants

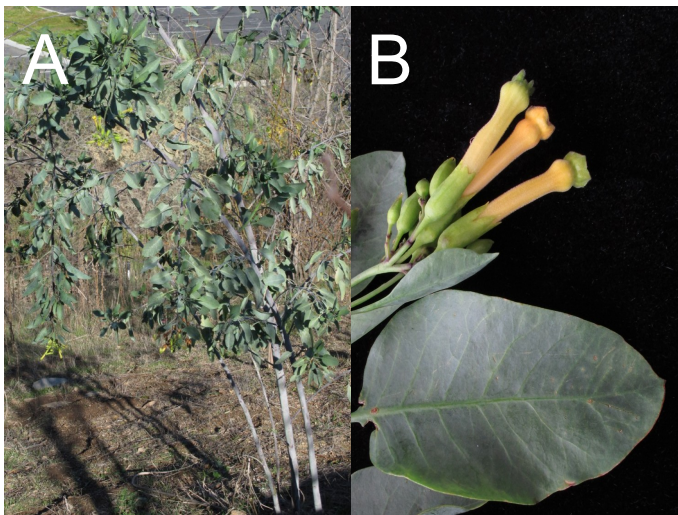


Fig. 1. (A) Growth habit of tree tobacco (*Nicotiana glauca*). (B) Close up leaves and flowers. Photos by Deborah Mathews.

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Figure 2. Leaf spots on a poinsettia plant caused by the bacterium *Xanthomonas axonopodis* pv. *poinsettiicola*. Photo courtesy of Ann Chase.

should be discarded and benches cleaned to remove sources of dried bacteria. Control can be difficult, but sprays of copper compounds have shown some level of success, mainly as a preventative, and some new research showed promising results with titanium dioxide sprays (Norman and Chen 2011).

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INSECT HOT TOPICS: Two new pests from Florida

by James A. Bethke

This new column focuses on insects that pose a threat to the ornamental plant production industry and have good potential for invasion and establishment in California.

For years it has reigned true that when a significant insect pest finds its way to Florida, it eventually finds its way to California. There are exceptions like the melon thrips (*Thrips palmi*) and the chilli thrips (*Scirtothrips dorsalis*), which I fully expected to be here by now. However, that's no reason to ignore what may be on the horizon. There are two new whiteflies in Florida that are driving my research colleagues crazy, and you should be on the lookout for them for sure. You should be isolating and closely checking incoming plants from Florida in search of these whitefly pests. We certainly don't need additional whitefly concerns in the California ornamental plant industry.

Fig Whitefly

The fig whitefly (*Singhiella simplex*), which is also sometimes called the "ficus whitefly," (fig. 1) is a new U.S. continental record. The insect was first found in 2007 in Homestead, Florida (Miami-Dade County) on ficus trees and hedges, and it spread to both Broward and Palm Beach counties by 2008. Populations grew to incredible levels during the next couple of years.

One of the most obvious symptoms of fig whitefly attack is the presence of defoliated ficus trees. Ficus, as you are aware, are very densely packed trees and hedges, and can be used as a barrier between buildings and yards. However, when attacked by this insect, the plants look completely bare. Further, this whitefly is reportedly causing severe branch dieback and even killing ficus trees and hedges.

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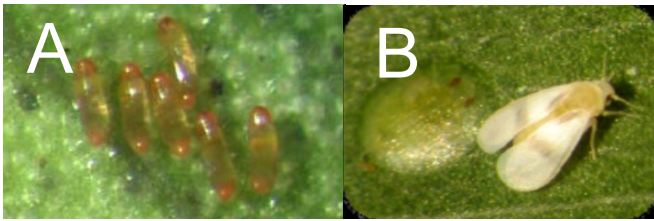


Fig. 1. The fig whitefly is a new invasive pest in Florida that defoliates ficus trees. (A) eggs and (B) nymph and adults. Photo courtesy of Katharine Mannion.

The most common fig tree attacked is the weeping fig (*Ficus benjamina*) but Katharine Mannion (University of Florida) reports that it can also be found on lofty fig (also called “false banyan tree” [*F. altissima*]), banyan tree (*F. bengalensis*), Cuban laurel (*F. microcarpa*), strangler fig (*F. aurea*), fiddle-leaf fig (*F. lyrata*) and banana-leaf fig (*F. maclandii* [= *F. binnendijkii*]).

