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Global Warming Means More Pests

By William Quarles

Photo courtesy of Dr. S.B. Vinson

Global warming will encourage many warm weather pests. The range of the red imported fire ant, *Solenopsis invicta,* shown here, is expected to expand to Illinois and New Jersey.

As most people know by now, our planet is getting warmer. Global measurements show that 11 of the last 12 years are the warmest observed since 1850. Average global surface temperatures have increased by about 0.7°C (1.3°F) over the last 100 years. Larger than average increases of 2-5°C (3.6-9°F) have been seen closer to the poles. Warming has caused melting of polar ice and the increase of ocean water levels. It has produced shorter and warmer winters, with earlier arrival of spring temperatures and later onset of winter conditions (Salinger et al. 2005; Houghton et al. 2001; Collins et al. 2007).

The warming is mostly due to increased concentrations of greenhouse gases, which include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Most of the increase is due to human activities, especially the burning of fossil fuels. Over the past 200 years, the atmospheric concentration of carbon dioxide has increased 35%. Climatic models based on greenhouse gases are predicting an average increase of 1.8°C to 4°C (3.2°F-7.2°F) over the period from 2007 to 2100 (Karl and Trenbeth 2003; Johansen 2002; Collins et al. 2007).

Some effects of global warming on insect populations have already been measured. According to one survey of about 1600 species, about 940 of them are showing the effects of climate change. Range boundaries are moving northward by an average 6.1 km/decade (3.7 mi) or about 6.1 m (20 ft) upward per decade. Spring events are taking place earlier. For instance, in Europe, 35 species of butterflies have already shifted their ranges 35-240 km (21-144 mi) northward (Parmesan et al. 1999). In California, 70% of 23 butterfly species now start their first flight about 24 days earlier than they did 31 years ago (Parmesan and Yohe 2003; Parmesan 2007).

Spring events such as budbreak on trees and breeding of toads and birds are happening about 5 days earlier with each decade (Root et al. 2003). In Europe deciduous trees now unfold 16 days earlier and defoliate 13 days later than they did 50 years ago. In Alberta, quaking aspen, *Populus tremuloides* is now blooming 26 days earlier compared to 100 years ago (Penuelas and Filella 2001).

The amount of future disturbance will depend on the actual temperature increase over the next 100 years. According to one study of 1100 species, climate changes due to global warming may cause 15-37% of those species to go extinct by 2050 (Thomas et al. 2004; Hance et al. 2007).

Warming Means More Pests

Global warming will probably lead to increased numbers of structural, agricultural, and forest insect pests. Public health pests and insect vectored diseases are likely to increase.

In This Issue

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Monitoring the Field of Pest Management

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Update

Part of the effect will be directly due to increased temperatures. But global warming is also expected to drive more extreme weather conditions: more and longer droughts, larger and more frequent storms, increased rainfall. All of this will have an effect on plant growth and will encourage insects (Easterling et al. 2000; Karl et al. 1995; Stireman et al. 2005).

Milder and shorter winters mean that warm weather pests will start breeding sooner (Bale et al. 2002). Those of medical importance, such as mosquitoes should have more of an impact (Hopp and Foley 2001; Epstein 2001). Other changes include expanded pest ranges, disruption of synchrony between pests and natural enemies (see below), and increased frequency of pest outbreaks and upheavals (Parmesan 2007; van Asch and Visser 2007).

Increased Structural Pests

A number of the structural insect pests in the U.S., such as the red imported fire ant, *Solenopsis invicta*; and the Argentine ant, *Lithepithema humile*; are exotic invaders that originated in tropical or subtropical climates. Though other factors are involved, such as food supply and moisture, we can expect temperature increases in the U.S. to favor these warm weather pests. As we see in Table 1, temperature increases should encourage ants, termite pests, clothes moths, flies, mosquitoes, fleas, stored product moths, woodboring beetles, and even bed bugs. For instance, a 3°C (5.4°F) increase in temperature will almost double the growth rate of the German cockroach, *Blattella germanica* (Noland et al. 1949). A 5°C (9°F) increase in temperature does the same for the Indianmeal moth, *Plodia interpunctella* (Cox and Bell 1991). Drywood termites such as *Incisitermes minor* prefer to swarm at temperatures of about 27°C (80.6°F) (Harvey 1946). Preferred soil temperatures of the western subterranean termite, *Reticulitermes hesperus* range from 29-32°C (84.2-89.6°F) (Smith and Rust 1994).

We can expect population increases of these pests in their current ranges, and we can expect their ranges to expand. Currently, subterranean termites such as *Reticulitermes* spp. are found all over the U.S., but the largest populations are found in the Southeast and California, where winter tem-

Table 1. Effects of Temperature on Insect Biology

Pest	Scientific Name	Temperature	Biology	Temperature	Biology	Reference
American cockroach	*Periplaneta americana*	>21C (69.8F)	year round activity	27C(80.6F)	egg to adult, 24 weeks	Benson and Zungoli 1997
Argentine ant	*Lithepithema humile*	<18C(64.4F)	egg laying ceases	6C (42.8F)	activity ceases	Newell and Barber 1913; Ebeling 1975
Bed bugs	*Cimex lectularius*	18C (64.4F)	128 days egg to adult	30C (86F)	24 days egg to adult	Usinger 1966
Brownbanded cockroach	*Supella longipalpa*	25C (77F)	egg hatch, 70 days	30C (86F)	egg hatch, 40 days	Willis et al. 1958
Brownbanded cockroach	*Supella longipalpa*	25C (77F)	egg to adult, 95-176 days	30C (86F)	egg to adult, 69-114 days	Willis et al. 1958
Cat flea	*Ctenocephalides felis*	13C (55.4F)	egg hatch, 6days	35C (95F)	egg hatch, 36 hours	Silverman et al. 1981
German cockroach	*Blattella germanica*	27C (80.6F)	egg to adult, 50-60 days	30C (86F)	egg to adult, 36 days	Noland et al. 1949
House fly	*Musca domestica*	<15C (59F)	no egg laying	11C (51.8F)	no development	Legner and McCoy 1966
House fly	*Musca domestica*	<20C (68F)	larval stage, 6-8 weeks	21-32C (69.8-89.6F)	larval stage, 3-7 days	Ehmann 1997
Indian meal moth	*Plodia interpunctella*	20C (68F)	life cycle, 60days	25C (77F)	life cycle, 30 days	Cox and Bell 1991
Old house borer	*Hylotrups bajulus*	20-31C (68-87.8F)	optimal temp. larvae	-------	-------	Cannon and Robinson 1985
Old house borer	*Hylotrups bajulus*	29-35C (84.2-95F)	optimal temperatures adults	>30C (86F)	adult flights	Cymorek 1968
Red imported fire ant	*Solenopsis invicta*	>24C (75.2F)	mating flights	22-36C (71.6-96.8F)	optimal foraging	Vinson and Sorensen 1986; Zavaleta and Royval 2002
Webbing clothes moth	*Tineola bisselliella*	20C (68F)	larval span, 129 days	29.5C (85.1F)	larval span, 67 day	Busvine 1980
Western drywood termite	*Incisitermes minor*	>27C (80.6F)	peak swarming	-------	-------	Harvey 1946
Western subterranean termite	*Reticulitermes hesperus*	29-32C (84.2-89.6F)	preferred soil temperature	-------	-------	Smith and Rust 1994
Yellow fever mosquito	*Aedes aegypti*	25-29C (77-84.2F)	optimum larval development	26C (78.8F)	optimal adult temperature	Fay 1964

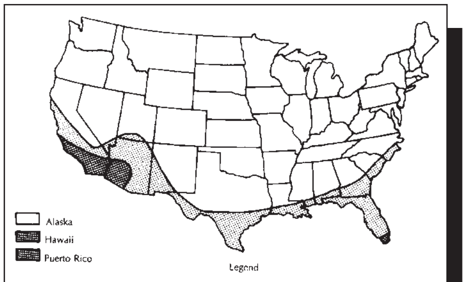
peratures are warmest. Formosan subterranean termites, *Coptotermes formosanus*, are tropical termites that have so far been limited to southern areas by cold winter temperatures (Potter 1997). With global warming, their range is likely to expand northward.

Drywood termites are now found mostly on the southern edge of the U.S. and along the Pacific Coast (Potter 1997). The range will probably expand when more areas are able to consistently reach the preferred swarming temperature of about 27°C (80.6°F). Since termites produce considerable amounts of the greenhouse gas methane, expansion of their ranges and numbers will add to the global warming problem (Thakur et al. 2003).

Red imported fire ants have already spread beyond the Southeast and are now found in Southern California. Due to global warming, the range in the U.S. is expected to increase by 5-21% over the next century (Morrison et al. 2005). A 1°C (1.8°F) increase will lead to large infestations in Tennessee and Virginia, and a 3°C (5.4°F) increase will extend the range to southern Illinois and New Jersey (Zavaleta and Royval 2002). Increasing temperatures also discourage some insect pathogens such as *Entomophthora muscae* that provide biocontrol of house fly populations. So nuisance fly activity will likely increase (Harvell et al. 2002). Though Africanized honeybee, *Apis mellifera scutellata*, is not usually a structural pest, warming means that its range will also expand northward (Zavaleta and Royal 2002; Rinderer et al. 1993).

Ticks are expanding their ranges. Effects of global warming are first seen at higher latitudes. In Sweden, the disease-carrying tick, *Ixodes ricinus*, has increased in abundance along its northernmost range. Numbers of ticks found on dogs and cats have increased from 22 to 44% between 1980 and 1994 (Parmesan 2007).

Mosquitoes are likely to become more troublesome over larger areas. Up to now, ranges have been somewhat limited by temperatures. For instance, *Aedes aegypti*, which carries yellow fever and dengue, is killed at temperatures below 10°C (50°F). It prefers water temperatures of 25-29°C (77-84.2°F) for larval development, and the adult thrives best at 26°C (78.8°F). Adult development rate of the malaria mosquito, *Anopheles gambiae*, is greatest at 28-32°C (82.4-89.6°F). Warmer winters that increase mosquito populations will also increase the geographical range of mosquito-vectored diseases (Bayoh and Lindsay 2003; Epstein 2001; Martens et al. 1997).



Range of drywood termites in the U.S.

From Potter 1997

Increased Human Diseases

Changes have already started. Pathogens for human diseases such as malaria, African trypanosomiasis, Lyme disease, tick-borne encephalitis, yellow fever, plague, and dengue have increased in incidence or geographic range in recent decades (Harvell et al. 2002). Warmer temperatures increase mosquito reproduction and biting activity, and pathogens inside the mosquitoes mature faster. For instance, transmission of malaria requires temperatures greater than 16°C (60.8°F), and a 5°C (9°F) increase in temperature doubles the growth rate of the falciparum protozoa that causes malaria. Small outbreaks of malaria have occurred in Texas, Georgia, Florida, Michigan, New Jersey, New York and Toronto since 1990 (Epstein 2001; Gil 1920). The first cases of dengue hemorrhagic fever in the U.S. were seen in Texas late in 2005 (Sci. New 2006).

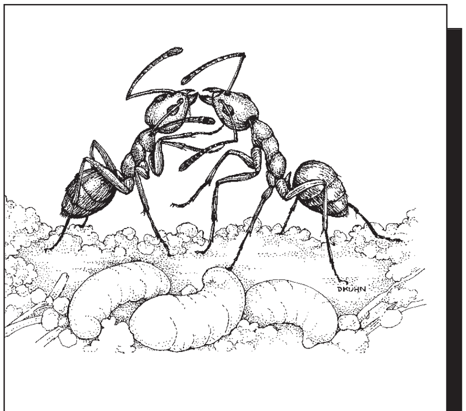
Warm winters followed by summer droughts are the conditions that favor diseases such as West Nile Fever. West Nile Fever got its start in the U.S. in 1999, when a mild winter led to large populations of mosquitoes early in the season. A subsequent drought forced *Culex* mosquitoes that carry the pathogen into close contact with bird populations, amplifying and spreading the disease (Epstein 2001). Shrinking water holes meant that birds and mosquitoes aggregated in the same areas. Drought depressed populations of predators such as dragonflies that prey on mosquitoes in water environments. The emergence of hantavirus in the U.S. in 1993 was also encouraged by global warming (Epstein 2001; Epstein 2000).

