The IPM Practitioner

Monitoring the Field of Pest Management

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Alternative Herbicides in Turfgrass and Organic Agriculture

By William Quarles

Photo courtesy of Marrone Bio Innovations

Alternative herbicides can be effective. Pictured here is an irrigation channel that has been treated with GreenMatch®, a reduced risk herbicide containing d-limonene.

A number of alternative herbicides have been developed and are now either commercially available, or waiting for EPA approval. Major markets for these herbicides include the turfgrass industry and organic agriculture. Demand for "green" herbicides in turfgrass is being driven both by environmental concerns and regulatory action. For instance, a number of provinces in Canada have banned cosmetic application of chemical pesticides such as 2,4-D for broadleaf weed control on lawns. Cultural methods can relieve some weed pressures, but alternative herbicides can make weed management less labor intensive (Abu-Dieyeh and Watson 2009; Hashman 2011; Bailey et al. 2010; Boyetchko et al. 2009).

In organic agriculture, weeds are the number one pest management problem and conventional synthetic herbicides cannot be used. Current organic options include hand weeding, cultivation, mulching and flaming (Quarles 2004; Sivesind et al. 2009). Alternative herbicides can reduce or eliminate costs of hand weeding (Evans and Bellinder 2009; Avila-Adame et al. 2008).

Alternative Herbicides in Turfgrass

Canadian provinces of Ontario, Quebec, and New Brunswick have banned cosmetic application of pesticides on lawns. More than 166 Canadian cities have joined in the Provincial Bans. As a result, urban streams in Ontario have seen an 80% reduction of the three most commonly used lawn herbicides—2,4-D, dicamba, and MCPP. About 77% of the Canadian population is benefiting from reduced exposure to synthetic lawn and garden pesticides (Ottawa 2010). Regulations on cosmetic pesticides in Toronto led to a 57% reduction in use on lawns between 2003 and 2007, and the use of alternatives has increased. In 2004, 49% of all households with lawns reported some use of natural lawn care methods. In 2007, this proportion was 67% (Toronto 2009).

The regulatory ban of synthetic herbicides does not mean that turfgrass weeds cannot be managed. The easiest treatment for lawn weeds is to ignore or tolerate them. Some "weeds" are even aesthetically pleasing and break up the monotony of a "perfect" lawn. When lawn weeds reach levels where they cannot be tolerated, active controls

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Update

Drawing by Diane Kuhn

Lawn weeds can be managed by hand weeding and other methods.

Photo courtesy Steve Ash

Weeding tools make the job easier.

Photo courtesy Flame Engineering

Handheld flamers are another option for lawn weeds.

such as hand pulling, mechanical removal, flaming, or hot water can be used (see Resources). Flaming can kill broadleaf weeds while sparing turfgrass (see Quarles 2003ab). Organic management and good cultural methods such as overseeding, fertilizing, and mulching can be effective. Special tools such as the Weed Hound make mechanical methods easier (Quarles 2003ab; Quarles 2008; Quarles 2009ab).

War on the Dandelion?

But aesthetic thresholds for lawn weeds vary considerably from person to person. When very low weed populations are demanded, integration of reduced risk herbicides into the IPM management program may be necessary. Many of the new alternative herbicides target the humble dandelion, *Taraxacum officinale*. The dandelion is a perennial weed that overwinters in the soil as seeds or as perennial roots. Plants may live 10-13 years, and populations may vary considerably in age and genetic composition (Abu-Dieyeh and Watson 2007b).

One reduced risk pre-emergent product already on the market for dandelion and lawn weed control is corn gluten meal. Vinegar, essential oils, citric acid, and soaps are available for spot treatments (see Resources). New products include iron chelates, sold under the brandnames Iron-X, Fiesta, and EcoSense (see Resources). A number of microbial herbicides are also in the pipeline. These include formulations based on *Phoma macrostoma*, *Sclerotinia minor* (Sarritor™), and *Streptomyces* sp (MBI 005).

Corn Gluten Meal

Corn gluten meal (CGM) is a waste product left over from the processing of corn to produce corn syrup. Corn gluten meal is 60% protein and approximately 10% nitrogen (N) by weight. It has been used as an ingredient in dog food, fish food, and other animal feeds (Christians 1991; Christians 1995).

Its high nitrogen content and herbicidal properties make corn gluten meal a near ideal “weed and feed”

Update

Dandelion, *Taraxacum officinale*

product. The product can be applied to mature turfgrass as a top dressing and fertilizer. Over time, it acts as a pre-emergence herbicide that suppresses growth of annual weeds such as crabgrass, *Digitaria* spp., clover, *Trifolium* spp., and dandelion, *Taraxacum officinale*. Reductions of about 90% were seen over a 4-year period (Bingaman and Christians 1995; Christians 1991; Christians 1995; Quarles 1999). Corn gluten meal can be purchased at feed stores and from a number of garden suppliers (see Resources).

Microbial Herbicides

Several microbials have shown promise as herbicides. Divine® and Collego® were commercialized in 1982. Devine was for control of stranglervine, *Morrenia odorata*, and Collego was for postemergence control of northern jointvetch, *Aeschynomene virginica* (Bailey and Mupondwa 2006). Since then, very few microbials have been commercially developed.

A review written in 2001 found only 8 microbial herbicides had been commercialized since 1980. These included 1. *Phytophthora palmivora* (DeVine) used on stranglervine, *Morrenia odorata*; 2. *Colletotrichum gloeosporioides* f.sp. *aeschynomene* (Collego) used on northern jointvetch, *Aeschynomene virginica*; 3. *C. gloeosporioides* (Hakatak®) used on *Hakea sericea*; 4. *C. gloeosporioides* (BioMal® or Mallet®) used on various mallow weeds, *Malva* spp.; 5. The rust pathogen, *Puccinia canaliculata* (Dr. BioSedge®) used on sedges such as *Cyperus esculentus*; 6. The bacterium *Xanthomonas campestris* pv *poae* (Camperico®) used on annual bluegrass, *Poa annua*; 7.*Cylindrobasidium laeve* (Stumpout®) used on *Acacia*; (8) *Chondrostereum purpureum* (BioChon®) used on broadleafed trees (Charudattan 2001; Bailey and Mupondwa 2006; Boyetchko and Rosskopf 2006). Also, *Alternaria cassiae* (Casst®) is sometimes sold for the control of sicklepod, *Senna* spp. (BIRC 2010).