Defoliation usually occurs after the whiteflies have been there for several generations, so Dr. Mannion suggests that you monitor your ficus plants for early signs of an infestation because it will be easier to manage the pest before it builds to high populations. Also, if infested trees or hedges are trimmed, bag the clippings to reduce the chance of spread.

Here are a few websites that have pictures, descriptions, and a distribution map of the pest:

<http://www.freshfromflorida.com/pi/pest-alerts/singhiella-simplex.html>

http://www.freshfromflorida.com/pi/enpp/ento/fig_whitefly.html

<http://mrec.ifas.ufl.edu/lso/IAWG/FIG/The%20Fig%20Whitefly.htm>

http://www.naplesnews.com/news/2007/nov/23/home_fig_whitefly_sucking_life_florida_weeping_fig/

Rugose Spiraling Whitefly

The rugose spiraling whitefly (*Aleurodicus rugioperculatus*) is another new whitefly in Florida (fig. 2), first found in Dade County in 2009. This insect has a larger

host range than the fig whitefly. Hosts include gumbo limbo (*Bursera simaruba*), *Calophyllum* species, black olive (*Bucida buceras*), copperleaf (*Acalypha wilkesiana*), broadleaf arrowhead (*Sagittaria latifolia*), cocoplum (*Chrysobalanus icaco*), Brazilian pepper (*Schinus terebinthifolius*), wax myrtle (*Myrica cerifera*), live oak (*Quercus virginiana*), mango (*Mangifera indica*), areca palm (*Dypsis lutescens*), *Veitchia* species and coconut (*Cocos nucifera*).

The most noticeable symptoms of an infestation of this whitefly are the abundance of the white, waxy material covering the leaves and excessive sooty mold. This whitefly is much larger than typical whiteflies and somewhat resembles the giant whitefly (*Aleurodicus dugesii*). They make similar waxy patterns on the undersides of the leaves as well.

It is likely that establishment of these whiteflies will occur in the landscape first since most landscape plants are typically not treated for pests, whereas they are in the ornamental plant production industry. However, when populations build, they will most certainly cause havoc in the plant production industry as well. To learn more about the rugose spiraling whitefly, see Dr. Mannion’s web site:

<http://trec.ifas.ufl.edu/mannion/>.

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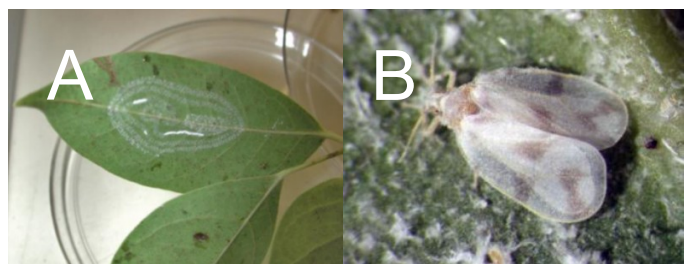


Fig. 2. The Rugose Spiraling Whitefly is a new invasive pest in Florida with a wide host range. (A) eggs, (B) adult. Photo courtesy of Katharine Mannion.

UC Cooperative Extension Santa Cruz/Monterey Counties

REGIONAL REPORT: Herbicides for vegetation control on roadsides

by Steve Tjosvold

Nurseries and farms may benefit from research that we recently completed for the County of Santa Cruz Public Works where we evaluated the effectiveness of several herbicides for roadside vegetation control. We tested organic and conventional herbicides as alternatives to the traditionally-used glyphosate (Roundup) herbicide. Several of these alternative herbicides could be considered for use on nursery and farm roadsides or other areas where low impact vegetation control could be useful.