Warmer and shorter winters allow more ticks to overwinter. Tick ranges are expanding northward and upward. Increased ranges for the ticks mean increased ranges for Lyme disease and tickborne pathogens (Epstein 2001). Global warming will likely increase the incidence of some other diseases. For instance, the approximately 1°C (1.8°F) increase of temperature in China has shifted the range northward of the snail that carries the pathogen that causes schistosomiasis. An additional 20.7 million people are now at risk for this disease (Yang et al. 2005).

There are direct effects on human health from climate change. The World Health Organization has estimated that droughts, floods, air and water pollution, and disease resulting from global warming could already be causing 150,000 deaths per year (Patz and Olson 2006). There may be also some effects on human health due to increased plant growth. Poison ivy, grows better and produces more potent toxin in elevated CO_2 concentrations (Mohan 2006). Increased growth of plants such as ragweed will likely increase allergies to ragweed pollen. Ragweed will grow larger and flower earlier (Ziska 2007; Patterson 1995).

Effects on Crops

Some crops may grow more vigorously in an enriched CO_2 atmosphere, but there is a tradeoff. Seed production drops as temperatures increase (Prasad et al. 2005). Floods and droughts associated with warming will likely cancel some of the increased growth. Also, global warming will encourage pest insects, diseases and weeds (Patterson 1995). Crop pests are showing increased geographical range, increased numbers of generations, and higher densities (Parmesan 2007).



Argentine ants, *Lithepithema humile*

Though the range of the pink bollworm, *Pectinophora gossypiella*, is now restricted to frost free areas of Arizona and Southern California, an increase of 1.5-2.5°C (2.7-4.5°F) in average global temperature will extend its range into the Central Valley of California. This change could cause considerable crop damage (Gutierrez et al. 2006).

Diversity of herbivorous insects and their impacts on plants generally increase with temperature (Wilf and Labandeira 1999). The pine aphid *Schizolachnus pineti* shows increased feeding, fecundity, and rate of population increase at 26°C (78.8°F) versus 20°C (68°F). Optimum fecundity is at 24-26°C (75.2°F-78.8°F), 4-6°C (7.2-10.8°F) higher than current mean daytime temperatures (Holopainen and Kaninulainen 2004). Though increased problems are generally expected, some pests may not increase. Increased densities of the aphid, *Obtusicauda coweni,* on sagebrush were not seen under field conditions in the Rocky Mountains (Adler et al. 2007).

As nighttime temperatures increase, growth rates of caterpillars such as imported cabbageworm, *Pieris rapae*, increase (Whitney-Johnson et al. 2005). Warmer winters have already lead to increased overwintering populations of some crop pests (Matsumara et al. 2005). These conditions will also increase damage from pest nematodes (Griffith et al. 1997).

Some pests will be able to have additional generations each year, leading to increased crop damage. For instance, diamondback moth, *Plutella xylostella*, is expected to complete two additional generations each year in Japan (Morimoto et al. 1998). This insect is already able to overwinter in cold areas such as Canadian Alberta (Dosdall 1994). Northward shifts of more than 1000 km (600 mi) are expected in Europe for the corn borer, *Ostrinia nubilalis* (Porter et al. 1991). The mountain pine beetle, *Dendroctonus ponderosae*, in the Rocky Mountains now produces one generation per year instead of one every two years (Parmesan 2007). Range and damage is expected to increase in Canadian pine forests (Logan and Powell 2004).

Increased Outbreaks and Upheavals

As a result of global warming, the weather will reflect greater numbers of catastrophic events such as droughts and floods. Increased frequency of extreme events will likely cause changes in herbivore populations. Studies of forest insects have led to predictions of increased frequency and longer durations of pest outbreaks (Volney and Fleming 2000; Logan et al. 2003). For instance, an outbreak of the lepidopteran *Argyresthia retinella* that occurred in Norway birch forests was attributed to drought and high temperatures (Tenow et al. 1999). The range of winter moth, *Operophtera brumata*, has increased in Norway birch forests (Hagen et al. 2007). Alternating cold and warm winters due to global warming encouraged an outbreak of the caterpillar *Thaumetopoea pityocampa* on Scots pine, *Pinus sylvestris* (Hodar and Zamora 2004; Buffo et al. 2007).

Increased range of the ambrosia beetle *Platypus quercivorus* led to an encounter with a fungus that causes oak dieback disease. The beetle then infected oaks with this pathogen, leading to an epidemic of the disease in Japan (Kamata et al. 2002). Global warming is expected to encourage pine damage from the European pine sawfly, *Neodiprion sertifer* (Virtanen et al. 1996), and from pine shoot beetle, *Tomicus destruens* (Faccoli 2007).

Pests Range Increases Vertically

As the lower slopes of mountain peaks get warmer, plants, animals, and pest populations have started to migrate upward. Tickborne encephalitis has moved upward in Europe in the last 30 years. The average rate of ascension correlates with the average yearly temperature increase (Zeman and Benes 2004).

Freezing isotherms have climbed about 160 m (525 ft) in the tropics since 1970. This means that those seeking refuge from malaria must travel higher. According to Epstein 2001, “insects and insect-borne diseases are now being reported in high elevations in east and central Africa, Latin America, and Asia.”

As mosquitoes climb upwards, they are having an effect on wildlife populations. In Hawaii, most of the native birds below 4500 feet (1372 m) have been killed by a form of avian malaria caused by *Plasmodium relictum*. Birds in cooler areas above this elevation escape the mosquitoes (Harvell et al. 2002).

Plants and Wildlife Climb Higher

This scramble for higher altitudes has also been seen for wildlife. A wildlife survey of Yosemite Valley, CA published by Professor Joseph Grinnell in 1924 has recently been updated. Fewer animals were found and species such as the California vole, *Microtus californicus*; and

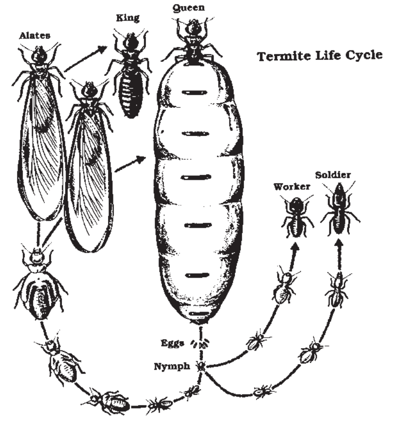
Pinon mouse, *Peromyscus truei*; and Allen's chipmunk, *Tamias senex* were found at higher altitudes (Brower 2006). As the animals climb higher, they take their pests and pathogens along with them.

Plants are also climbing to higher elevations in mountain regions. Plant elevation is a sensitive indicator of global warming, as a 500 m (1640 ft) shift upward is equivalent to a 300 km (180 mi) shift northward (Epstein 2001).

Phenology and Synchrony of Plants and Pests

Phenology describes the timing of biological events. For instance, each plant has a characteristic time for flowering, budbreak, and seed production that is generally set by climate, photoperiod, and temperature. Insect development is also characterized by a number of timed events, such as time of egg hatch. For caterpillars that feed on leaves, survival is best when leaf budbreak is timed with egg hatch (van Asch and Visser 2007).

In the warmer springs associated with global warming, both caterpillars and their host plants have been developing earlier. But insects and plants can respond differently to the same temperature increase. As a result, insect and plant growth may no longer be synchronized (van Asch and Visser 2007). Systems with tight synchrony between phenology of plants and insects will be most affected by warming temperatures. For instance, the synchronization between budbreak of oak tree, *Quercus robur*, and the hatching of winter moth, *Operophtera brumata*, has already been disturbed in England. Eggs of the insect are hatching before leaves are available to eat (Visser and Holleman 2001). Evolution works to correct for these kind of problems, but if the rate of adaptive change is too slow, the species can go extinct (van Asch and Visser 2007).



Western subterranean termite, *Reticulitermes hesperus*

Effects on Beneficial Insects

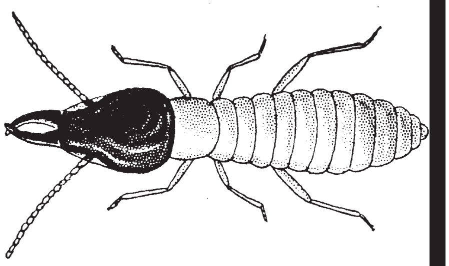
Temperature can have a profound effect on the relationship of pests and predators. Effects of predators can be encouraged or discouraged by temperature increases. For instance, below 11°C (51.8°F), the pea aphid reproduction rate exceeds the rate at which the lady beetle, *Coccinella septempunctata* can consume it. Above 11°C (51.8°F), the situation is reversed. In contrast, natural enemies of the spruce budworm, *Choristoneura fumiferana*, are less effective at higher temperatures (Harrington et al. 2001).

Herbivorous insects may expand their ranges as a result of global warming. As a consequence, they may migrate into areas where natural enemies are not present. Their parasitoids may or may not follow them to new locations. The most extreme effects will be likely on monophagous parasitoids that will have difficulty adapting to a new host (Hance et al. 2007).

As mentioned earlier, some migrations have already started. Two lepidopteran species that feed on mint have migrated northward from their range in Monterey County, CA to the San Francisco Bay Area and the Sacramento Valley (Powell et al. 2000).

Disruption of Parasitoids

Problems are projected to be worse at higher trophic levels. Among insects, parasitoids are likely to bear the brunt of the impact (Thomas et al. 2004; Hance et al. 2007). Parasitoids, herbivores and plants have evolved together in a relatively stable climate. Parasitoids must be able to overwinter to survive, and often have a lower temperature tolerance than their hosts (Karban 1998). Species dependent on a close synchrony with their host are most susceptible to extinction. For instance, parasitoids with a slightly lower base temperature than the host emerge earlier during warmer springs. If this happens more than one season in 20, early parasitoid emergence can lead to extinction due to a crash of the host population (Godfray et al. 1994; Hance et al. 2007).



Formosan soldier, *Coptotermes formosanus*

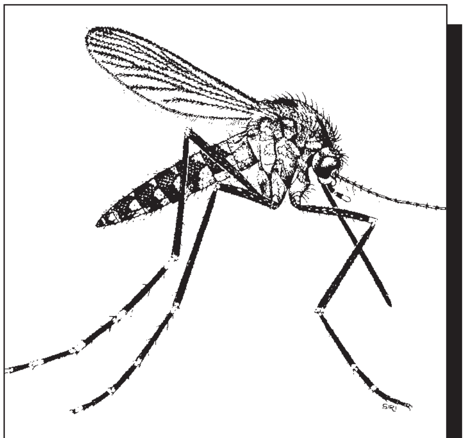
The life of a developing parasitoid depends on suppressing or fooling the host's immune system. Some studies suggest that higher temperatures increase the probability that a host will kill its parasitoid. For instance, parasitism of the caterpillar *Spodoptera littoralis* by the parasitoid *Microplitis rufiventris* is less efficient at 27°C (80.6°F) than at 20°C (68°F) (Thomas and Blanford 2003).

Parasitoid populations may also be disrupted by extreme events and variable climate. A large worldwide study of field collected caterpillars has shown that increased variability in climate leads to reduced parasitism rates. More frequent disturbances mean caterpillars have fewer parasites. Reduced parasitism rates are likely due to "increased lags and disconnections between herbivores and their carnivores that occurs as climatic variability increases" (Stireman et al. 2005).