Microbial herbicides have been slow to catch on in the IPM marketplace. Problems have been high cost and generally narrow host range. When the host range is too narrow, so that only one weed is targeted, then the market is limited. If the host range is too broad, there are possible risks to economic crops. Because microbials developed have not been broadspectrum materials, they have been sporadically available only in niche markets (Charudattan 2001; Hallett 2005; Bailey and Mupondwa 2006).

New Microbial Herbicides

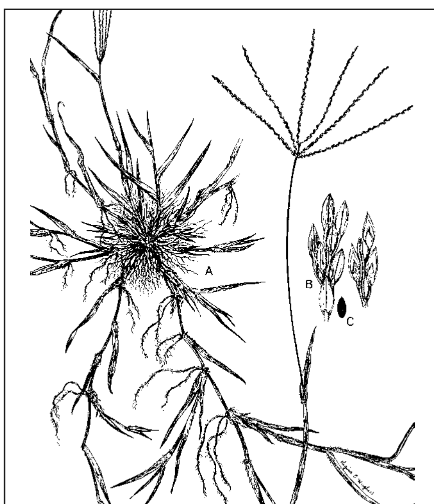
The new microbial herbicides now being commercialized have a wider spectrum of efficacy, and thus more market potential. Possible problems with broader host range materials can be minimized if they have either short persistence or limited dispersal (Hallett 2005; Goettel et al. 2001). One new microbial, *Phoma macrostoma*, has limited dispersal and relatively short persistence. When released, it lives about four months. Another microbial, the fungus *Sclerotinia minor*, does not spread from the release point and only lasts about 11 days in a turfgrass environment. Yet another product, MBI 005, uses the *Bacillus thuringiensis* strategy. The microbe itself is killed before release into the environment, limiting dispersal from the application site (Zhou et al. 2004; Abu-Dieyeh and Watson 2007ab; Hashman 2011).

MBI 005 (*Streptomyces*)

MBI 005, which was developed by Marrone Bio Innovations, is expected to receive EPA registration in September of 2011. The microbial *Streptomyces acidiscabies* is grown in a production facility where it produces herbicidal secretions. The living organism is then killed and harvested along with the herbicide it has produced. This method of production allows the use of a broad-spectrum microbial that poses no non-target problems in the field. Since it is not alive, it cannot grow and spread beyond the release point. According to Tom Hashman of Marrone Bio Innovations, "Our testing and review of activity shows both preemergent and postemergent activity across a variety of broadleaf, grass and sedge weeds. There is excellent crop tolerance in grassy crops such as cereals, rice and corn; we also see excellent utility in various turf species" (Hashman 2011).

Phoma macrostoma Strain 94-44B

Phoma macrostoma was isolated from Canada thistle, *Cirsium arvense*, which was growing in Saskatchewan (Graupner et al. 2003). It is a weak plant pathogen



Large crabgrass, *Digitaria sanguinalis*

widely distributed in nature that is saprophytic and lacks a sexual stage. When applied to soil, it kills several important weeds, including Canada thistle, dandelion, *Taraxacum officinale*; chickweed, *Stellaria media*, scentless chamomile, *Matricaria perforata*, and others. It colonizes plant leaves and roots, secreting compounds called macrocidins that bleach weeds and cause chlorosis (Graupner et al. 2006).

Field tests have shown it effective for dandelion (68%), annual sow thistle (97%) and wild mustard (82%). Soil moisture and uniform application rates are needed for product effectiveness, and it works best on emerging seedlings. The fungus attacks broadleaf plants such as canola and lentil, but grasses, and monocots such as wheat, barley, and oats are unaffected. Field tests in Guelph, Ontario found 92% dandelion control at 84 days after application (Bailey 2009ab).

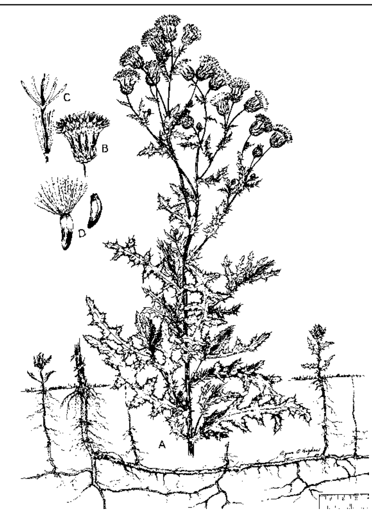
A series of tests found application to soil gave 36-100% control of dandelion depending on doses used and isolates employed. It persists in soil for about four months, and is not detectable after a year. It is a poor competitor, and soils with high microbial activity restrict its growth. Commercial application rates are expected to be 16-32 g/m^2 (5-10 oz/100 ft^2), and it has limited mobility in soil. Field tests found it 1-8 cm (0.4-3.1 in) deep in the soil, but the fungus was not detected 30 and 60 cm (12-24 in) away horizontally from where it was applied (Zhou et al. 2004).

Generally, the fungus and its metabolites stay where they are applied. However, the macrocidins are water soluble. This solubility increases efficacy because plant colonization may not be necessary for herbicidal effectiveness. Weeds may also absorb macrocidins through their roots. Macrocidins are released from the fungus with rainfall, and when soil is not saturated with water, bioactivity remains on site. When soil is saturated, macrocidins might be carried offsite with runoff; "hence, it is recommended that this bioherbicide should not be applied when the soil is saturated" (Bailey et al. 2010).

Scotts Co. of Marysville, OH applied for EPA registration March 10, 2010 and for California registration January 6, 2010. According to Karen Bailey, the researcher who isolated the fungus, it should receive EPA approval by September 2011 (Bailey 2011).

Sclerotinia minor IMI344141 (Sarritor)

Sclerotinia minor was isolated from diseased lettuce plants in Quebec. It has a broad host range



Canada thistle, *Cirsium arvense*

and 37 broadleaf turfgrass weeds are vulnerable. Damage to weeds is variable and depends on degree of contact with the microbial and environmental conditions. The fungus especially attacks and kills dandelion seeds and seedlings. It is applied in granular form as the formulation Sarritor. When applied pre-emergent, the fungus reduced dandelion emergence by 78%; post-emergent application 10 days after sowing dandelions led to a 97% reduction. Grasses show no longterm damage from the fungus. Grass germination experiments showed a slight reduction of vigor at one week, but four weeks later the treated grasses were more robust than controls (Abu-Dieyeh and Watson 2007a).