The County of Santa Cruz maintains approximately 340 miles of road that are actively managed for weed control. Traditionally, vegetation management has consisted of an initial mowing, where necessary to reduce biomass, followed by a carefully timed glyphosate application as it regrows. This often eliminated the need for additional vegetation control measures for the remainder of the year. Glyphosate, however, has received considerable attention by groups and individuals questioning its safety in the environment, and the Santa Cruz County Board of Supervisors established a moratorium on roadside spraying on county-maintained roadways. Mowing was left as the only viable option for roadside vegetation management, but mowing was more than 275% the cost of a comparable glyphosate application (in a 2010 analysis). Moreover, management is especially difficult because French broom (*Genista monspessulana*) is one of the most common and important invasive weeds found growing on these roadways, as well as other areas of the central coastal area and other parts of California (fig. 1.) It resprouts readily from the root crown and is a prodigious seed producer. In light of budgetary constraints that the County faces, the pur-



Fig. 1. French broom (*Genista monspessulana*) was a common invasive weed found in this herbicide efficacy study on Santa Cruz County roadways.

pose of our research was to evaluate the use of alternatives to glyphosate, especially those herbicides that are organic, biorational, or exhibit characteristics that could be used for vegetation management in a sustainable way.

The trial was established along Empire Grade Road near Bonny Doon, California. The site was heavily infested with French broom. There was a single application of herbicide on May 4, 2010 in replicated and randomized plots, followed by evaluations of weed control at intervals after the application (2 weeks and 1, 2, and 4 months). As expected, glyphosate was found to be very effective in controlling French broom and many other weeds. Products that had some systemic activity — aminopyralid + triclopyr (Milestone) and glufosinate (Finale) — were effective in killing some smaller French broom plants (basal diameters less than 9 millimeters) and inhibiting growth of larger plants. The organic and other contact herbicides — lemongrass oil (Greenmatch EX), 20% acetic acid (Weed Pharm), clove oil (Matran), and pelargonic acid (Scythe) — did not kill French broom. French

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broom and other perennial weeds recovered quickly, in almost all cases, just 2 weeks after herbicide treatment (fig. 2). The applications were repeated on May 5, 2011 to the same experimental plots, and showed similar but more profound results. For example, desirable native California bunch grasses started to establish in the plots treated with aminopyralid + triclopyr, a broad leaf herbicide, while the plots treated with glyphosate were almost devoid of vegetation. The French broom plants in the organic lemongrass oil plots were very similar to those in plots that were left untreated.

Of the contact herbicide group we tested, pelargonic acid and clove oil desiccated foliage most effectively and therefore showed the greatest promise for management with repeated applications. We therefore established another trial using pelargonic acid with multiple applications, each application timed after there was some regrowth of French broom (Sept. 7, Oct. 27 and Dec. 7, 2011). The trial is still ongoing, but so far we have demonstrated that at least 3 successive applications might be needed for killing French broom.



Figure 2. Typical symptoms 2 weeks following a contact herbicide application. In this case clove oil (Matran) was applied. Note that the foliar burn was incomplete, and some vegetative buds sprouted from stems.

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**UC Cooperative Extension
 Ventura and
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REGIONAL REPORT: Managing Invasive Plants in Nurseries

by **Julie Newman**

Invasive plants are a major problem, costing Californians at least \$82 million each year. A weed can be any plant that does not belong in a given area, but an invasive plant is generally a non-native plant that is specifically harmful to natural ecosystems. Invasive plants are much more problematic in natural habitats than conventional weeds due to their ability to aggressively disperse, establish and spread, without human assistance or disturbance. This results in displacement of native vegetation and disruption of wildlife habitats. Furthermore, the unbalanced growth of invasive plants can clog waterways and lead to increased flooding, while the added biomass of invasive plants in drier environments enhances fire damage.

REGIONAL REPORT: Ventura/Santa Barbara Counties, continued from page 22

The California Invasive Plant Council (Cal-IPC), a nonprofit organization, has created a useful inventory of invasive plants (<http://www.cal-ipc.org/ip/inventory/index.php>). Using a process based upon 13 criteria, they have listed about 200 species as threats to California's wildlands. About 63% of these plant species were intentional introductions from all over the world. The majority of these intentionally introduced plant species came through the nursery industry as ornamental landscape plants and have escaped from gardens, such as periwinkle (fig. 1). However, some invasive plants, such as pampasgrass (*Cortaderia selloana*), were directly planted in natural areas for many years for erosion control.