Stireman et al. (2005), found caterpillars were attacked by both tachinid flies and parasitic wasps. Tachinids were able to adjust to climate variability but highly host specific parasitic wasps adjusted poorly. As the weather patterns become more variable, field crops such as corn, that depend on biological control from host specific parasitoids such as *Trichogramma* spp. are likely to suffer increased pest attacks (Stireman et al. 2005).

Plant Diseases

Many plant diseases, especially those caused by fungi, are expected to increase as a result of warmer temperatures and perhaps increased rainfall. Warmer winters increase the overwintering success of plant pathogens. Optimum growth for many fungal pathogens occurs at 20-25°C (68-77°F). Increased growth of plants will also increase host densities and favor plant diseases (Harvell et al. 2002; Garrett et al. 2006). Tomato leafcurl in Italy is already spreading northward (Parella et al. 2004). Global warming is likely to increase the spread of rice stripe disease in Japan (Yamamura and Yokozawa 2002).


Pest mosquito, *Aedes sp.*

Increasing temperatures are expected to increase potato yields in cold countries like Finland, but the increase will likely be cancelled by increases in potato blight caused by *Phytophthora infestans* (Kaukoranta 1996). Global warming may have already caused increased spread and severity of some virus potato diseases in India (Garg 2005).

Global warming has been implicated in the increased severity of oak dieback caused by *Phytophthora cinnamomi*. This organism is encouraged by wet and warm soil (Brasier 1996). Sudden oak death, which appeared in the U.S. is caused by a similar organism, *P. ramorum*. The connection between global warming and this outbreak has not been explored.

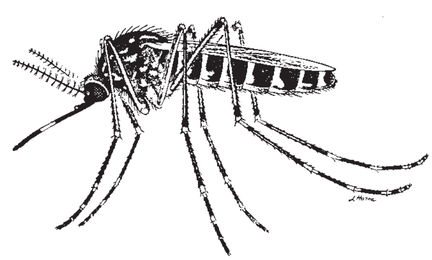
Weeds

Plants can be divided into C3 and C4 types, according to how they utilize CO_2 in photosynthesis. Wheat, rice and soybeans are C3 plants. These respond to increased CO_2 concentrations with increased growth. Corn, sorghum, sugarcane, and millet are C4 plants that are less responsive to CO_2 increases. Weeds also follow this division. Lambsquarters, Canada thistle, jimsonweed, quackgrass, plantain, and velvetgrass are C3 weeds. Redroot pigweed, purple nutsedge, itchgrass, and johnsongrass are C4 weeds. Increased CO_2 levels encourage the growth of C3 weeds, and increase the water use efficiency of both C3 and C4 weeds. Increased temperatures encourage C4 weeds (Patterson 1995; Patterson et al. 1999).

Subtropical weeds in the U.S. are likely to spread northward. Increased temperature may mean that serious weeds such as Japanese honeysuckle, *Loniceria japonica*, and kudzu, *Pueraria lobata*, could extend their northern limits by several hundred km. Problems with several other weed species are expected to increase (Patterson 1995; Zavaleta and Royval 2002). Witchweed, a root parasite of corn might be able to expand from North Carolina into the U.S. Corn Belt. Perennial weeds may be harder to control, since increased photosynthesis may lead to greater storage of food supplies. Buildup of high starch concentrations in leaves of C3 plants may also interfere with the use of herbicides (Rosenzweig and Hillel 1995; Patterson 1995).

Stopping Global Warming

Global warming is probably going to lead to increased pest populations. We can expect larger problems with structural, garden, forest, and agricultural pests. Other disruptions such as increased floods, drought and hurricanes are likely. But just to identify the problem is not enough. We need to find some solutions.


Pest mosquito, *Culex sp.*

IPM methods provide enough flexibility that we will be able to deal with many of the pests. But reducing the amount of global warming is desirable. Part of the solution is to burn less fossil fuel. Turning to renewable energy sources such as solar and wind should reduce global warming. Using energy efficient household appliances is part of the solution. Driving more fuel efficient cars will reduce greenhouse emissions. There are also some technological solutions that may or may not be practical. Such as injection of CO_2 produced by power plants into deep brine deposits (Socolow 2007).

According to Rosenzweig and Hillel (1995), agriculture may account for about 15% of the greenhouse gas emissions caused by humans. We can reduce the effects of global warming by buying organic produce and encouraging organic farming. Organic farming leads to an increase in soil carbon in the form of organic matter. Each acre of organic production takes about 3,500 pounds (1590 kg) of CO_2 from the air and adds it to soil each year. Changing corn and soybean production to organic methods would remove about 580 billion pounds (264 billion kg) of carbon dioxide from the atmosphere each year. Organic farming methods help slow down the depletion of carbon from the soil, decreasing the amount of carbon dioxide released. Carbon is added to the soil by the cultivation of cover crops for use as green manures. Also, synthetic fertilizers, which require large amounts of energy to produce are not used (Hepperly 2007).

Increased use of agroforestry methods could help. Agroforestry blends tree crops with field crops, and both types of crops benefit as a result. Agroforestry can lead to fewer pests in field crops because large monocultures are broken up. Mean uptake of CO_2 and carbon sequestration from agroforestry has been estimated at 95 Mg/ha (95 metric tons/ha) (Albrecht and Kandji 2003).

Part of the greenhouse gas emission is due to deforestation. Tropical deforestation is responsible for about 20% of CO_2 emissions caused by humans each year. Planting trees can help absorb carbon dioxide, leading to increased carbon sequestration. So general reforestation efforts could help reduce global warming (UCS 2007).

Global warming is one of those problems that is caused by human activities and can be solved by human activities. By acting now, we can mitigate the problem and will not have to face the doomsday forecasts of melting icecaps, flooded seacoasts, and species extinctions.

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References

Adler, L.S., P. de Valpine, J. Harte and J. Call. 2007. Effects of longterm experimental warming on aphid density in the field. *J. Kansas Entomol. Soc.* 80(2):156-168.

Albrecht, A. and S.T. Kandju. 2003. Carbon sequestration in tropical agroforestry systems. *Agric. Ecosys. Environ.* 99(1/3):15-27.

Bale, J.S., G.J. Masters, I.D. Hodkinson et al. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biol.* 8(1):1-16.

Bayoh, M.N. and S.W. Lindsay. 2003. Effect of temperature on the development of the aquatic stages of *Anopheles gambiae* (Diptera: Culicidae). *Bull. Entomol. Res.* 93(5):375-381.

Benson, E.P. and P.A. Zungoli. 1997. Cockroaches. In: Mallis, pp. 122-202.

Brasier, C.M. 1996. *Phytophthora cinnamomi* and oak decline in southern Europe. Environmental constraints including climate change. *Ann. Sci. For.* 53(2/3):347-358.

Brower, K. 2006. Disturbing Yosemite. *Calif. Mag.* 117(3)14-23; 41-44.

Buffo, E. A. Battisti, M. Stastny and S. Larsson. 2007. Temperature as a predictor of survival of the pine processionary moth in the Italian Alps. *Agric. For. Entomol.* 9(1):65-72. [CAB Abstracts]

Busvine, J.R. 1980. *Insects and Hygiene*, 3rd ed. Chapman and Hall, New York. pp. 398-399 of 568 pp. [cited in Katz, 1997]

Cannon, K.F. and W.H. Robinson. 1981. Wood consumption and growth of *Hylotrupes bajulus* larvae in three environments. *Environ. Entomol.*10:458-461.

Collins, W., R. Colman, J. Haywood, R.R. Manning and P. Mote. 2007. The physical science behind climate change. *Sci. Amer.* 297(2):64-73. see www.ipcc.ch for the latest IPCC report on climate change.

Cox, P.D. and C.H. Bell.1991. Biology and ecology of moth pests of stored foods. In: Gorham, pp. 181-193.

Cymorek, S. 1968. *Hylotrupes bajulus. Zeit. Angew. Ent.* 62:316-344. [CAB Abstracts]

Dosdall, L.M. 1994. Evidence for successful overwintering of diamondback moth, *Pluttella xylostella*, in Alberta. *Can. Entomol.* 126(1):183-185.

Easterling, D.R., G.A. Meehl, C. Parmesan et al. 2000. Climate extremes, observations, modeling, and impacts. *Science* 289:2068-2074.

Ebeling, W. 1975. *Urban Entomology*. University of California, Division of Agricultural Sciences, Oakland, CA. 695 pp.

Ehmann, N.R. 1997. Flies, gnats and midges. In: Mallis, pp. 773-834.

Epstein, P. 2000. Is global warming harmful to health? *Sci. Amer.* August: 50-57.

Epstein, P. 2001. Climate change and emerging infectious diseases. *Microbes and Infection* 3:747-754.

Faccoli, M. 2007. Breeding performance and longevity of *Tomicus destruens* on Mediterranean and continental pine species. *Ent. Exp. Appl.* 123(3):263-269. [CAB Abstracts]

Fay, R.W. 1964. The biology and bionomics of *Aedes aegypti* in the laboratory. *Mosq. News* 24(3):300-308.

Garg, I.D. 2005. Virus and virus like diseases of potato and their management. In: *Challenging Problems in Horticultural and Forest Pathology*, eds. R.C Sharma and J.N. Sharma. Indus Publishing Co., New Delhi India. [CAB Abstracts]

Garrett, K.A., S.P. Dendy, E.E. Frank, M.N. Rouse and S.E. Travers. 2006. Climate change effects on plant disease: genomes to ecosystems. *Annu. Rev. Phytopathol.* 44:489-509.

Gil, C.A. 1920. The relationship between malaria and rainfall. *Ind. J. Med. Res.* 8:618-632. [cited in Epstein 2001]

Godfray, H.C.J, M.P. Hassell and R.D. Holt. 1994. The population dynamic consequences of phenological asynchrony between parasitoids and their hosts. *J. Anim. Ecol.* 63:1-10. [CAB Abstracts]

Gorham, J.R., ed. 1991. *Ecology and Management of Food Industry Pests*. FDA Bull. No. 4, Washington, DC. 595 pp.

Griffith, G.S., R. Cook and K.A. Mizen. 1997. *Ditylenchus dipsaci* infestation of *Trifolium repens*. II Dynamics of infestation development. *J. Nematol.* 29(3):356-369.

Gutierrez, A.P., T. D'Oultremont, C.K. Ellis and L. Ponti. 2006. Climatic limits of pink bollworm in Arizona and California: effects of climate warming. *Acta Oecologica* 30(3):353-364. [CAB Abstracts]

Hagen, S.B., J.U. Jepson, R.A. Ims and N.G. Yoccoz. 2007. Shifting altitudinal distribution of outbreak zones of winter moth, *Operophtera brumata* in sub-arctic birch forest a response to global warming? *Ecography* 30(2):299-307. [CAB Abstracts]

Hance, T. J. van Baaren, P. Vernon and G. Boivin. 2007. Impact of extreme temperatures on parasitoids in a climate change perspective. *Annu. Rev. Entomol.* 52:107-126.

Harrington, R., R.A. Fleming and I.P. Woiwod. 2001. Climate change impacts on insect management and conservation in temperate regions. Can they be predicted? *Agric. For. Meterol.* 3:233-240. [Cited in Hance et al. 2007]

Harvell, C.D., C.E. Mithchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfeld and M.D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. *Science* 296:2158-2162.

Harvey, P.A. 1946. Life history of *Kalotermes minor*. In: Kofoid et al., pp. 217-233.

Hedges, S. 1997. Ants. In: Mallis, pp. 503-589.

Hepperly, P. 2007. The organic farming response to climate change. *Pesticides and You* 27(1):14-19.

Hodar, J.A. and R. Zamora. 2004. Herbivory and climatic warming: a Mediterranean outbreaking caterpillar attacks a relict, boreal pine species. *Biodivers. Conserv.* 13(3):493-500.