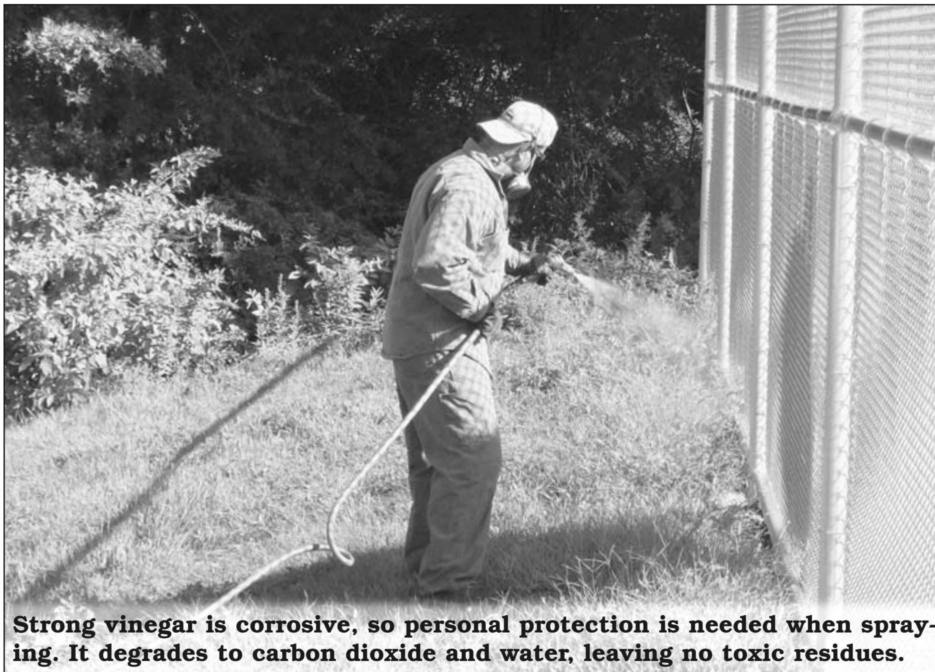
S. minor has a broad host range. This fact means that it can successfully attack many genetic variants of dandelion. Young plants are more vulnerable than old ones. Grass competition increases efficacy of dandelion control. The microbial plus overseeding reduced dandelion populations 70-80% in the first year, increasing to 95% in the second year (Abu-Dieyeh and Watson 2007b; Abu-Dieyeh and Watson 2009).

Sclerotinia minor was registered in Canada on September 22, 2010, and according to Jerry Walker of Sylvan BioProducts, U.S. registration should be completed soon. It is sold as a granular formulation under the brandname Sarritor (see Resources).

Effectiveness of Microbials

Microbials act in a different way than chemical pesticides. Since they are living organisms, they must have a food supply and a favorable environment for growth. Efficacy can sometimes be compromised by environmental conditions. Lack of optimal growing conditions of temperature and moisture can lead to product failure. Even if the material is broadspectrum, effectiveness can be a factor of timing and the age of the weed. So to make proper use of microbials, more knowledge is needed than with the application of chemical controls (Templeton and TeBeest 1979; Watson 1991; Hallett 2005).

For instance, although Sarritor can kill 37 different species of turfgrass weeds, it is most effective against dandelion. Herbicidal effects may be due to secretion of oxalic acid. Successful use depends on temperature, moisture, and especially relative humidity. Seedlings and young dandelion plants are destroyed, but older plants may resprout from the root crown. The best time for application is in the fall and spring, and especially the spring. Sarritor works best with help from vigorous turfgrass growth. Thus, overseeding and good cultural methods, such as high mowing height increases the effectiveness. After application, turf



Strong vinegar is corrosive, so personal protection is needed when spraying. It degrades to carbon dioxide and water, leaving no toxic residues.

Photo courtesy Susan Lewis, Pharm Solutions

must be watered for at least three days if rainfall is not present. During hot summer months, Sarritor is generally ineffective unless turf is covered for at least three days after application with jute or other material to increase the relative humidity (Abu-Dieyeh and Watson 2007ab; Abu-Dieyeh and Watson 2009).

Microbial Safety

The microbials being developed occur naturally in the environment, and the product registration information available suggests few problems. For instance, the *S. minor* fungus present in Sarritor is not toxic to birds, bees, wild mammals, insects, or earthworms. But care must be taken not to destroy non-target plants, especially aquatic plants. The formulation should not be applied to water or to areas where the broadspectrum herbicide will produce negative results. So, lawn clippings should not be applied to gardens or allowed to contaminate water (Canada 2010).

Possible problems with microbials include allergies (Goettel et al. 2001). The granular formulation Sarritor has potential to irritate skin and lungs, and the dust should not be inhaled. The granules should be applied within 12 hours of rainfall or irrigation. Once watered in, they present less inhalation risk (Canada 2010).

When registration of these microbials is complete, we will report on any new information in future issues of the *IPM Practitioner*.

Alternative Herbicides in Organic Agriculture

Synthetic pesticides cannot be used in organic agriculture, but natural or non-synthetic materials are allowed. Commercially available materials include vinegar and essential oils such as clove and lemongrass oil (see Resources). Eventually, some of the new microbials may be registered for organic agriculture (Hallett 2005; Bailey 2009b). Vinegar is obtained by the aerobic bacterial oxidation of ethanol, producing acetic acid. The characteristic odor of vinegar is due to acetic acid, and effectiveness of vinegar as a weed killer increases with its concentration. For instance, 200 grain vinegar contains 20% acetic acid. This product is much stronger than table vinegar, which contains about 5% acetic acid (Evans et al. 2009).

Vinegar is a broadspectrum herbicide, but some weed species are killed easier than others. It is more effective for small weeds, and efficacy increases with the percent of acetic acid. Researchers at the USDA tested vinegar as an herbicide in 2002. They found vinegar at 10, 15, or 20% acetic acid concentration provided 80-100% kill of selected annual weeds, including giant foxtail, *Setaria faberi*; up to 3 inches (7.6 cm) in height, common lambsquarters, *Chenopodium album*; up to 5 inches (12.7 cm), smooth pigweed, *Amaranthus hybridus*; up to 6 inches (15.2 cm), and velvetleaf, *Abutilon theophrasti*; up to 9 inches (22.9 cm). Control of annual weeds with table vinegar at the 5% acetic acid concentration was variable. Shoots of Canada thistle, *Cirsium arvense*; were highly susceptible to 5% vinegar. However, there was regrowth from the roots (Quarles 2002; Miller 2007).