The first step in managing invasive plants is to avoid contributing to the problem. Responsible nursery growers select plant species that minimize environmental liability issues, thus maintaining a positive

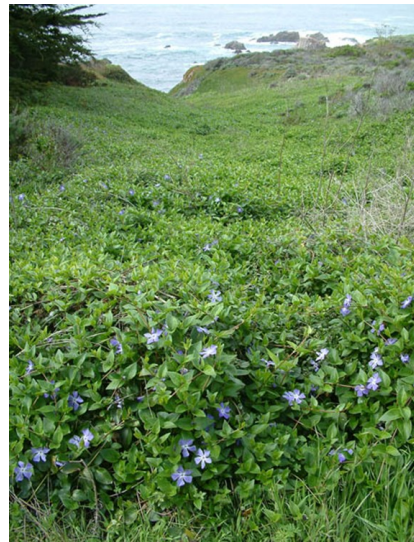


Fig. 1. Periwinkle (*Vinca major*) is an example of an invasive plant species that has escaped from garden plantings to invade many coastal and riparian areas in California. In a 2003 survey of retail nurseries by Master Gardeners, it was available in 74% of the 92 nurseries surveyed. Photo by Bob Case. Source: Cal-IPC.

public image of the industry through their environmental stewardship. Moreover, nurseries located in proximity to natural areas must be especially careful not to be a direct source of wildland invasions. Furthermore, the use of invasive plants on the nursery property in plant demonstrations and for esthetic purposes and environmental management (e.g., landscaping, screening, erosion management, vegetated buffers) should be avoided, especially when the property is located near or in natural areas.

So how do you know if your plant inventory includes invasive species? One resource is PlantRight (<http://www.plantright.org>) an alliance of leaders from the horticulture industry (including nurseries), scientists (including UC), environmental groups, and government agencies that works to reduce sales of invasive plants in the state. PlantRight's website lists invasive plants by region of California with descriptions, photos and suggested plant alternatives. Similar information can be found in the popular brochure, *Don't plant a pest!* found on the Cal-IPC's website (<http://www.cal-ipc.org/landscaping/dpp/index.php>). Another resource for local growers is our Master

The Tenacious 21 — Ventura Country's Top Problem Invasive Plants

- Arundo (*Arundo donax*)
- Tamarisk (*Tamarix ramosissima*)
- Perennial pepperweed (*Lepidium latifolium*)
- Spanish broom (*Spartium junceum*)
- Castor bean (*Ricinus communis*)
- Tree tobacco (*Nicotiana glauca*)
- Ice plant (*Carpobrotus edulis*)
- Pampas grass (*Cortaderia jubata* and *Cortaderia selloana*)
- Several Thistle varieties – Yellow star, Milk, Italian, Artichoke (*Centaurea solstitialis*, *Silybum marianum*, *Carduus pycnocephalus*, *Cynara cardunculus*)
- Myoporum (*Myoporum laetum*)
- Vinca (*Vinca major*)
- Cape Ivy (*Delairea odorata* and *Senecio mikanioides*)
- Sweet Fennel (*Foeniculum vulgare*)
- Black Mustard (*Hirschfeldia incana*)
- Poison Hemlock (*Conium maculatum*)

REGIONAL REPORT: Ventura/Santa Barbara Counties, continued from page 23

Gardener Program. A small group of Ventura County Master Gardeners have received training from Plant-Right which has allowed them to survey Ventura County nurseries and provide information to nursery owners as part of a statewide UC Cooperative Extension effort to reduce the spread of invasive plant species. Survey results (specifically from retail nurseries) from the statewide project are available in an online UC IPM publication on invasive plants at <http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74139.html>. Beginning in April, the Ventura County Master Gardener volunteers will restart the survey program. Following a review of nursery plant inventory they will be available to meet with the nursery owner/manager to provide suggestions for alternative non-invasive plants for any invasive species that they find. Retail and wholesale nurseries in Ventura County can schedule an appointment by calling our Master Gardener helpline at (805) 645-1455 or by email at mgventura@ucdavis.edu.



Fig. 2. Arundo (*Arundo donax*) is difficult to eradicate and threatens California's riparian ecosystems by outcompeting native species. The Ventura County Resource Conservation District assists agriculture in control efforts and is developing a project to remove arundo and other non-native invasive plants in the Calleguas Creek Watershed. Photo by Joseph M. DiTomaso.