Holopainen, J.K. and P. Kainulainen. 2004. Reproductive capacity of the grey pine aphid and allocation response of Scots pine seedlings across temperature gradients: a test of hypotheses predicting outcomes of global warming. *Can. J. For. Res.* 34(1):94-102. [CAB Abstracts]

Hopp, M.J. and J.A. Foley. 2001. Global change relationships between climate and the dengue fever vector, *Aedes aegypti. Climatic Change* 48(2/3):441-463. [CAB Abstracts]

Houghton, J.T. et al. 2001. *Climate Change 2001: the Scientific Basis*. Cambridge University Press, Cambridge, UK.

Johansen, B.E. 2002. *The Global Warming Desk Reference*. Greenwood Press, Westport, CT. 353 pp.

Kamata, N., K. Esaki, K. Kato, Y. Igeta and K.Q Wada. 2002. Potential impact of global warming on deciduous oak dieback caused by ambrosia fungus *Raffaelea* sp. carried by ambrosia beetle *Platypus quercivorus* (Coleoptera: Playpodidae) in Japan. *Bull. Ento. Res.* 92(2):119-126. [CAB Abstracts]

Karban, R. 1998. Caterpillar basking behavior and nonlethal parasitism by tachinid flies. *J. Insect Behav.* 11:713-723.

Karl, T.R., R.W. Knight, D.R. Easterling and R.G. Quayle. 1995. Trends in U.S. climate change during the twentieth century. *Consequences* 1:3-12.

Karl, T.R. and K.E. Trenbeth. 2003. Modern global climate change. *Science* 302:1719-1723.

Katz, H.L. 1997. Clothes moths. In: Mallis, pp. 427-462.

Kaukoranta, T. 1996. Impact of global warming on potato late blight: risk, yield loss and control. *Agric. Food Sci. Finland* 5(3):311-327. [CAB Abstracts]

Kofoid, C.A., S.F. Light, A.C. Horner, M. Randall, W.B. Herms and E.E. Rowe, eds. 1946. *Termites and Termite Control*, 2nd ed., rev. University of California Press, Berkeley, CA. 795 pp.

Legner, E.F. and C.W. McCoy. 1966. The house fly, *Musca domestica*, an exotic species in the western hemisphere incites biological control studies. *Can. Entomol.* 98:243-248.

Logan, J.A., J. Regniere and J.A. Powell. 2003. Assessing the impacts of global warming on forest pest dynamics. *Frontiers Ecol. Environ.* 1:130-137. [cited in Parmesan 2007]

Logan, J.A. and J.A. Powell. 2004. Modelling mountain pine beetle phenological response to temperature. Info. Rpt. BC-X-399, Canadian For. Serv. [CAB Abstracts]

Mallis, A. 1997. *Handbook of Pest Control*, 8th ed. S. Hedges, and D. Moreland eds. Mallis Handbook and Technical Training Co., Cleveland, OH. 1454 pp.

Martens, W.J.M., T.H. Jetten and D. Focks. 1997. Sensitivity of malaria, schistosomiasis and dengue to global warming. *Climatic Change* 35:145-156.

Matsumura, M., M. Tokuda, N. Endo, S. Ohata and S. Kamitani. 2005. Distribution and abundance of the maize orange leafhopper *Cicadulina bipunctata* (Homoptera: Cicadellidae) in Kikuchi, Kumamoto, Japan in 2004. *Kyushu Plant Prot. Res.* 51:36-40. [CAB Abstracts]

Mohan, J.E. 2006. Biomass and toxicity responses of poison ivy, *Toxicodendron radicans*, to elevated atmospheric CO2. *Proc. Natl. Acad. Sci.* (USA) 103(24):9086-9089.

Morimoto, N., O. Imura and T. Kiura. 1998. Potential effects of global warming on the occurrence of Japanese pest insects. *Appl. Entomol. Zool.* 33(1):147-155. [CAB Abstracts]

Morrison, L.W., M.D. Korzukin and S.D. Porter. 2005. Predicted range expansion of the invasive fire ant, *Solenopsis invicta*, in the Eastern United States based on the VEMAP global warming scenario. *Diversity and Distributions* 11(3):199-204. [CAB Abstracts]

Newell, W. and T.C. Barber. 1913. The Argentine ant. *USDA Bureau Entomol. Bull.* 122:1-98.

Noland, J.E., J.H. Lilly and C.A. Bauman. 1949. A laboratory method for rearing cockroaches and its application for dietary studies on the German roach. *Ann. Entomol. Soc. Amer.* 42(1):63-70.

Parella, G., D. Alioto and A. Ragozzino. 2004. Yellow leaf curl on tomatoes in Campania. *Inform. Agrario* 60(41):58-60 [CAB Abstracts]

Parmesan, C., N. Ryrholm, C. Stefanescu et al. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399:579-583.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37-42.

Parmesan, C. 2007. Ecological and evolutionary responses to recent climate change. *Annu. Rev. Ecology, Evolution, and Systematics* 37:637-669.

Patterson, D.T. 1995. Weeds in a changing climate. *Weed Sci.* 43(4):685-700.

Patterson, D.T., J.K. Westbrook, R.J.V. Joyce, P.D. Lingren and J. Rogasik. 1999. Weeds, insects, diseases. *Climatic Change* 43(4):711-727.

Patz, J.A. and S.H. Olson. 2006. Climate change and health: global to local influences on disease risk. *Ann. Trop. Med. Parasitol.* 100(5/6):535-549. [CAB Abstracts]

Penuelas, J. and I. Filella. 2001. Responses to a warming world. *Science* 294:793-795.

Porter, J.H., M.L. Parry, and T.R. Carter. 1991. The potential effects of climatic change on agricultural pest insects. *Agric. For. Meterology* 57(1/3):221-240. [CAB Abstracts]

Potter, M.F. 1997. Termites. In: Mallis, pp. 233-332.

Powell, J.A., P. Russell, S. Russell and F.A.H. Sperling. 2000. Northward expansion of two mint feeding species of *Pyraustra* in California. *Holarctic Lepidoptera* 7(2):55-58. [CAB Abstracts]

Prasad, P.V.V., L.H. Allen, Jr. and K.J. Boote. 2005. Crop responses to elevated carbon dioxide and interaction with temperature: grain legumes. *J. Crop Improv.* 13(1/2):113-115.

Rinderer, T.E., B.P. Oldroyd and W.S. Sheppard. 1993. Africanized bees in the U.S. *Sci. Amer.* 269(6):84-90.

Root, T.L., J.T. Price, K.R. hall, S.H. Schneider, et al. 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421:57-60.

Rosenzwieg, C. and D. Hillel. 1995. Potential effects of climate change on agriculture and the food supply. *Consequences* 1(2):1-10.

Salinger, M.J., M.V.K. Sivakumar and R. Motha. 2005. Reducing vulnerability of agriculture and forestry to climate variability and change. *Climatic Change* 70(1/2):341-342.

Sci. News. 2006. Dengue strikes United States. *Science News* 170:286.

Schneider, S.H. and T.L. Root. 2002. *Wildlife Responses to Climate Change.* Island Press, Washington. 437 pp.

Silverman, J., M.K. Rust and D.A. Reierson. 1981. Influence of temperature and humidity on survival and development of the cat flea, *Ctenocephalides felis* (Siphonoptera: Pulcidae). *J. Med. Entomol.* 18(1):78-83.

Smith, J.L. and M.K. Rust 1994. Temperature preferences of the western subterranean termite, *Reticulitermes hesperus. J. Arid Environ.* 28:313-323.

Socolow, R.H. 2005. Can we bury global warming? *Sci. Amer.* 293(1):49-55.

Stireman, J.O. et al. 2005. Climatic unpredictability and parasitism of caterpillars: implications of global warming. *Proc. Natl. Acad. Sci.* (USA) 102(48):17384-17387.

Tenow, O., A.C. Nilssen, B. Holmgren and F. Elverum. 1999. An insect (*Argyresthia retinella*) outbreak in northern birch forests, released by climate changes. *J. Appl. Ecol.* 36(1):111-122.

Thakur, R.K., N. Hooda and V. Jeeva. 2003. Termites and global warming, a review. *Indian Forester* 129(7):923-930. [CAB Abstracts]

Thomas, M.B. and S. Blanford. 2003. Thermal biology in insect parasite interactions. *Trends Ecol. Evol.* 18:344-350.

Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont et al. 2004. Extinction risk from climate change. *Nature* 427:145-148.

UCS (Union of Concerned Scientists). 2007. Recognizing forests' role in climate. *Permaculture Activist* 65:9-13.

Usinger, R.L. 1966. *Monograph of Cimicidae*, Vol. 7, Thomas Say Foundation Series, Entomological Society of America, College Park, MD. 585 pp.

Van Asch, M. and M.E. Visser. 2007. Phenology of forest caterpillars and their host trees: the importance of synchrony. *Annu. Rev. Entomol.* 52:37-55.

Vinson, S.B. and A.A. Sorensen. 1986. *Imported Fire Ants: Life History and Impact.* Texas Dept. Agric., PO Box 12847, Austin, TX 78711, 28pp.

Virtanen, T. S. Neuvonen, A. Nikula, M. Varama and P. Niemela. 1996. Climate change and the risks of *Neodiprion sertifer* outbreaks on Scots pine. *Silva Fennica* 30(2/3):169-177. [CAB Abstracts]

Visser, M.E. and L.J.M. Holleman. 2001. Warmer springs disrupt the synchrony of oak and winter moth phenology. *Proc. Royal Soc. London*, Series B. 268:(1464):289-294. [CAB Abstracts]

Volney, W.J.A. and R.A. Fleming. 2000. Climate change and impacts of boreal forest insects. *Agric. Ecosys. Environ.* 82(1/3):283-294.

Whitney-Johnson, A., M. Thompson and E. Hon. 2005. Responses to predict global warming in *Pieris rapae*: consequences of nocturnal versus diurnal temperture change on fitness. *Environ. Entomol.* 34(3):535-540.

Wilf, P. and C.C. Labandeira. 1999. Response of plant insect associations to Paleocene Eocene warming. *Science* 284:2153-2156.

Willis, E.R., G.R. Riser and L.M. Roth. 1958. Observations on reproduction and development in cockroaches. *Ann. Entomol. Soc. Amer.* 5(1):53-69.

Yamamura, K. and M. Yokozawa. 2002. Prediction of a geographical shift in the prevalence of rice stripe disease transmitted by the small brown planthopper, *Laodelphax striatellus* (Hemiptera:Delphacidae) under global warming. *Appl. Entomol. Zool.* 37(1):181-190. [CAB Abstracts]

Yang, G.J., P. Vounatsou, X.N. Zhou, M. Tanner and J. Utzinger. 2005. A potential impact of climate change and water resource development on the transmission of *Schistosoma japonicum* in China. *Para. Roma* 47(1):127-134. [CAB Abstracts]

Zavaleta, E.S. and J.L. Royval 2002. Climate change and the susceptibility of U.S. ecosystems to biological invasions: two cases of expected range expansion. In: Schneider and Root, pp. 277-341 of 437 pp.

Zeman, P. and C. Benes. 2004. A tickborne encephalitis ceiling in Central Europe has moved upwards during the last 30 years. *Int. J. Med. Microbiol.* 293(Suppl. 37):48-54 [CAB Abstracts]

Ziska, L. 2007. Climate change, plant biology and public health. *Pesticides and You* 27(1):9-13.

ESA Annual Meeting Highlights—5th Part

By Joel Grossman

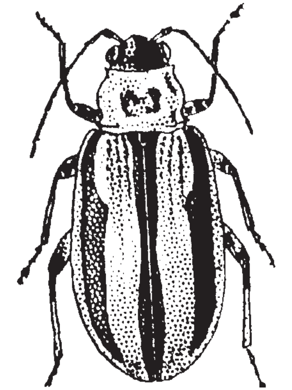
These Conference Highlights are from the annual meeting of the Entomological Society of America (ESA), Dec. 10-13, 2006, in Indianapolis, Indiana. ESA's next annual meeting is December 9-12, 2007, in San Diego, California. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org).