EPA Registration of Strong Vinegar

Commercial development of vinegar herbicides has been hampered until recently due to lack of EPA registration. In February 2011 a commercial formulation of vinegar called Weed Pharm® was given EPA approval for use in organic crops (Lewis 2011). Earlier, Weed Pharm EPA registration had been obtained for non-crop uses. The active ingredient of Weed Pharm is 20% acetic acid. A disadvantage of Weed Pharm is that concentrated vinegar is corrosive, so care must be used during application. Respiratory protection, gloves, safety glasses, and long sleeved shirts are needed. Sprayers must be cleaned carefully after use, or corrosion will result. The advantage is that once it is applied, it is degraded to carbon dioxide and water, leaving no toxic residues in the environment.

Several studies have shown the effectiveness of strong vinegar as a weed control product. As mentioned above, mortality may vary with the species. For instance, 20% acetic acid led to 100% mortality of two-leaf redroot pigweed, *Amaranthus retroflexus*, 9 days after treatment. But velvetleaf, *Abutilon theophrasti*, showed only 18% mortality when treated this way. Younger and smaller weeds are more susceptible than older ones. Treatment is more effective when the sun is shining and temperatures are warm. Increasing application volume can compensate for reduced concentrations. So 15% vinegar applied at 636 liter/ha (68 gal/acre) gives similar results as 30% vinegar at 318 liter/ha (34 gal/acre). Since concentrated solutions of acetic acid are corrosive, reducing concentration makes the material easier to handle (Evans et al. 2009).

Vinegar Herbicide in Organic Corn

Weed management with vinegar in organic agriculture is a balancing act. Vinegar must be concentrated enough to kill the weeds, but not so concentrated that it kills the crop. Best results are obtained when applications are made early in the season. Smaller weeds are more vulnerable, and early application gives the crop time to recover before harvest. In one study, there was 91% control of small weeds one Day After Treatment (DAT) with 20% vinegar at 636 liter/ha (68 gal/acre). Average control over all weed sizes tested was 83%. Early treatment of Trinity or Avalon sweet corn with 20% acetic acid at 318 liter/ha (34 gal/acre) led to similar yields as hand weeding (Evans and Bellinder 2009).

Organic Onions and Potatoes

Vinegar is also useful in organic onions and potatoes. Application of 15% vinegar at 636 liter/ha (68 gal/acre) early in the season gave about 6% damage to onions one DAT, but the crop recovered before harvest, and yields were similar to totally handweeded onions. However, the early vinegar treatment led to a 60% reduction in the amount of handweeding necessary to produce high yields (Evans and Bellinder 2009).

This organic farmer is spraying GreenMatch® to suppress weeds before transplanting celery.

Photo courtesy of Marrone Bio Innovations

Other treatments for onions include cultivation, flaming, and the application of corn gluten meal. Corn gluten meal applied to spring transplanted onions at 4,000 kg/ha gave about 72% total weed control and 83% broadleaf weed control for 46 days after planting. This is a very large application rate, and cost might be too great for commercial production (Webber et al. 2007; Quarles 2004; Sivesind et al. 2009).

Potato foliage is extensively injured by both early and late season vinegar sprays. However, the crop mostly recovers from injury. In fields with heavy weed pressure, yields from vinegar treatments are similar to those seen with handweeding (Evans and Bellinder 2009).

Clove Oil in Organic Agriculture

Effectiveness of clove oil depends on the concentration. For redroot pigweed 1.7% clove oil was marginally effective, but 3.4% applied at the rate of 318 liter/ha (34 gal/acre) gave 94% control after six days to the four leaf stage of the weed. Velvetleaf is harder to control with clove oil. The same 3.4% treatment resulted in 60% control of the four leaf stage after six days (Evans et al. 2009).

Clove oil is more effective on small weeds than large ones, and is more effective for broadleaf weeds than grasses. In field tests conducted in sweet corn, onion, and potato, clove oil did not control grassy weeds. Applications of 3.4% clove oil at 318 liter/ha (34 gal/acre) rate also did not give effective control of typical crop weeds such as lambsquarters, *Chenopodium album*; purslane, *Portulaca oleracea*, chickweed, *Stellaria media* and others. Weed control averaged about 43%. In these tests vinegar was more economical and "showed a greater potential for broadspectrum weed control" (Evans and Bellinder 2009). Other researchers have found that clove oil must be used at higher concentrations to give effective control of broadleafed weeds (Abouziena et al. 2009; Boyd and Brennan 2006).

GreenMatch® and GreenMatch EX®

Another alternative herbicide for organic agriculture is GreenMatch. GreenMatch is approved by the Organic Materials Review Institute (OMRI) for use in organic agriculture, and it has California EPA registration for a large number of crops. The active ingredient of GreenMatch is 55% d-limonene, which is a major component of orange oil. Orange oil has been commercialized as a reduced risk treatment for ants and drywood termites (Mashek and Quarles 2009). The d-limonene dissolves the waxy cuticle of plants, causing them to desiccate and die. GreenMatch is more effective for broadleaf weeds than grassy weeds. Good coverage is necessary for good weed control, and application rates of 60 gal/acre (560 liter/ha) or more are required. For broadcast operation, it is diluted to about 14% of original strength. Spot applications use a dilution to 20% (Marrone 2010).

Treatment of younger weeds is more effective than older ones. For instance, GreenMatch gives 96% control of 19-day old broadleaf weeds such as pigweed, *Amaranthus* spp. and black nightshade, *Solanum nigrum*; but only 17% control of 26-day old plants (Lanini 2010). Weed populations of wild mustard, buckhorn plantain, hairy fleabane, lambsquarters and shepherd's purse are reduced 90% at 28 days after treatment (Marrone 2010).

GreenMatch EX contains 50% lemongrass oil, which is an EPA 25b exempt material (Quarles 1996a). According to company data, Greenmatch EX at 10-15% dilution and applied at 100 gal/acre (935 liter/ha) gave excellent control against "spurge and thistle, good control against bindweed, clover, and crabgrass; and satisfactory control against bermudagrass." Smooth crabgrass was highly sensitive to the product. Poor efficacy was seen with henbit and dandelion (Avila-Adame et al. 2008).