When unfamiliar weeds are found on the nursery property, the first step is proper identification. Our County website has a web page on local weeds and invasive plants that can assist you (http://ceventura.ucdavis.edu/Com_Ag/invasive/). You can search the database by scientific name or common name and flip through the photos to identify the plant. There are several photos of each plant representing different life stages.

Controlling plants such as arundo in natural areas of the nursery can be labor-intensive and costly and must be conducted in a manner that protects natural habitats (fig. 2). For example, in southern California, public agencies that manage or regulate rivers and streams restrict invasive plant control activities during spring to fall because threatened and endangered birds, such as the Least Bell's Vireo or Southwestern Willow Flycatcher, nest during this period. There are often rare species of native plants that also need to be protected in many of these infested sites. In addition, herbicide sprays in stands mixed with native plants may not be allowed, and permits from multiple agencies may be required for removal of invasive species. Ventura County nursery growers who need advice on controlling invasive species should contact the Ventura County Resource Conservation District/ Natural Resources Conservation Service office at (805) 386-4685. Growers can also refer to the Cal-IPC website for control recommendations in the Invasive Plants of California's Wildlands and in other resources listed on the Invasive Plant Management page (<http://www.cal-ipc.org/ip/management/index.php>).

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UC Cooperative Extension San Diego and Riverside Counties

REGIONAL REPORT: Thrips resistance management

by James A. Bethke

A number of scientific papers have documented the ability of western flower thrips to develop resistance to conventional insecticides. Research has shown that one thrips strain remained resistant in a pesticide-free environment for 4 years (approximately 100 generations). Western flower thrips has great potential of fast resistance development because of a short generation time, high fecundity and a haplodiploid breeding system. It has been shown that both metabolic and target-site resistance mechanisms are employed, which makes this bug a tough bug.

One of the important findings we observed this last year was the identification of western flower thrips populations in San Diego County that are exhibiting high levels of resistance to one of the most effective thrips products on the market, Conserve (spinosad, Dow AgroSciences). We believe it is highly correlated with the amount used on affected properties. In addition, we tried to find alternatives that could be used against a Conserve-resistant population, but with little success.

Our studies conducted at the Center for Applied Horticulture Research in Vista use a discriminating dose assay of Conserve to help determine if growers have resistant populations of thrips. Typically, a suspected insect population will be exposed to varying concentrations of an insecticide to determine the LC50 and LC95 for the population, which is the “lethal concentration” that will kill 50% or 95% of the exposed individuals. The final product is a probit line. A discriminating dose, on the other hand, uses only the high and low concentrations. Quite simply, if the low dose isn’t killing the majority of the insects, there is some tolerance to the pesticide at some level, and if the high dose isn’t working, there is significant resistance present. It’s

just a hint of what might be going on, and allows us to study the resistant populations rather than conduct onerous probit line analyses on all populations.

We used the discriminating dose assay on thrips from nine different growers to determine if the thrips populations at their facilities were resistant to Conserve, one of the best products on the market today against thrips. Some growers were able to kill 100% of the thrips at both high and low doses and other growers couldn’t kill more than 20% at either dose. The data in table 1 shows a simplified version of the results.

It is most important to rotate products from different IRAC classes every 14 to 21 days against western flower thrips to catch different generations of thrips with different modes of action. Dr. Ray Cloyd from Kansas State University has suggested the rotations in table 2 as an example of rotational regimens. In addition to the rota-

Table 1. Discriminating dose responses of western flower thrips to high and low rates of Conserve (spinosad).

Grower #	Plant	Mortality @ High Rate	Mortality @ Low Rate
1	Limonium	81.2%	50.0%
2	Butterfly Bush	100%	100%
3	Unknown	92.5%	51.3%
4	Butterfly Bush	100%	93.7%
4	Daisy	96.7%	90.9%
4	Snaps	85.7%	88.7%
5	Alstroemeria	81.2%	66.7%
5	Gypsophila	67.1%	34.6%
6	Crape Myrtle	100%	94.9%
7	Bacopa	23.0%	27.8%
7	Daisies	31.0%	13.2%
8	Spathiphyllum	10.7%	10.9%
9	Impatiens	18.2%	10.7%

REGIONAL REPORT: San Diego and Riverside Counties, continued from page 25

Table 2. Rotational regimen of different pesticide modes of action against western flower thrips found in ornamental plant production.