Squash Bug Biocontrol

Reduced-risk pesticides have lower toxicity to humans and non-target organisms and less environmental risk than "high-risk" pesticides such as organophosphates, carbamates, and pyrethroids. "By using reduced risk pesticides such as spinosad to manage pests such as cucumber beetle, squash vine borer, aphids and squash bugs in pumpkin and squash systems it was possible to significantly increase biological control of squash bugs, *Anasa tristis*, compared with using high-risk pesticides," said Gerald Brust (Univ of Maryland, 27664 Nanticoke Rd, Salisbury, MD 21801; jbrust@umd.edu). "This increase in biological control resulted in a 50% yield increase in the reduced-risk systems compared with the control, and yield equal to the high-risk system."

Populations of predators such as minute pirate bugs, *Orius* sp., and assassin bugs were significantly higher when spinosad rather than pyrethroids were sprayed at the bases of pumpkin and squash plants every 10 days. Spinosad plots had about 1.56 adult pirate bugs per plant; versus 0.08 per plant in systems using high-risk pesticides; and 1.83 in no-pesticide systems. Squash bug parasitism by the tachinid fly *Trichopoda pennipes* was "9-16 times greater in reduced risk systems compared with high-risk systems and were 21.5% greater than in the control," said Brust.

Squash Traps Cucumber Beetle


Striped cucumber beetle, *Acalymma vittatum*

Striped cucumber beetle, *Acalymma vittatum*, a major U.S. cucumber pest, feeds on roots, scars fruit, defoliates older plants and can kill small plants, making it a top priority for Michigan organic cucumber growers, said Matthew Kaiser (Michigan State Univ, B18 Food Safety Toxicol Bldg, East Lansing, MI 48824; kaiserm3@msu.edu). Blue Hubbard squash shows particular promise as a protective trap crop by reducing cucumber defoliation.

Trap crops of blue Hubbard squash protect cucumbers most consistently in the early season. Later in the season cucumber beetles became so numerous at one site that the squash trap crop was destroyed, and the cucumber crop was attacked. The squash trap crop held up better at another site, protecting cucumbers later into the season and trapping 15-20 beetles per squash plant. Cucurbitacin sprays on grass did not attract beetles.

IPM Beats Beet Root Maggot

Sugarbeet root maggot, *Tetanops myopaeformis*, scrapes beet root surfaces, causing about 40% damage in the $1.5 billion sugarbeet industry in the Upper Midwest region around North Dakota and Minnesota, which accounts for almost half of U.S. beet sugar production. About 75% of the region's sugarbeets are treated with the pesticide turbophos, said Ayanava Majumdar (North Dakota State Univ, 202 Hultz Hall, Fargo, ND 58105; ayanava.majumdar@ndsu.edu). IPM alternatives in Minto and St. Thomas, North Dakota, included the microbial insecticide *Metarhizium anisopliae* and low and high cover crop seeding rates for oats (Newdak) and rye (Dacold) broadcast just ahead of planting sugarbeets.

In 2005, the combination of *Metarhizium anisopliae* and cover crops in sugarbeet fields was as effective as turbophos. In 2006, a drought year, IPM produced similar results, except in St. Thomas, where turbophos was more effective. High seeding rates of the grain cover crops had a large effect via modifying the micro-habitat. Majumdar is working on adjusting the seeding rate for greatest effectiveness.

Resistant Rice with Endophytes

"The rice leaffolder, *Cnaphalocrocis medinalis*, is a migratory rice pest in many Asian countries including Japan," and management "acutely depends on chemical pesticides because biological and cultural control is ineffective," said Youichi Kobori (National Agric Res Center, 3-1-1 Kannondai, Tsukuba, Ibaraki, Japan; koboriy@affrc.go.jp). Resistant rice infected with the endophytic bacteria, *Herbaspirillum* sp. B65 and *Azospirillum* sp. B510a, may provide an alternative.

Rice endophytes have a milder effect on pests than synthetic insecticides, and widespread use might select for resistant pest biotypes. An IPM approach combining pheromone mating disruption and endophytes might be more sustainable in reducing rice leaffolder populations below the economic injury level. "The combination of endophyte use and mating disruption is environment-friendly," said Kobori. "This technology would contribute to sustainable farming through conserving native natural enemies, especially polyphagous spiders."

Rice endophytes are now being tested against the rice brown planthopper, *Nilaparvata lugens*, "one of the most injurious insect pests of rice plants in Japan," said Yukie Sato (National Agric Res Center, 3-1-1 Kannondai, Tsukuba, Ibaraki, Japan; satoyuky@affrc.go.jp). "Use of the endophytes enables us to reduce the cost and environmental risks of the insect pest management."

"Rice plants infected with bacterial endophytes, *Herbaspirillum* sp. and *Azospirillum* sp., show moderate resistance against the most serious rice pests, the brown planthopper and the whitebacked planthopper," said Yoshito Suzuki (National Agric Res Center, 3-1-1 Kannondai, Tsukuba, Ibaraki, Japan; pa8422@affrc.go.jp). However, "use of the endophytes frequently fails to suppress brown planthopper density to an acceptable level ... unless additional tactics are incorporated into the management system." Conservation biocontrol may help "prevent brown planthopper from rapidly developing a biotype resistant to endophyte-infected rice plants."

$3.5 Million Arkansas Armyworm Savings

Wheat can stand considerable defoliation, and lowering treatment thresholds can save money. Research by Tim Kring (Univ of Arkansas, AGRI 321, Fayetteville, AR 72701; tkring@uark.edu) has resulted in new thresholds to manage infestations of spring armyworm, *Pseudaletia unipuncta*. The new threshold for wheat insects in Arkansas is unique since the armyworm is allowed to completely defoliate maturing wheat. Adoption by producers is high, and savings generated by the application of this threshold are significant. More than 700,000 acres (283,000 ha) of Arkansas wheat were treated for armyworm in 2001, and none of these applications would have been recommended under the threshold."

Armyworm infests 25% of wheat fields in a typical year and 75% of fields in an outbreak year. Even with wheat plantings reduced 60% to 370,000 acres (150,000 ha) in 2006, "adoption of the threshold has eliminated unnecessary applications on more than 90,000 acres (36,400 ha) each year," said Kring. "This represents a statewide savings to producers of $720,000 annually with current acreage, or more than $3.5 million since adoption of the threshold."

Growers were convinced by experimental results from an artificial defoliation method in which wheat leaves were removed from bottom to top over four days, simulating typical Arkansas late-season armyworm defoliation of wheat plants in the field. Even after removal of all the wheat leaves and the awnings protecting the panicles, there was no measurable grain yield or weight loss. Germination tests are underway to extend the threshold to wheat seed producers concerned about seed viability and germinability.

Washing Away Thrips

In the southern states, high levels of tobacco thrips, *Frankliniella fusca*, and tomato spotted wilt virus (TSWV) are associated with dry winter/spring weather; low thrips and virus levels are associated with rainy weather. "TSWV incidence increases with increasing immature *F. fusca* populations," said Shannon Voss (North Carolina State Univ, 3210 Ligon St, Raleigh, NC 27607; scvoss@ncsu.edu). Four days of high simulated rainfall during April, three days of naturally high rainfall in March and May, or six days of high rainfall in March, April or May was sufficient to suppress the growth of immature thrips populations. Continued high rainfall throughout May further depressed thrips populations, whereas immature thrips populations rebounded in dry weather.

Thrips Biocontrol Nematode

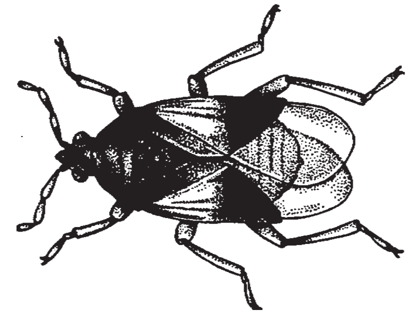
Tobacco thrips, *Frankliniella fusca*, is one of at least nine thrips species capable of transmitting tomato spotted wilt virus (TSWV) in Florida peanuts. More female thrips acquire the virus, but males are more efficient at spreading it. The entomogenous nematode *Thripinema fuscum* "is a potential biocontrol agent," said Kelly Sims (Univ of Florida, PO Box 110620, Gainesville, FL 32611; simsk@ufl.edu).

T. fuscum can sterilize female thrips and alter early spring feeding behavior. Infected thrips feed less frequently, reducing the primary and secondary spread of TSWV.

Hunter Fly Biocontrol

First detected in North America by an upstate New York IPM scout monitoring greenhouse sticky traps, the hunter fly, *Coenosia attenuata*, is an example of a beneficial insect spread around on plant material, said John Sanderson (Cornell Univ, 135 Insectary Bldg, Ithaca, NY 14853; jps3@cornell.edu). Native to southern Europe, hunter flies were subsequently detected on sticky traps in two-thirds of surveyed NY greenhouses, as well as in Texas, Louisiana, Florida, Illinois and all

Conference Notes



Insidious flower bug, *Orius sp.*

around the U.S., including outdoors in Los Angeles, CA.

Voracious generalist predators, hunter flies practice a sit-and-wait strategy, only pursuing "right-sized" prey flying by. Specialized mouth parts suck out the body contents of pests such as leafminers, whiteflies, adult fungus gnats and shore flies. When prey densities are low, hunter flies turn cannibalistic. Larval hunter flies live in the soil and are also predatory.

Though in the same family as house flies (Muscidae), high numbers of hunter flies in potted plants are hardly noticeable. Indeed, the IPM scout who originally detected hunter flies mistakenly thought that these natural enemies were nocturnal, because they were so invisible despite being present in large numbers providing biocontrol. Even USDA-APHIS has no problem with movement of hunter flies.

Walnut Intercrop Cuts Alfalfa Weevil

"Previous studies in our lab have demonstrated that alfalfa intercropped with walnut supported significantly more parasitic Hymenoptera and/or predators than did traditionally grown alfalfa," said Terryl Woods (Univ of Missouri, 1-31 Agric Bldg, Columbia, MO 65211; woodst@missouri.edu). "The presence of walnut trees appears to increase natural enemy numbers, and significantly increase parasitism of alfalfa weevil, *Hypera postica*, over time. Although alfalfa yields were poorer in narrow (12.2 m; 40 ft) alleyways, wider (24.4 m; 80 ft) alleyways produced as much alfalfa as an open field while retaining the insect community benefits of an agroforestry practice." Major alfalfa weevil natural enemies included the parasitoid *Bathyplectes* and the fungus *Zoophthora*.

Monitoring Biocontrol with DNA

Soybean aphids, *Aphis glycines*, that can reduce soybean yields by 40-50%, are spreading across the Upper Midwest and are a concern in Indiana, which produces 8% of U.S. soybeans on 5.9 million acres (2.4 million ha). There is a need to have more detailed information on soybean aphid biocontrol. Monitoring the impact of beneficials within the ecological food web is now possible using molecular detection systems, said James Harwood (Univ of Kentucky, S-225 Agricultural Science Center North, Lexington, KY 40546; james.harwood@uky.edu).

Prey-specific antibodies and PCR amplification of DNA can reveal details of predator-prey linkages within complex ecosystems. Harwood created DNA primers for *Orius insidiosus* and major prey species. There was no cross-amplification of DNAs among the species, but DNA decay rates of each species had to be calculated. Soybean aphid DNA disappears from predators in 30-40 hours. Soybean thrips DNA decays faster, as does Asian lady beetle DNA.

DNA monitoring revealed that *Orius* increased soybean aphid consumption as aphid populations increased. *Orius* also consumed large numbers of soybean thrips, a scarce pest that may be a favored food item. *Orius* did not consume lady beetle eggs.