Resources

Essential Oils

Clove oil (Matran II®) EcoSmart Technologies, 318 Seaboard Lane, Suite 208, Franklin, TN 37067; 888/326-7233, Fax 615/261-7301; www.ecosmart.com

Clove oil (Burn Out®) St. Gabriel Laboratories, 14044 Litchfield Rd., Orange, VA 22960; 800/801-0061, 540/672-0866, Fax 540/672-0052; www.milkyspore.com

Clove oil and cinnamon oil (Weed Zap®) JH Biotech Inc., 4951 Olivas Park Drive, Ventura, CA 93006; 800/428-3493; 805/650-8933; Fax 805/650-8942; www.jhbiotech.com

d-limonene (GreenMatch®) Marrone Bio Innovations, 2121 Second St., Suite B-107, Davis, CA 95618; 530/750-2800; www.marronebioinnovations.com

Lemongrass oil (GreenMatch EX®) Marrone Bio Innovations, see above

Microbials

Phoma macrostoma strain 94-44B—Scotts applied March 10, 2010 for EPA registration and January 6, 2010 for California registration.

Sclerotinia minor strain IMI 344141 (Sarritor®) Sylvan BioProducts, 198 Nolte Drive, Kittanning, PA 16201. 866-352-7520; 724/316-6729.

Streptomyces (MBI 005)—Marrone Bio Innovations, see above

Miscellaneous

Acetic Acid (20% vinegar, Weed Pharm®)—Pharm Solutions Inc., PO Box 1500, Cambria, CA 93428; 805/927-7500; 805/927-7501; www.organicpesticides.org.

Citric acid, garlic (All Down®) Summerset Products, 130 Columbia Court, Chaska, MN 55318; 800/237-7583, 952/556-0075, Fax 952/361-4217; www.summersetproducts.com

Corn gluten meal—Gardens Alive, see below. Peaceful Valley Farm Supply, PO Box 2209, 125 Clydesdale Court, Grass Valley, CA 95945; 530/272-4769, Fax 530/272-4794; www.groworganic.com. Grain Processing Corporation, 1600 Oregon St., Muscatine, IA 52761; 563/264-4265, Fax 563/264-428; www.grainprocessing.com

Iron Chelate—(Iron X®) Gardens Alive, 5100 Schenley Place, Lawrenceburg, IN 47025; 812/537-8650, Fax 812/537-8660; www.gardensalive.com

Iron Chelate—(EcoSense®, Fiesta®, Ortho Elementals®) Scotts Co., Marysville, OH. www.scotts.com

Conclusion

A number of alternative herbicides have been developed and are now either commercially available, or waiting for EPA approval. Major markets for these herbicides include the turfgrass industry and organic agriculture. Cultural methods such as overseeding, fertilizing, and mulching reduce weed populations in turfgrass, but alternative herbicides may make weed management less labor intensive. Integration of alternative herbicides into IPM programs may produce effective results without the environmental problems seen with conventional chemical herbicides.

In organic agriculture, weeds are the number one pest management problem, and conventional synthetic herbicides cannot be used. Current organic options include hand weeding, cultivation, mulching and flaming. Alternative herbicides may be able to relieve weed pressures, reducing or eliminating costs of hand weeding.

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Calendar

January 3-6, 2011. 23rd Advanced Landscape IPM Short Course. College Park, MD. Contact: U. Maryland, 301/405-3913; Ex 3911.

January 22, 2011. Annual Bay Area Environmental Education Fair (BAEER). Civic Center, San Rafael, Marin County, CA. Contact: 510/657-4847; kenpacx@yahoo.com

January 26-29, 2011. 31th Annual Ecofarm Conference. Asilomar, CA. Contact: Ecological Farming Association, 406 Main St., Suite 313, Watsonville, CA 95076; 831/763-2111; www.eco-farm.org

January 30-February 1, 2011. Annual Meeting Association Applied IPM Ecologists. Embassy Suites, Monterey, CA. Contact: www.aaie.net

February 1-2, 2011. National Bed Bug Summit. Washington, DC. Contact: www.epa.gov

February 7-10, 2011. Annual Meeting Weed Science Society of America. Portland, OR. Contact: www.wssa.net

February 24-26, 2011. 22st Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

March 6-8, 2011. California Small Farm Conference. Doubletree, San Jose, CA. Contact: www.californiafarmconference.com

May 12, 2011. EPA Conference, Indoor Environmental Quality in Schools. San Antonio, TX. Contact: Stacy Murphy, murphy.stacy@epa.gov

May 22-25, 2011. International Urban Wildlife Management. Austin, TX. Contact: D. Foss, Texas Parks and Wildlife, Houston, TX. 281/456-7029; Ext. 21; www.urbanwildlife2011.org

June 5, 2011. Organic Market Gardening. Farmington, MN. Contact: MOSES, PO Box 339, Spring Valley, WI 54767; 715/778-5775

June 19-23, 2011. 13th Annual IOBC Working Group, Insect Pathogens and Entomoparasitic Nematodes. Innsbruck, Austria. Contact: hermann.strasser@uibk.ac.at

June 23-25, 2011. 68th Annual Convention, Pest Control Operators of CA. Disneyland, Anaheim, CA. Contact: www.pcoc.org

August 6-10, 2011. Annual Meeting American Phytopathological Society. Honolulu, HI. Contact: APS, 3340 Pilot Knob Rd., St. Paul, MN 55121; 651/454-7270; www.aps.net

August 7-12, 2011. 96th Annual Ecological Society of America Conference. Austin, TX. Contact: ESA, 1900 M St. NW, Suite 700, Washington, DC; 202/833-8773; esahq@esa.org

November 13-16, 2011. ESA Annual Meeting, Reno, NV. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

Conference Notes

ESA 2010 Annual Meeting Highlights – Part 1

By Joel Grossman

These Conference Highlights are from the Dec. 12-15, 2010, Entomological Society of America (ESA) annual meeting in San Diego, California. ESA's next annual meeting is November 13-16, 2011, in Reno, Nevada. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

The squash bug, *Anasa tristis*, can transmit cucurbit yellow vine disease (CYVD) bacteria, *Serratia marcescens*. "Non-chemical control of *A. tristis* in cucurbit crops is almost impossible without knowing their population dispersal from overwintering sites and within-field population dynamics," said Vimal Varghees (West Virginia Univ, Morgantown, WV 26506; Vimal-varghese@gmail.com). "*A. tristis* overwinters in plant debris and woods, but much information regarding overwintering ecology of *A. tristis* is still not known."

In organic pumpkin plots, squash bug eggs, adults, and nymphs were found aggregated along the borders. Among the possible explanations: More sunshine makes field edge plants more vigorous and attractive to squash bugs; or adjacent woodlands and grasslands may be overwintering sites, with the field edges offering easy egg-laying access. Whatever the cause, the field edge aggregation effect "indicates that only areas with squash bug aggregation can be controlled to reduce pesticide input and management cost, justifying a site-specific pest control," said Varghees. In other words, pumpkin borders can be treated like a squash bug trap crop.