First Application	Second	Third	Fourth
Spinosad	Chlorfenapyr	Abamectin	Methiocarb
Novaluron	Pyridalyl	Chlorfenapyr	Spinosad
Beauveria	Acephate	Spinosad	
Abamectin	Pyridalyl	Chlorfenapyr	Spinosad
Chlorpyrifos	Novaluron	Abamectin	Bifenthrin

Alternatively, the first application in the table can be the first pesticide used multiple times for a period of 14–21 days prior to changing to the next pesticide in rotation.

tional regimens, it is important to hold the most effective products for the times of the year when they are needed the most, so that they will remain highly effective. The persistent uses of the most effective chemicals almost ensure resistance in western flower thrips.

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Field Observations — UC Cooperative Extension San Diego and Riverside Counties

Many people associate invasive pests with unusual or exotic insects — they don't think of a weed as being invasive. Yet, weeds can easily find their way into the United States as a seed or seedling and go unnoticed — some actually look like the marketable commodity. County inspectors look for specific weeds that are rated Q or A and are known to be a significant pest or invasive. One such weed caused concern in potted stock that was moved from one county to another and caught. The weed, hairy crabweed (*Fatoua villosa*) [fig. 1A]), looked like the seedling of the commodity being shipped, Hawai'i woodnettle (*Laportea interrupta* [fig. 1B]). Hairy crabweed is in the Moraceae family, is native to tropical Asia and it is on the CDFA Plant Quarantine Manual's Q & A rated weed list. The California Weed Law and Noxious Weed List can be found on the CDFA web page for Encycloweedia

(http://www.cdfa.ca.gov/plant/ipc/encycloweedia/encycloweedia_hp.htm). Hairy crabweed was found in Los Angeles and San Diego counties. These were very small plants and the situation would have been avoided if the plants had been pulled when found. This is another case illustrating the importance of isolating plants coming in from overseas to avoid having your entire stock put on hold while you wait for a quarantine pest to be eradicated.

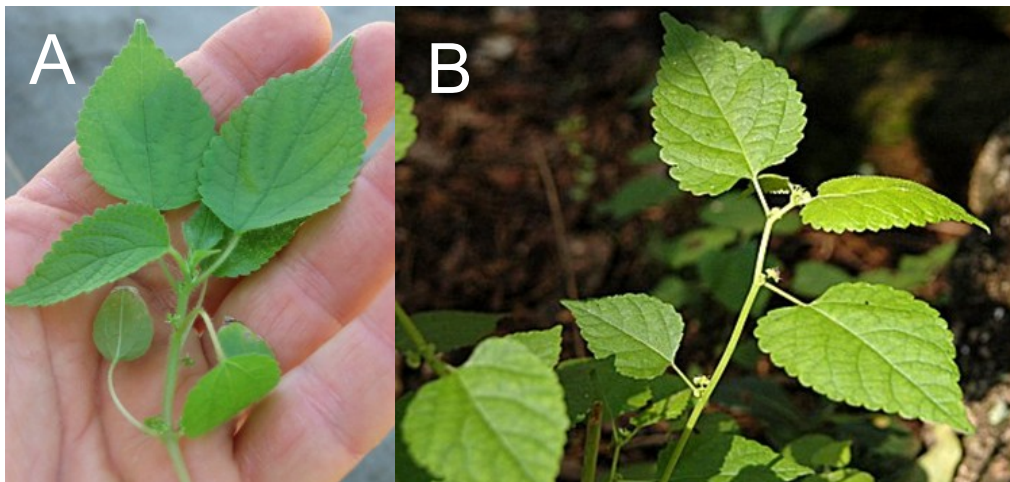


Fig. 1. (A) Hairy crabweed (*Laportea interrupta*) is a noxious weed that was found on a commodity shipping of (B) Hawai'i woodnettle (*Laportea interrupta*). Although small plants of both species resemble each other, hairy crabweed is in the Urticaceae family and Hawai'i woodnettle is in the Moraceae family.

GLEANINGS FROM MEETINGS: Scouting and spray evaluation workshop

by Steve Tjosvold

Forty growers and allied industry representatives attended the UCNFA Scouting and Spray Evaluation Workshop held in Watsonville on August 23, 2011. A lively discussion was anticipated for the field demonstration component of this workshop, and that is what we got!