PCR techniques can also be used for real-time molecular measurement of biological control by predators, said Donald Weber (USDA-ARS, BARC-West 011A, Beltsville, MD 20705; weberd@ba.ars.usda.gov). Examples include predation of spotted lady beetle, *Coleomegilla maculata* on pests such as Colorado potato beetle, *Leptinotarsa decemlineata*, as well as predation of spined soldier bug, *Podisus maculiventris* on Mexican bean beetle, *Epilachna varivestis*. Though there was much variability and complexity, all predator egg predation was detected. Sensitivity is such that even 1.5% predation on pest eggs was detected.

Fungi Destroy Midwest Aphids

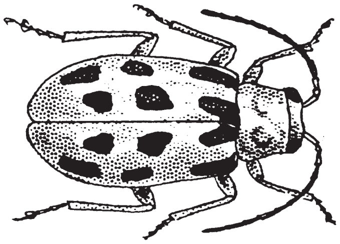
"Fungal pathogens cause natural aphid mortality and when epizootics occur, diseases rapidly spread and destroy local aphid populations," said Takuji Noma (Michigan State Univ, B-11 CIPS, East Lansing, MI 48824; noma@msu.edu). "All cases of soybean aphid, *Aphis glycines*, mycosis examined in 2005 involved the fungal pathogen *Pandora neo-aphidis*." Up to 90% of migratory morphs, but only 3% infection of wingless soybean aphids were infected. The aphid-attacking fungi "coincided with peak or post-peak aphid densities." The fungi were not found when or where aphid populations were low.

Pandora neoaphidis was also recovered from cadavers of pea aphid, *Acyrthosiphon pisum*, and corn leaf aphid. *Rhopalosiphum maidis*. The pathogen *Zoophthora* sp. was identified from cadavers of spotted alfalfa aphid, *Therioaphis maculata*. Fungi also attacked potato aphid, *Macrosiphum euphorbiae*. Crops containing fungi that attacked aphids included soybean, alfalfa, clover and corn. No aphid fungal infections were detected on winter wheat.

IPM for Cucumber Beetle

The western spotted cucumber beetle (WSCB), *Diabrotica undecimpunctata undecimpunctata*, has a wide host range that includes snap beans, lettuce, spinach and corn. Pest feeding on snap bean pods can cause crop rejection if there are too many "bean bites" in this $1,000/acre ($2,500/ha) crop occupying 16,500 acres (6,677 ha) in Oregon. "The grower mantra was just spray and be done with it, don't risk it," as at $4.50/acre ($11.25/ha) a cheap insecticide could be mixed into a fungicide spray, said John Luna (Oregon State Univ, 4017 Agric Life Sci Bldg, Corvallis, OR; lunaj@oregonstate.edu).

In a 250-grower cooperative considered very progressive, about 90% of snap bean fields were sprayed, because the treatment threshold was reduced from six beetles per 20 sweep net sweeps to two beetles per 20 sweeps. Growers figured they would always have at least two beetles, and so did not bother scouting. In 2006, after two years of OSU research growers were given weekly scouting reports and allowed to choose their treatment thresholds. Most fields had less than six beetles per 20 sweeps and no economic damage; though to save scouting time, 10 sweep samples were used. Scouting cost $2.25/acre ($5.60/ha).


Spotted cucumber beetle, *Diabrotica sp.*

In 2006, 53% of 310 snap bean fields occupying over 5,000 acres (2,023 ha) were not sprayed. The number of unsprayed fields would have been higher, but some growers ignored the scouting reports and sprayed anyway. Where snap bean fields bordered corn fields, cucumber beetles gathered in very high numbers at field edges, though few beetles were found in bean field interiors. Most likely cucumber beetles fed in the beans and moved into corn to lay eggs; but beetle movement back and forth between crops cannot be ruled out. Since bean-corn edges were found in about 25% of fields, edge scouting was incorporated into scouting protocols and some growers only sprayed field edges.

Every grower except one benefited from the snap bean IPM program. That one grower, for reasons still unclear, lost a field and fed the rejected beans to the pigs. Luna suspects nearby grass seed fields played a role in that loss, a case of bad crop field diversity. When that one grower suffered, it was like "shock and awe" and all the growers immediately sprayed. However, at the end of the season the growers felt the collective benefit of the program was so great that they would move forward with this sustainable IPM approach in 2007.

Leafy Spurge IPM

"In the Northern Great Plains of North America, leafy spurge, *Euphorbia esula*, may reduce herbage production by as much as 75% when this weed infests pastures and rangelands, resulting in economic losses of nearly $130 million per year to this region," said Ankush Joshi (North Dakota State Univ, Hulz Hall, Fargo, ND 58105; ankush.joshi@ndsu.edu). "Most tools used against leafy spurge are not economical, practical and/or efficacious." Hence, an IPM approach combining herbicides (Imazapic™), *Aphthona* spp. flea beetles for biological control and native grass mixes planted 23 months after beetle releases were evaluated for long-term sustainable leafy spurge control.

"There was a greater reduction in leafy spurge when herbicide was combined with *Aphthona* flea beetles or native grass species," said Joshi, though it is best to wait a year after herbicide treatments before releasing biological control beetles. In 2004, two years after herbicide application, leafy spurge declined from 90 to 41% (49% reduction) in herbicide only plots compared to 69% reduction in plots that received a combination of herbicide and biological control. This reduction was maintained by the flea beetles without additional herbicide application.

Field Borders and Corn Borer IPM

"The European corn borer (ECB), *Ostrinia nubilalis*, is a serious pest of corn and other crops throughout the Midwest U.S., costing farmers more than $1.85 billion annually in crop loss and pest management costs," said William Terrell Stamps (Univ of Missouri, 1-31 Agric Bldg, Columbia, MO 65211; stampst@missouri.edu). "Conservation reserve program CP33, *Habitat Buffers for Upland Birds*, provides incentives for establishing borders in and around cropland that provide food and shelter for grassland birds." However, despite financial incentives farmers are not planting vegetation borders around fields, fearing it will lead to pest increases. Hence, a number of 9.1 m (30 ft) corn field borders were tested: (1) a mixture of warm-season grasses and legumes; (2) a mixture of cool-season grasses and legumes; (3) tall fescue, a cool-season grass; and (4) a corn border control.

"[Corn borer] stalk infestation of warm-season vegetation-bordered corn was always 2 to 3 times less (14% versus 29%) than that of cornfields surrounded by the other three border treatments," said Stamps. Warm-season borders were also the most diverse, being a mixture of little bluestem, *Andropogon scoparius*, side-oats grama, *Bouteloua curtipendula*, and lespedeza, *Lespedeza stipulacea*. Tall fescue was the only border that led to increased cornfield ECB infestations.

Trichogramma Cuts Corn Borer

"The egg parasitoid *Trichogramma ostriniae* from China has been shown to be a good biocontrol agent for European corn borer, said Thomas Kuhar (VPI&SU, 33446 Research Dr, Painter, VA 23420; tkuhar@vt.edu). In 2004, "weekly inundative releases of 150,000 *T. ostriniae* per acre (375,000/ha) in bell pepper fields resulted in high rates of ECB egg parasitism and a significant reduction in cumulative fruit damage.”

In 2005 and 2006, *Trichogramma ostriniae* releases against ECB in potatoes were monitored with yellow sticky cards and sentinel egg masses. There was 20-40% ECB egg parasitization with releases made from a single point in the center of small fields. At wind speeds of 1.1-1.6 m/sec (3.6-5.2 ft/sec), *Trichogramma* dispersed downwind. At wind speeds of 0.9-1.1 m/sec (3.0-3.6 ft/sec), *Trichogramma* dispersal was primarily upwind.

Parasitism decreased at increasing distances from the release point. Parasitism was best in a 0.25 acre (0.1 ha) area around the *Trichogramma* release point. Thus, even in 1-acre (0.4-ha) fields, multiple release points are best for uniform dispersal of *T. ostriniae* in crops such as peppers and potatoes.

Plum Curculio and Nematodes

Insecticides to kill adults have been the main management method for an isolated plum curculio, *Conotrachelus nenuphar*, population in northern Utah’s Box Elder County. A more sustainable control approach using the entomopathogenic nematodes (EPN), *Heterorhabditis bacteriophora* and *Steinernema feltiae*, was tested for three years and provided best results after the first year. “We found no significant differences between EPN species,” said Hong-Geun Kim (Utah State Univ, 5305 Old Main Hill, Logan, UT 84322; kimh@biology.usu.edu), who studied the EPNs at varying temperatures.

Leafy spurge, *Euphorbia esula*

Nematodes were applied to turf beneath trees 3-7 times in summer for 1, 2 or 3 years. “Funnel-shaped screen wire traps with a benzaldehyde lure (IPM Technologies, Portland, OR) were placed on tree trunks from May to October in each year to monitor plum curculio,” said Kim. Experimental plot size was so small that “interplot interference” masked any differences between untreated trees and EPN-treated trees. However, plum curculio trap catches declined from 40-60 per tree after one year of EPN treatment to about 10 in years 2 and 3. This indicates that multi-year nematode applications are a selective and “environmentally sustainable” IPM tactic “for reducing the risk of insecticides and suppressing insect populations.”

Organic vs IPM Apples

“Two demonstration plantings of disease-resistant apple cultivars, each 1 acre (0.4 ha), are established at the Dixon Springs Agricultural Center in southern Illinois,” said Richard Weinzierl (Univ of Illinois, 1102 S. Goodwin Ave, Urbana, IL 61801; weinzier@uiuc.edu). “One is managed in compliance with organic certification standards; the other is identified as an IPM planting, with pesticides applied according to results of insect and weather monitoring data.”

The scab-resistant apple cultivars are Enterprise, Goldrush and Liberty; disease-susceptible Golden Delicious was planted in border rows. Half of each orchard was left as an untreated control to compare injury from codling moth, *Cydia pomonella*; Oriental fruit moth (OFM), *Grapholita molesta*; potato leafhopper, *Empoasca fabae*; San Jose scale, *Quadraspidiotus perniciosus*; leafrollers, Japanese beetle and plum curculio. The treated half of organic orchards received air blast sprayer applications of kaolin clay (Surround™), spinosad (Entrust® 80W), and pyrethrins (Pyganic® 5.0 EC). IPM plots were sprayed with Avaunt, Assail, Imidan and Danitol.

Midseason IPM and organic plots had significantly less insect damage than untreated controls. In harvest samples, the trend was similar. IPM plots had 0.3% of fruit internally infested with insect larvae. Organic plots had 6.3% fruit infestation, almost all plum curculio. Untreated IPM and organic plots had almost 20% internal fruit infestation.

Apple Aphid Biocontrol

Woolly apple aphid (WAA), *Eriosoma lanigerum*, is a root, leaf and wound feeder and a “native secondary pest of apples in the USA,” where apples are the summer host and American elm, *Ulmus americana*, is the winter host. “Apple is the only host in the Northern Areas of Pakistan,” which “are situated in the extreme north along with the Chinese border surrounded by the world’s most fascinating and unique mighty mountains of the Himalaya, Karakuram and Hindukush ranges,” said Abdul Hakeem (2431 Joe Johnson Dr, 205 Ellington Plant Sci Bldg, Knoxville, TN 37996; ahakeem@utk.edu).

Biocontrol of the pest aphid increased apple profits in Pakistan’s Northern Areas. *Aphelinus mali*, a solitary parasitoid wasp imported from the Netherlands, is “one of the key components to management of WAA in Pakistan,” said Hakeem. Aphid parasitism after *A. mali* releases was 67% in May, 57% in September, and 25-43% in June, July and August. Parasitism averaged 45%, and was best at low aphid densities and moderate temperatures.