Biocontrol Fungi Beat Museum Beetles

"Hide beetles, *Dermestes maculatus*, feed on carrion and dried animal products and are pests of poultry houses, silkworm culture, museums, and a variety of stored foods," said Jeff Lord, (USDA-ARS, 1515 College Ave, Manhattan, KS 66502; jeffrey.lord@ars.usda.gov). The biocontrol fungi *Beauveria bassiana, Metarhizium anisopliae* and *Isaria fumosorosea* all have "mycoinsecticide registration, broad host ranges, and variation in potency for target insects." Moisture usually makes the fungi more effective against insects. However, stored product insects are most susceptible under dry conditions when there is desiccation stress.

"Of the three fungi tested, *B. bassiana* is the most efficacious for *D. maculatus* larvae," said Lord. "Like several previously tested stored product beetles, hide beetles are more susceptible to *B. bassiana* under desiccation stress than at under higher moisture conditions, exclusive of saturation. Substrates effect the persistence of fungal inoculum, and conidia that come to rest on woody surfaces quickly lose viability."

Argentine Ant Baits

"The Argentine ant, *Linepithema humile*, is an invasive ant considered a serious threat to urban, agricultural and natural environments that exhibits strong associations with sap-feeding insects (i.e. aphids, scales)," said Cesar Valencia (Texas A&M Univ, College Station, TX 77843; entomip2000@tamu.edu). *L. humile* is best managed using toxic liquid baits with sugar attractants or solid protein bait formulations. Workers collect and distribute these baits within the colony via trophallaxis.

"Management of *L. humile* in small areas (less than 8 ha or 20 acres) is best achieved by using liquid bait stations containing boric acid," said Valencia. "For larger areas the management using this strategy becomes notoriously difficult, so broadcast baits are recommended." In central Texas, broadcast baits similar to those used against red imported fire ant, *Solenopsis invicta*, provide less than 50% *L. humile* control, so improvement is needed.

Field experiments against large populations of *L. humile* in Somerville Lake, Texas, in April to August 2010 compared bait matrices of corn, soybean oil, fish oil, fish, and sugar. These bait matrices were formulated with toxicants: methoprene, fipronil, abamectin, boric acid, hydramethylnon, and pyriproxyfen. Each bait product was placed on a plastic lid on the ground in a circle; numbers of ant workers attracted and amount of bait taken was monitored every 30 minutes for two hours.

Argentine ants were significantly more attracted to and removed more particles of fish powder, fish oil, Advance Carpenter Ant Bait (ACAB; contains fish products), ACAB 375A, and pyriproxfen (Esteem™) plus fish powder. Fish powder and confectioners sugar increase attraction to less-preferred baits. Bait attraction is highest in the warmest months, particularly July and August. Bait testing is continuing in larger infested areas. Similar bait selection test regimens are recommended in other areas.

Argentine Ant Bait Station

A heavy infestation of Argentine ants, *Linepithema humile*, threatens endangered chicks of least tern, *Sterna antillarum browni*, at Oceanside, California's White Beach, where pesticide sprays are prohibited. Thus, a PVC pipe bait station (with access holes and caps on the top and bottom) containing sucrose but lacking a toxicant was developed and tested in 2008 and 2009. "The novel bait station was referred to as a 'virtual bait station' because the sucrose solution bait itself did not contain any toxicant," said Dong-Hwan Choe (Univ of California, ESPM, Mulford Hall, Berkeley, CA 94720; dchoe003@berkeley.edu).

Conference Notes

"Foragers were permitted to cross surfaces treated with diluted fipronil enroute to the sucrose solution bait dispensed in the bottom," said Choe. "The workers picked up a dose that showed delayed toxicity over 3-5 days. The fipronil was later transferred to nestmates by physical contact." Ant activity was significantly reduced, and ants were still visiting the bait station 10 weeks later.

The "virtual bait station" was buried in the sand to protect the interior fipronil deposits. Bait cartridges were refilled with sucrose or replaced (exchanged) each monitoring period. Instead of fipronil, the inner liner of the bait station could contain other compounds such as insect growth regulators or microbials. The inner lining containing the fipronil or other compound could also be made replaceable or refreshable to improve bait station economics.

"Installation around residential areas would be more practical with smaller size," said Choe. "It could be hidden in garden vegetation or hedges. This will also help protect bait stations from direct sunlight, heat, or pets without burying them in the ground."

Hot Dog Baits & Boiling Water

Central Texas landscapes have caves, endangered camel crickets, native ant species needing protection, and red imported fire ants, *Solenopsis invicta*, said Natalie Cervantes (Texas Agrilife Ext Serv, 3355 Cherry Ridge St, San Antonio, TX 78230; NTCervantes@ag.tamu.edu). IPM alternatives such as toxic baits used to fight fire ants need to be used sparingly to protect native ants and endangered crickets in these areas.

Though expensive and labor-intensive, pickaxes are used to break into fire ant mounds. Then trucks inject boiling water into the mounds. Treatment of fire ant mounds is triggered when 300 *S. invicta* are captured per 10 bait hot dogs. Esteem® Ant Bait (pyriproxyfen) needs to be used in a way minimizing impacts on native ants and camel crickets.

The lure-switch-bait (LSB) method takes advantage of the fact that *S. invicta* tends to "quickly recruit and dominate resources" (such as hot dog lures). An area can be pre-baited with hot dog lures; if large numbers of *S. invicta* show up in 45-60 minutes, then the active bait can be substituted for the lure.

Environmental impacts and non-target effects are minimal, because so little bait active ingredient is used. But the main advantage is that fire ants, not native ants, are there first to take the bait. When LSB is synchronized with boiling water injections into fire ant mounds, native ant populations increase.

Botanical Tick Control

"Plant phytotoxicity and short residual activity are two problems that may limit the potential to use nootkatone, a component of essential oil derived from citrus, as a natural acaricide to control the black-legged tick, *Ixodes scapularis*," said Robert Behle (USDA-ARS, 1815 N University St, Peoria, IL 61604; robert.behle@ars.usda.gov). "Maillard and lignin encapsulated formulations reduced volatility of nootkatone by 2.5x and 5.0x, respectively when compared with emulsifiable formulation." In other words, encapsulated nootkatone formulations lasted 250% to 500% longer. Encapsulated formulations were just as toxic to tick nymphs, and had less plant toxicity.