But first we started in a classroom setting. Farm Advisor Steve Tjosvold presented information on establishing a scouting program for traditional pests and diseases, and then to get a little more specific, he talked about scouting for the important quarantine pest, the Light Brown Apple Moth. UC Davis Professor Ken Giles talked about the theory of spray application and the practical means to evaluate the spray application uniformity in the field. Steve Tjosvold then showed videos of air-assisted sprayers making applications in nurseries, and discussed the results of the evaluation of those applications with moisture-sensitive papers. (Moisture-sensitive paper turns from yellow to blue when contacted by water droplets.)

Then the fun really began when we visited a production area at Suncrest Nursery (with owner Stan Iversen

general manager Jim Marshall hosting). Steve had previously placed moisture-sensitive paper out in a large block of nursery stock, and then the custom-built air-assisted sprayer made an application of water just as it would when making an application of pesticide. All attendees walked out in the field and collected the paper, and placed them onto a large board. Ken Giles then discussed what he saw and the results demonstrated by the paper. As previously mentioned, this field demonstration generated lots of discussion. A final presentation was provided by Neal Murray (UC Cooperative Extension research associate, Santa Cruz County) who talked about bait and pheromone traps for LBAM, and traps were available to see.

A comparable meeting is being planned for the Central Valley in May.

<http://ucanr.org/sites/UCNFA/>.

Steve Tjosvold is Environmental Horticulture Farm Advisor UC Cooperative Extension, Santa Cruz County.



New publications from Agriculture and Natural Resources (ANR)*

compiled by Steve Tjosvold

Agritourism and Nature Tourism in California- Second Edition

Publication Number: 3484
Author: H George, E Rilla
Inventory Type: Paperback
Language: English
ISBN-13: 978-1-60107-742-4
Copyright Date: 2011
Length: 151 pp

Kikuyugrass: Pest Notes for Home and Landscape

Publication Number: 7458
Author: CA Wilen, DW Cudney, CL Elmore, VA Gibeault
Inventory Type: PDF File
Language: English
ISBN-13: 978-1-60107-139-2
Copyright Date: Rev. 2011
Length: 4 pp.

Lawn Diseases: Prevention and Management: Pest Notes for Home and Landscape

Publication Number: 7497
Author: Authors: J Hartin, P Geisel, MA Harivandi
Inventory Type: PDF File
Language: English
ISBN-13: 978-1-60107-178-1
Copyright Date: Rev. 2011
Length: 11 pp.

Sprinkle Irrigation of Row and Field Crops

Publication Number: 3527
Author: B Hansen, L Schwankl, S Orloff
Inventory Type: Paperback
Language: English
ISBN-13: 9781601076991
Copyright Date: 2011
Length: 87 pp

Bee and Wasp Stings: Pest Notes for Home and Landscape (recently updated)

Publication Number: 7449
Author: E Mussen
Inventory Type: PDF File
Language: English
ISBN-13: 978-1-60107-130-9
Copyright Date: Rev. 2011
Length: 3 pp.

Field Bindweed: Pest Notes for Home and Landscape

(recently updated)
Publication Number: 7462
Author: SD Wright, CL Elmore, DW Cudney
Inventory Type: PDF File
Language: English
ISBN-13: 978-1-60107-143-9
Copyright Date: Rev. 2011
Length: 4 pp.

*These publications are available at the ANR Catalog website <http://anrcatalog.ucdavis.edu>.

UCNFA Educational Programs for 2012

information at <http://ucanr.org/sites/UCNFA/>

Scouting and Spray Evaluation
May 24, 2012 Woodlake

**Effective Use of Pesticides in Ornamental
Plant Production (1/2 day English, 1/2 day
Spanish)**
June 5, 2012 Ventura

Nursery Risk Management
June 2012 Southern California

Nursery Risk Management
June 26, 2012 Watsonville

ABCs of Horticulture in English full day
July 11, 2012 San Marcos

ABCs of Horticulture in Spanish full day
July 12, 2012 San Marcos

Water Alliance Conference
August 21, 2012 Davis

**Erosion and Pesticide Runoff Management
in Nurseries**
September 27, 2012 Watsonville

Disease Management Symposium
October 25, 2012 Watsonville



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