Olive Fruit Fly Biocontrol

The U.C. Berkeley Insectary & Quarantine facility has investigated the biology and host range of 10 African and Pakistani parasitoids (all Braconidae) of olive fruit fly, *Bactrocera oleae*, a longtime Mediterranean pest that showed up in arid southern California in 1998 and has since spread throughout the state. "The effectiveness of insecticides is limited by abundant roadside and residential olive trees that serve as reservoirs for rapid reinvasion into treated orchards," said Karen Sime (Univ of California - Berkeley, Center for Biological Control, Berkeley, CA 94720; ksime@nature.berkeley.edu). "Furthermore, as insecticides may disrupt the biological controls that have been successfully developed for scale pests, classical biological control is considered the best option for long-term management."

According to Kim Hoelmer (USDA-ARS, 501 S. Chapel St, Newark, DE 19713; khoelmer@udel.edu), the olive pest is thought to have an African origin. Wild olives, *Olea europaea cuspedata*, are found in a wide range of habitats in southern and eastern Africa, and in Asia south of the Himalayan crest as far east as southwestern China. Olive fruit flies are found in much the same range, but natural enemies have mostly been studied in cultivated Mediterranean olives, not wild hosts and habitats.

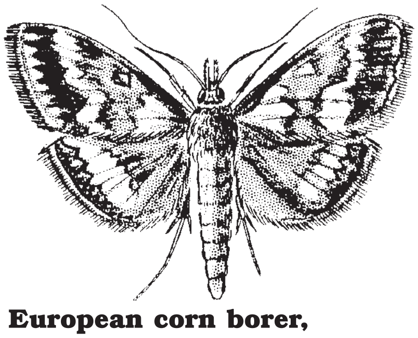
To identify new natural enemies of olive fruit fly, exploration was conducted in South Africa's arid West Cape Province. Common southern African parasitoids such as *Psyttalia lounsburyi, P. concolor, Bracon celer* and *Utetes africanus* have ovipositor length variation of 300% (1-3 mm). Hoelmer et al. theorized that wild fruits with their thin pulp "allow braconid species with different ovipositor lengths access to fly larvae in fruit," whereas "flies in larger cultivated fruit with thicker pulp may be less accessible for parasitism, or for shorter periods of time."

Female Apple Moth Lures

Peter Landolt (USDA-ARS, 5230 Konnowac Pass Rd, Wapato, WA 98951; landolt@yarl.ars.usda.gov) has been working on attractants for female pest moths (Noctuidae). Attractants for female moths have an impact on reproduction and populations by removing eggs. The search for female attractants includes: fermented sweet baits, floral scents, male-produced pheromones, and cues used by females to select egg-laying sites.

Historically, special recipes to ferment sweet baits have been used by moth collectors. For instance, fermented baits are painted on the sides of trees to collect underwing moths, which do not respond well to light traps. Landolt has used fermented sugar baits in McPhail traps to capture pests such as grass loopers, *Mocis latipes*, in Florida.

Though many different moth species respond to sweet fermented baits, they are not convenient to use. So Landolt tried to identify attractants in the fermented mixtures. Field testing produced 8 compounds that caught moths, with acetic acid by far the best. Acetic acid mixed with 3-methyl-1-butanol was "synergistically attractive" to several Noctuidae moths in Washington apple orchards. A bottle dispenser with a hole in the lid was used as the trap, as high release rates were needed for these two very volatile compounds. Landolt used the attractants in an attract and kill technology against *Lacanobia* fruitworm.


European corn borer, *Ostrinia nubilalis*

The USDA's late Everett Mitchell (Gainesville, FL) recommended baiting a badminton shuttlecock, as it was successful as a floral mimic against cabbage looper and diamondback moth in cabbage fields. The inside of the badminton shuttlecock was coated with pesticide and a lure placed inside — "And it is still working, so I've been sticking with it," said Landolt. "In apple we hang it in the tree, up in the upper levels; that's where most of the moth movement is."

Landolt used 50 bait stations per acre (125/ha), 250 total evenly spaced in a 5 acre (2 ha) apple orchard plot. Three types of traps were used for monitoring: pheromone traps (males); traps baited with acetic acid and 3-methyl-1-butanol; and a central blacklight trap placed so as to not be visible and not interfere with the other traps. Monitoring showed there was a 75% knockdown of female *Lacanobia* fruitworm with the feeding attractant traps (acetic acid and 3-methyl-1-butanol), "with a caveat that there is a possibility that this could be disruption," said Landolt. "Maybe the moths can't find the (acetic acid) monitoring traps because of the same lures in the lure kill stations." The overall trend, however, was significantly fewer pest moths, as pheromone monitoring traps caught fewer male moths.

In a longer term study with lures set up to work 4 weeks, results were noticeable within a day. Fewer moths were in the treated plot compared to the control plot. Age of females in the traps was examined according to reproductive state to ensure that old females that had already laid their eggs were not being trapped. Since the vast majority of trapped females were still in the reproductive state, the lure and kill technology was removing eggs from the pest population.

Floral Baits

A parallel set of work indicated that the moths attracted to fermented sugar baits are also attracted to flowers. Some moth species visit flowers a lot, and some rarely or never visit flowers. Likewise, some flowers are visited often by moths and some flowers rarely have moth visitations. Landolt has been working with night-blooming jasmine, Oregon grape, 4 o'clocks and butterfly bush.

Conference Notes

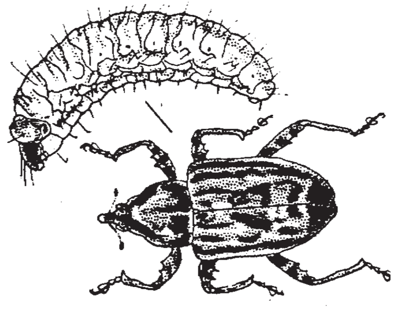
Alfalfa looper and cabbage looper were the subject of floral blend experiments. Alfalfa looper, *Autographa californica*, was by far most attracted to phenylacetaldehyde (PAA), and only a little attracted to beta-myrcene in single component lure tests. A number of compounds that were not attractive alone were synergistic when combined with PAA. Soybean looper, *Pseudoplusia includens*, is also attracted to PAA. Velvetbean caterpillar, *Anticarsia gemmatalis*, has almost no attraction to either PAA or linalool alone; but the combination of PAA and linalool is strongly synergistic.

Attract-and-kill station (badminton birdie) experiments in alfalfa fields reduced female alfalfa looper moths by 75%, with no change in numbers of male moths caught. In screenhouse experiments in lettuce, a favored host plant, alfalfa looper moths fed sugar before being released were not attracted to the lures. However, unfed moths were attracted and killed. This fact raises strong concerns about sugar source competition making the lures less effective in the field. Though it was not the case in alfalfa field experiments, "that is certainly something to watch in the future," said Landolt.

Fungal Micro-Factories

"Whey-based fungal micro-factories are a novel technology designed to dramatically increase the level of biocontrol fungi after application into the environment," said Stacie Grassano (105 Carrigan Dr, Univ of Vermont, Burlington, VT 05405; sgrassan@uvm.edu). "Insect-killing fungi are being extensively investigated for hemlock woolly adelgid (HWA), *Adelges tsugae*, suppression. Mycotal™ (Koppert UK Ltd), a European Union registered product containing *Lecanicillium muscarium* shows activity against HWA in laboratory trials.

HWA, which is "spreading through the eastern U.S. causing extensive tree mortality," may be controlled at a lower cost with low dose micro-factory applications of biocontrol fungi instead of conventional high dose applications. "Sweet whey, an inexpensive cheese byproduct, acts as a nutritive base for the fungus in micro-factories," said Grassano. "The dramatic increase in spore concentrations in treatments that contain whey demonstrates the potential for whey-based fungal micro-factories to increase post-application abundance of biocontrol fungi such as *L. muscarium*."



Plum curculio,
Conotrachelus nenuphar

"This technology may be applicable to fungal biocontrol agents other than entomopathogens, such as mycoherbicides, and fungi for management of mites, diseases and nematodes attacking plants," said Grassano.

Purple Traps Tree Beetles

Nadeer Youssef (Tennessee State Univ, 472 Cadillac Lane, McMinnville, TN 37110; nyoussef@blomand.net) has found that purple traps are more attractive to buprestid beetles than white traps or traps with 10 other colors including pink, magenta and red. Beetles trapped included flatheaded apple tree borer, *Chrysobothris femorata*; emerald ash borer, *Agrilus planipennis*; and the metallic wood-boring beetle, *Acmaeodera tubulus*.

In 2006, 18 new prototype traps "constructed of purple chloroplast corrugated plastic" captured 3,502 buprestid beetles from April to July at a site in Georgia. *Agrilus subrobustus* (native to Japan, China, Korea) was detected for the first time in the U.S.; since it feeds on dead wood it is not expected to have the same impact as emerald ash borer. However, "the collection of a non-native buprestid validates the value of this trap as a survey tool for the detection of invasive buprestids," said Youssef.

Trapping Emerald Ash Borer

"Improved survey tools are needed for early detection of emerald ash borer (EAB), *Agrilus planipennis*, infestations," said Therese Poland (USDA-FS, 407 S. Harrison Rd, East Lansing, MI 48823; tpoland@fs.fed.us). "Current survey techniques involving visual inspection, girdled trap trees and trunk dissection are less than ideal because external symptoms are not evident for at least a year after attack and trap trees are destructive and labor intensive."

A 3 m (9.8 ft) tall purple tree bole trap with a middle sticky band incorporated multiple attractive stimuli, including the color purple, an open edge visual silhouette and rough bark texture. Volatile chemical stimuli included: leaf volatiles (hexanal; E-2-hexenal; E-2-hexenol; Z-3-hexenol); bark volatiles (manuka oil); and stress-induced volatiles. "More beetles were captured on upper panels of multi-traps with leaf blend and lower panels of multi-traps with bark blend," said Poland.

"Trap height is important for capture, especially early in the EAB flight period," and "purple panel traps are relatively more effective in open areas than in wooded areas," said Joseph Francese (USDA-APHIS-PPQ, Bldg 1398, Otis ANGB, MA 02542; joe.francese@aphis.usda.gov). "Flat-paneled traps are relatively more effective than crossvane traps." Trap color is being further studied with "electroretinographic studies to determine the optimal color wavelength for EAB attraction."

Male EAB summer flight activity is concentrated at the tree tops, which could be related to visual recognition of females for mating.

Calendar

September 18-19. California's Water Future; Expanding the Role of Groundwater. Sacramento, CA. Contact: www.waterresources.ucr.edu

September 28-30, 2007. 8th Annual Renewable Energy Roundup. Fredericksburg, TX. Contact: www.theroundup.org

October 10-12, 2007. Design of Experiments. Wageningen University, Netherlands. www.wbs.wur.nl

October 14, 2007. 25th Anniversary Silicon Valley Toxics Coalition. Contact: www.svtc.org

October 14, 2007. 25th Anniversary Party, Pesticide Action Network. Ferry Building, San Francisco, CA. Contact: PAN, 49 Powell St. #500, San Francisco 94102, www.panna.org/25years

October 15, 2007. Registration Deadline for Apprenticeship in Ecological Horticulture. Contact: Center for Agroecology, UC Santa Cruz, CA. 831/459-2321; apprenticeship@ucsc.edu; www.ucsc.edu/casfs

October 15-18, 2007. 16th International Plant Protection Congress, Glasgow, UK. Contact: C. Todd, BCPC, 7 Omni Biz. str., Omega Park, Alton Hampshire GlU34 2QD, UK. www.bcpc.org

October 19-21, 2007. 18th Annual Bioneers Conference. San Rafael, CA. Contact: Bioneers Conference, 6 Cerro Circle, Lamy, NM 87540; 505/986-0366, www.bioneers.org

October 28-30, 2007. 13th Annual Alternatives to Methyl Bromide Conference. Doubletree Hotel, San Diego, CA. Contact: MBAO, 6556 N. Dolores Ave., Fresno, CA 93711, 559/449-9035, www.mbao.org

November 1-2, 2007. 3rd Annual Sustainable Agriculture Expo, Paso Robles, CA. Contact: www.sustainableagexpo.org