"Field trials to evaluate the ability of the plant-derived compounds nootkatone and garlic to control nymphs of the black-legged tick, *Ixodes scapularis*, were conducted in summer 2008-2010 at residential properties in Connecticut," said Anuja Bharadwaj (Connecticut Agric Exper Stn, 123 Huntington St, New Haven, CT 06504; Anuja.Bharadwaj@ct.gov). "An emulsifiable concentrate of nootkatone in 2008 provided 100% control within a few days after application, but control declined to 21% by 3 weeks. A lignin-encapsulated (LE) nootkatone formulation was applied in 2009, and both the LE nootkatone and a Maillard-reaction encapsulated (ME) were applied in 2010. A minimal risk (25B) garlic-based product was also evaluated in 2009 and 2010."

"The LE nootkatone provided 100% control of *I. scapularis* in 2009, while the garlic-based product suppressed tick activity for 4 weeks," said Bharadwaj. "The LE and ME nootkatone provided 80% and 62% tick control 8 days post-application, respectively, in 2010. Garlic provided 89% and then 67% suppression of ticks for 1 week and 4 weeks post-application, respectively." Residual time was less than a week on filter paper disks placed in the treatment area; persistence was longer in the soil.

German Roaches Return

After 50 years, German cockroaches, *Blattella germanica*, are once again back as a major problem in North Carolina homes, said Richard Santangelo (North Carolina State Univ, Raleigh, NC 27695; rick_santangelo@ncsu.edu). Traditionally, PCOs have targeted the kitchen and bathroom for German cockroach treatments, as this is where the major food and water sources are presumed to be. However, trapping studies reveal that 50% of German cockroach populations are elsewhere, in living rooms and bedrooms. Thus, whole-home gel-baiting by university researchers was compared with traditional kitchen and bathroom gel-baiting by PCOs.

A major end goal was reducing German cockroach allergens (e.g. Bla g1). In Raleigh, NC, it was remarkably easy to find homes with over 30 German cockroaches per two rooms. A helpful IPM approach included persuading occupants to change two common practices: eating and storing food in bedrooms. Water in bedrooms was associated with permanent cockroach aggregations.

The PCOs, who were gel-baiting kitchens and bathrooms unaware of the comparison aspect of the study, reduced German cockroach populations 53%-76%. University researchers treating whole homes reduced German cockroach populations 97%-99%. Whole-home treatments eliminated cockroach reinfestations from populations outside kitchens and bathrooms; thereby reducing return visits. However, whole-home gel-baiting requires more time; the first visit was the longest, and thereafter visits lasted 40 minutes per home.

Flowers Boost Lettuce Aphid Biocontrol

"Flowers are tried in many crops, but the ecological mechanisms are left untested," said Erik Nelson (Univ of California, 137 Mulford Hall, Berkeley, CA 94720; ehnelson@berkeley.edu). "Therefore, biocontrol workers can't evaluate flower planting as a general strategy. If we test the mechanisms, we can improve the flower planting strategy."

Observations of 370 syrphid flies (aphid predators) revealed that males fed mainly on nectar, but females ate pollen plus nectar. Field cage studies contained 30 lettuce plants with aphids and 3 female syrphid flies, *Eupeodes* spp. Cages with flowers had very few aphids. Cages without flowers had several hundred aphids. Syrphid flies produced more offspring in cages with flowers, resulting in higher aphid consumption (more biocontrol).

Methyl Salicylate Lures

"Exploiting chemical ecology in conservation biological control incorporates practices that attract insect predators and parasitoids into crop systems," said John Sedlacek (Kentucky State Univ, 400 East Main St, Atwood Bldg, Rm 126, Frankfort, KY 40601; john.sedlacek@kysu.edu). In hops and grapes, synthetic methyl salicylate attracts green lacewings, *Chrysopa nigricornis*, aphid eating syrphid flies, predatory big-eyed bugs, *Geocoris pallens*, seven-spotted lady beetles, *Coccinella septempunctata*, and spider mite eating lady beetles, *Stethorus punctum*. Methyl salicylate has also been shown to attract a spider, *Erigonidium graminicolum*, to cotton; and minute pirate bugs, *Orius* spp., to cotton and strawberries.

In these experiments, lures of methyl salicylate (PredaLure®; AgBio Inc) were stapled to tobacco sticks at crop canopy height in the center of organic and conventional sweet corn plots. "Beneficial insects were sampled weekly during silking using 15 x 15 cm (5.9 x 5.9 in) yellow sticky traps stapled to a tobacco stick at (corn) ear height," said Sedlacek. "Seven species of lady beetles, the big-eyed bug, green lacewing, and brown lacewing were captured in the conventional sweet corn. Five species of lady beetles, the big-eyed bug, and green lacewing were caught in the organic sweet corn. Pink lady beetle, *Coleomegilla maculata*, and big-eyed bug, *Geocoris* sp. were the most abundant predators caught, representing over 75% and 17% of the total number of individuals caught, respectively, during 2009 and 2010."

Beneficial Bugs Induce Tomato Resistance

"The presence of generalist predators can work as an early cue of the closeness of herbivores, and may impact the induction of defense genes in tomato," said Helene Quaghebeur (Pennsylvania State Univ, 501 ASI Bldg, University Park, PA 16802; hmq1@psu.edu). North American tomato fields commonly have generalist predators preying on soft-bodied herbivorous insect pests. Among the common predators are minute pirate bugs, *Orius insidiosus*, and spined soldier bugs, *Podisus maculiventris*. Induction of jasmonic acid (JA) pathway defense genes by these two generalist predators was measured in 4-week old tomato plants.

"The presence of *Orius insidiosus* adults significantly induces several genes of defense regulated by the JA pathway," said Quaghebeur. "The level of defense gene expression depends on the gender and reproductive status of the predator. Mated females generally cause the highest, most significant level of gene induction. *Podisus maculiventris* adults and nymphs significantly induce JA-regulated genes, but generally not as strongly as *Orius insidiosus*."

Onion Thrips Avoid Yellow-Green Foliage

"Onion thrips, *Thrips tabaci*, is the most important insect pest worldwide of onions, *Allium cepa*," and can cause over 50% yield losses, said John Diaz-Montano (Cornell Univ, NYSAES, Geneva, NY 14456; jd325@cornell.edu). Onion thrips are hard to control, because they hide in the narrow spaces between inner leaves and are resistant to insecticides. Onion cultivar resistance to thrips is linked to factors such as leaf and bulb color and leaf structure.

"We screened 49 onion varieties and found that resistant varieties had yellow-green colored foliage compared to the susceptible ones that had blue-green color foliage," said Montano. "Most of the cultivars resistant to onion thrips had lower reflectance in the UV range compared to the susceptible checks. It is possible that onion thrips prefer onion cultivars with higher UV reflectance (270-400 nm) that provides them with shelter from heat and this characteristic may make these onion cultivars more attracted and susceptible to onion thrips."

Floral Greenhouse IPM

Ontario, Canada's thriving floricultural greenhouse industry needs to prevent cuttings from introducing western flower thrips, *Frankliniella occidentalis*, into chrysanthemums and silverleaf whitefly, *Bemisia tabaci* Biotype B, into poinsettia. "Reduced risk control methods would permit growers to establish insect pest-free and insecticide residue-free cuttings from the outset, thus ensuring that ongoing greenhouse biological control programs are not affected negatively," said Wendy Romero (Univ of Guelph, Guelph, ON N1G 2W1, Canada; wromero@uoguelph.ca).

Greenhouse chrysanthemum cuttings can be disinfested with non-phytotoxic hot water. Hot water at 39°C (102°F) for 30 minutes or 41°C (106°F) for 15 minutes produced over 80% thrips mortality. Cuttings can also be dipped into solutions of insecticidal soap, horticultural oil, spinosad, *Beauveria bassiana* (fungi), and *Steinernema feltiae* (nematodes). Spinosad and insecticidal soap provided 60-75% thrips mortality. Horticultural oil killed 100% of adults, and 64-82% of immature thrips. *Beauveria bassiana* killed over 90% of immature and adult thrips. *Steinernema feltiae* provided 50-60% thrips control.

Silverleaf whitefly eggs and nymphs on poinsettia cuttings were stopped (>83% control) by horticultural oil plus washing. Insecticidal soap killed over 90% of whitefly nymphs, but under 15% of eggs. Hot water at temperatures safe to poinsettia cuttings killed less than 20% of whitefly eggs and nymphs.

Microbial Beats Beet Armyworm

"A novel bacterium *Burkholderia* spp. was isolated from a soil sample and is being developed into a microbial bioinsecticide," said Huazhang Huang (Marrone Bio Innovations, 2121 Second St, Suite B-107, Davis, CA 95618; hhuang@marronebio.com). "Other species in this genus are beneficial for plants, and are known to promote plant growth and symbiosis." Also, "*B. xenovorans* is known for its ability to degrade chlororganic pesticides and polychlorinated biphenyls (PCBs)."

"The insecticidal activities of this bacterium are due to multiple secondary metabolites. One of the active compounds with a molecular weight of 540 has been purified and identified. The lethal median dose (LD50) of this compound against 3rd instar larvae of beet armyworm, *Spodoptera exigua*, is 0.1 µg per individual by topical application." This *Burkholderia* sp. also shows "good to excellent activity" against cabbage looper, *Trichoplusia ni*; diamondback moth, *Plutella xylostella*; tufted apple bud moth, *Platynota idaeusalis*; codling moth, *Cydia pomonella*; and obliquebanded leafroller, *Choristoneura rosaceana*.

Hemlock Woolly Adelgid Biocontrol

"The hemlock woolly adelgid (HWA), *Adelges tsugae*, is an exotic pest of forest and ornamental hemlock trees in the eastern United States," said Sarah Grubin (Oregon State Univ, 321 Richardson Hall, Corvallis, OR 97331; Sarah.Grubin@oregonstate.edu). "Native to China, Japan and western North America, HWA was first found in the eastern U.S. in 1951. As of 2009, 18 states ranging from Maine to Georgia have reported infestations of HWA. HWA has established in natural stands in the eastern U.S. causing widespread mortality of the two hemlock species native to eastern North America."

Pest management efforts are focused on classical biological control with predatory beetles such as *Laricobius nigrinus,* said Grubin. The native western North American predatory flies *Leucopis atrifacies*, *L. argenticollus* and *L. piniperda* also show potential as classical biocontrol agents for introduction to the eastern U.S.

"In Great Smoky Mountains National Park (GRSM), hemlock woolly adelgid (HWA) was first reported in 2002," said Abdul Hakeem (Univ of Tennessee, 205 Ellington Plant Sci Bldg, Knoxville, TN 37996; ahakeem@utk.edu). "Since then thousands of hemlock trees have died due to excessive feeding of this invasive pest. In the southern U.S. death of hemlock trees usually occurs within 5-7 years after infestation."

In the absence of effective native natural enemies in the eastern U.S., half a million Asian lady beetles, *Sasajiscymnus tsugae*, were released at 166 sites in GRSM from 2002 to 2008. Beat-sheet sampling and upper canopy sweep-net sampling at 56 sites revealed that *S. tsugae* was established at 18% of release sites, particularly older release sites; indicating 5-7 years for establishment after release.

Fly IPM With Natural Odors

Catnip, *Nepeta cataria*; tropical sandalwood, *Santalum album;* and balsam torchwood, *Amyris balsamifera* contain good repellents against stable flies, *Stomoxys calcitrans*, and other fly species, said Junwei Zhu (USDA-ARS, Univ of Nebraska, 305B Entomol Hall, Lincoln, NE 68583; Jerry.Zhu@ars.usda.gov).

Catnip is one of the best repellents against stable flies, house flies, horn flies, face flies, and other insects. *Beta*-caryophyllene, *alpha*-pinene, and *ZE*- and *EZ*-nepetalactone are among the catnip compounds repelling stable flies. Catnip also has good fumigant toxicity towards stable flies and other flies, with less than 10-20 minutes for knockdown at most doses. Sprayable formulations are necessary to knockdown stable fly populations.

In cattle tests, 15% catnip formulations repelled flies from cattle legs. Oil based formulations can supply up to 14 hours repellency, versus 5 hours for water formulations requiring higher dosages. A wax pallet with oatmeal is good for stable fly egg development; but when catnip is added, larval growth is inhibited and pupal weight is lower. In Petri dish tests, catnip inhibits or suppresses several different bacteria. Dairies are beginning to use catnip for its combined anti-bacterial activity, high relative safety, and fly repellency. Good repellents for the horn fly, *Haematobia irritans*, besides catnip include geranic acid, geraniol, octanoic acid, nonanoic acid, and decanoic acid.

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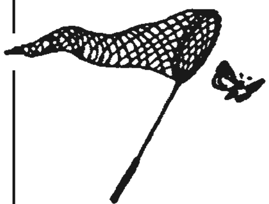

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