November 9-11, 2007. Cultivating the Family Farm. Yakima, WA. Contact: Tilth Producers of WA, PO Box 85056, Seattle, WA 98145; www.tilthproducers.com

November 27-29, 2007. NOSB Meeting, Washington, DC. Contact: www.ams.usda.gov/nosb

November 30-December 1, 2007. 6th Annual Sustainable Agriculture Pest Management Conference. San Luis Obispo, CA. Contact: CCOF, 2155 Delaware Avenue, Suite 150, Santa Cruz, CA 95060; www.ccof.org

December 6-8, 2007. Acres USA Farming Conference. Louisville, KY. Contact: www.acresusa.com

December 9-13, 2007. Annual Meeting Entomological Society of America. San Diego, CA. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; Fax 301/731-4538; www.entsoc.org

January 7-11, 2008. Advanced IPM Landscape Short Course. University of Maryland, College Park, MD. Contact: D. Wilhoit, 301/405-3913; www.raupplab.umd.edu/conferences/advlandscape/

January 17, 2008. Bay Friendly IPM Landscape Course. Contact: www.bayfriendly.org

January 23-26, 2008. Ecological Farming Conference. Asilomar, Pacific Grove, CA. Contact: Ecological Farming Association, 406 Main St., Suite 313, Watsonville, CA 95076; 831/763-2111, Fax 831/763-2112; www.eco-farm.org

February 24-26, 2008. California Small Farm Conference. Visalia, CA. Contact: 888/712-4188; www.californiafarmconference.com

March 25-27, 2008. 20th Anniversary: SARE 2008 National Conference, Kansas City, MO. Contact: www.sare.org/2008conference/

December 7-11, 2008. Annual Meeting Entomological Society of America. Charlotte, NC. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; Fax 301/731-4538; www.entsoc.org

Conference Notes

"It should be possible to enhance efficiency of high level traps by optimizing trap color (green is better than purple near canopy periphery) and design and possibly through the use of chemical attractants," said David Lance (USDA-APHIS-PPQ, Bldg 1398, Otis ANGB, MA 02542; david.r.lance@aphis.usda.gov). "While placing traps at or near tops of trees may not seem feasible, the current standard sampling practice involves felling and peeling trees."

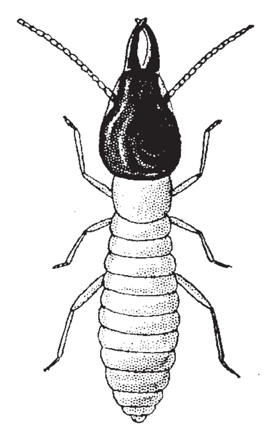
"Conventional ground survey for EAB is difficult and time-consuming and is problematic because all stages except the adult are spent inside the host tree, where they are difficult to detect," said David Williams (USDA-APHIS-PPQ, Bldg 1398, Otis ANGB, MA 02542; david.w.williams@aphis.usda.gov). "The survey for new beetle infestations using remote sensing technology—in particular hyperspectral imaging (HSI)—holds great promise to alleviate these difficulties." HSI utilizes 227 very narrow spectral bands of land reflectance; this combination of "wide spectral range and high resolution" allows detection of very subtle tree color differences that might indicate stress from EAB.

Debarking Destroys Borers

"Since its discovery in 2002, the emerald ash ash borer has killed an estimated 20 million ash trees, *Fraxinus* sp., in urban, rural and forested areas in Michigan alone," said Robert McDonald (Michigan State Univ, 243 Nat Sci Bldg, East Lansing, MI 48824; mcdon182@msu.edu). "Quarantines imposed in affected states generally prohibit transport of EAB life stages in ash logs, firewood or nursery trees to prevent inadvertent introduction of EAB to new areas."

"Currently ash logs must be milled before they can be transported outside a quarantined area," said McDonald, who demonstrated the value of on-site log debarking machines. A debarking machine removed the upper 1.2 inches (3 cm) of bark and wood, along with all 7,750 EAB on 26 sawlogs and 99% of 3,211 EAB on 15 reject logs.

"Results show that an on-site log debarker can effectively remove overwintering EAB, allowing for the transport and utilization of ash logs outside of quarantined areas," said McDonald. "Increased utilization of ash saw logs can help reduce EAB density while providing economic benefits to landowners."



Formosan subterranean termite, *Coptotermes formosanus*

Logging Encourages Spruce Budworm

"The first year after a selective cut [of spruce trees], the remaining trees grow vigorously but experience a decrease in certain defensive compounds, such as monoterpenes and tannins, resulting in trees that are more susceptible to spruce budworm, *Choristoneura fumiferana*, attack," said Michael Cardinal-Aucoin (Concordia Univ, 7141 Sherbrooke St. W, Montreal, QC, Can-ada H4B 1R6; m_cardin@alcor.concordia.ca). Indeed, tannins extracted from white spruce when fed to spruce budworm reduce pupal weight and increase mortality.

"It is clear that the spruce budworm can detect tannins and tannic acid," said Cardinal-Aucoin, who subjected balsam fir, *Abies balsamea*, to 0-40% thinning the year before collecting needles to make aqueous extracts. "Tests with aqueous extracts from their host plant revealed an ability to distinguish between trees subjected to different thinning regimes."

Aspen Pheromones

Trembling aspen trees in Alberta, Canada, can be defoliated by forest tent caterpillars, *Malacosoma disstria*, and the large aspen tortrix, *Choristoneura conflictana*, two moth pests with overlapping adult flight periods, said Brad Jones (Univ of Alberta, CW 405, Biol Sci Centre, Edmonton, AB, Canada T6G 2E9; bcjones@ualberta.ca). Though these pests have no shared pheromone components, the overlapping flight periods made them good candidates for a rubber septa lure combining both moth pheromones. Indeed, a combined pheromone lure proved as effective for each species as individual lures.

Furthermore, male moth pheromone monitoring trap catches correlated with larval defoliation damage to aspen trees. Right now there is no control for the large aspen tortrix, and aspen is usually not sprayed. *Bacillus thuringiensis* (BT) is sometimes used against forest tent caterpillars. Jones hopes to develop a predictive model for pest damage based on pheromone trap catches.

Q Fever Pet Threat

In Georgia animal shelters, 32% of ticks (dogs were not tested) carried the Q fever pathogen (*Coxiella burnetii*), which "is important to public health because highly infected ticks on dogs in animal shelters may transmit Q fever agent to humans via biting and/or aerosol of tick feces," said Quentin Fang (Georgia Southern Univ, PO Box 8042, Statesboro, GA 30460; qfang@georgiasouthern.edu). "Ticks are vectors of Q fever agent but play a secondary role in transmitting because the agent is mostly transmitted to humans via aerosol."

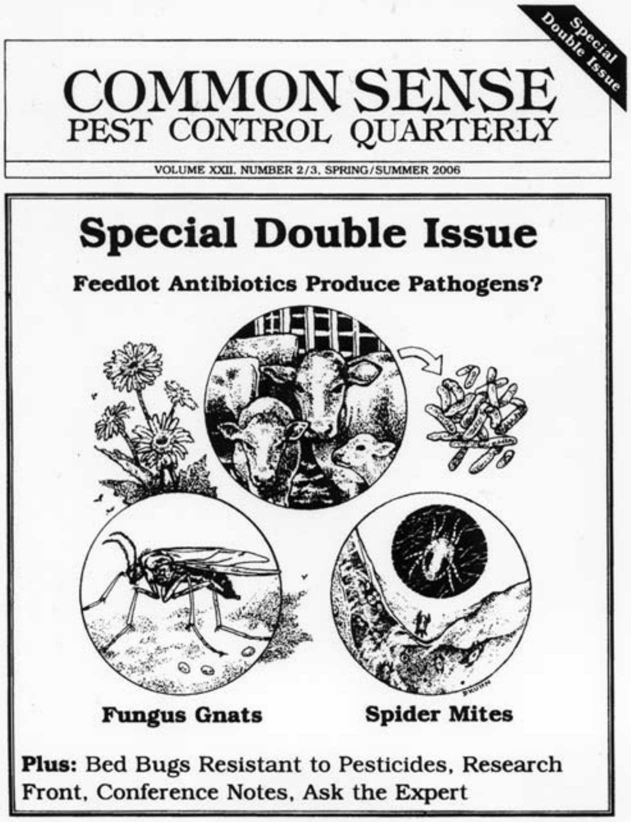
Traditionally those at risk have mainly been veterinarians and farmers helping birth sheep, cattle, goats and other farm animals, as *C. burnetii* builds up in placental tissues. Infected animals excrete the pathogen in milk, urine and feces. Human infection typically occurs from inhalation of dust contaminated with dried birth materials and feces.

About half the people infected with Q fever develop clinical symptoms, which may include: 1-2 weeks of high fever; severe headache; sore throat; nausea; chills; sweats; abdominal and chest pains; non-productive cough; vomiting; diarrhea; and general malaise. Weight loss and abnormal liver function (some develop hepatitis) are common, and 30-50% of those with symptoms develop pneumonia. Most patients recover in several months without treatment, but 1-2% die.

Cold Tolerant Termites

Like most subterranean termites (Rhinotermitidae), the Formosan subterranean termite, *Coptotermes formosanus*, a tropical species introduced to the USA after World War II, does not undergo winter diapause and was not thought to survive below –5°C (23°F). "However, Hu and Oi reported its infestation in north Alabama where the winter temperatures could go below –15°C (5°F)," said Dunlun Song (Auburn Univ, 363 Funchess Hall, Auburn, AL 36849; huxingp@auburn.edu). The physiological mechanism for cold tolerance involves lowering the critical thermal minimum (Hu and Appel 2004).

Song tested termite cold tolerance by placing tubes of soil with termites into programmable incubators. "The low numbers of termites in the portion exposed to cold or falling temperatures indicate cold-avoidance behavior" by both the more cold-tolerant eastern subterranean termite, *Reticulitermes flavipes*, and *Coptotermes formosanus*, said Song. Lower mortalities of *R. flavipes* in this experiment indicate they are more cold tolerant than *C. formosanus*. This research will help predict termite range expansion in global warming.



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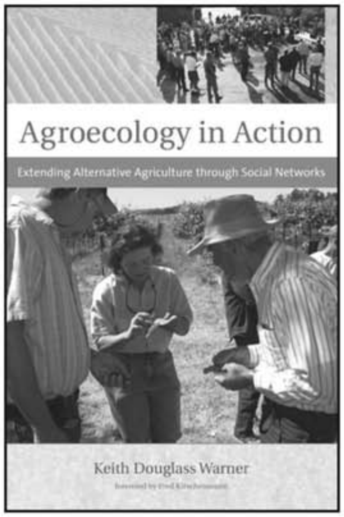

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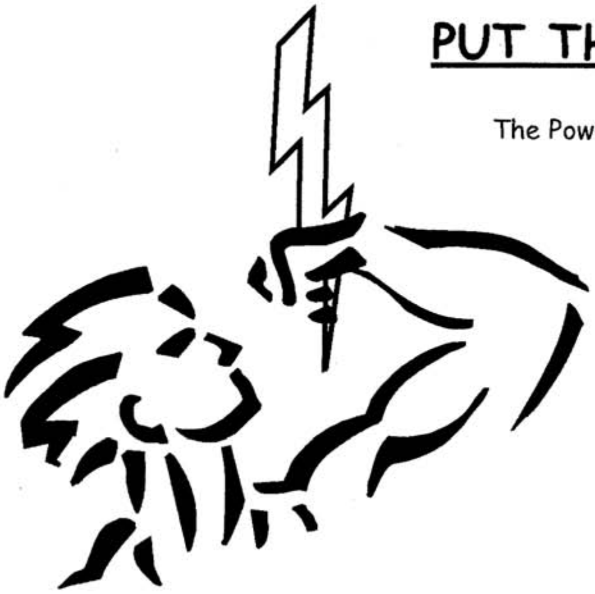

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