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Special Pheromone Report

Brave New World—Systemic Pesticides and Genetically Engineered Crops

By William Quarles

Almost overnight, genetically engineered (GE) crops have profoundly changed agriculture in the U.S. Leading the way have been corn, soybean, and cotton crops resistant to the herbicide glyphosate. As a result, traditional farming and IPM methods have been tossed aside and replaced with a simplistic solution. Seeds are drilled into the soil without cultivation. When weeds appear, fields and crops are sprayed with glyphosate, usually by aerial application. Repeated applications are needed, and glyphosate resistant (GR) crops are often grown in the same field, year after year (Duke and Powles 2009; Mortensen et al. 2012).

Glyphosate is systemically absorbed by the crop, and it appears in the food sold for consumption (EPA 2011; Arregui et al. 2004; Duke 2011). Other GE changes include crops that grow their own pesticide. Genes from the bacterium *Bacillus thuringiensis* (BT) are inserted into plant genomes. Each plant cell produces insecticidal proteins, and these insecticides are incorporated into the food (Gassmann 2012).

Genetically engineered foods are not labeled, despite the fact that 90% of Americans support labeling (Acres 2012). Consumers are exposed to these new genetic creations and their systemic pesticides without their knowledge. The effects of longterm, widespread exposure to these products have not been fully investigated, and most of the studies supporting their safety have been produced by industry (Antoniou et al. 2011; Antoniou et al. 2012).

Photo courtesy Glenda Denniston, UW-Madison Lakeshore Nature Preserve

Glyphosate applications associated with GR crops have destroyed milkweed habitat of the monarch butterfly, *Danaus plexippus*, leading to an 81% reduction of Midwest monarch populations.

Large Pesticide Increase

Overall, GE crops have caused a large pesticide increase. BT crops have led to less applied insecticide, but GR crops need large amounts of glyphosate. Roundup Ready® GR crops were introduced in 1996, and cumulative pesticide use over 16 years has increased by about 400 million lbs (182 million kg) (Benbrook 2009; Benbrook 2012). These production systems are not sustainable, but agribusiness has bet America's future on GE crops, in exchange for large, shortterm corporate profits.

GE crops are not sustainable because farmers rely on larger amounts of fewer pesticides. Weeds and pest insects then become resistant, and resistance increases pesticide applications (Duke and Powles 2009). GR crops actually reduced herbicide applications over the first three years after their introduction. But rapid emergence of resistant weeds has caused large glyphosate increases each year. For instance, there was a 31% increase

In This Issue

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Update

in glyphosate use from 2007 to 2008 (Benbrook 2009).

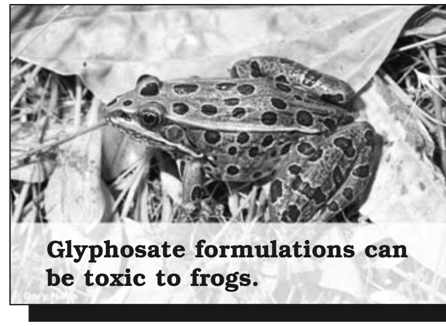
Repeated use of the same pesticides is leading to their buildup in soil and contamination of water and air (Chang et al. 2011; Battaglin et al. 2005). GE crops have caused destruction of habitat for the monarch butterfly and other environmental problems (Hartzler 2010; Pleasants and Oberhauser 2012; Antoniou et al. 2012). Resistance to BT and invasion of secondary pests have led to systemic seed treatments with neonicotinoid pesticides that have toxic effects on bees (Quarles 2011; Hopwood et al. 2012; Krupke et al. 2012). More than 45% of U.S. cropland is now treated with systemic chemical pesticides (Stokstad 2012).

Scope of the Problem

GE canola, sugarbeets, corn, soybeans, and cotton are grown commercially in the U.S. (Duke and Powles 2009). Since most of the acreage is devoted to GE soybeans, cotton, and corn, only these crops will be discussed here. In 2008, herbicide resistant soybeans, cotton, and corn represented 92%, 93%, and 63% of total acres planted to each crop in the U.S., and amount was increasing each year (Benbrook 2009). In 2011, 94% of all U.S. soybeans were GE glyphosate resistant. Since GR soybeans were first planted, there has been a 97% glyphosate increase in soybeans, from 3 million lbs (1.4 million kg) in 1994 to 92 million lbs (41.7 million kg) in 2006 (Pleasants and Oberhauser 2012).

In 2011, about 72% of all U.S. corn was GE glyphosate resistant. There has been a 94% glyphosate increase in corn, from 4 million lbs (1.8 million kg) in 2000 to 63 million lbs (28.5 million kg) in 2010 (Pleasants and Oberhauser 2012).

California has fewer acres of GE crops planted than areas such as the Midwest, but glyphosate use in California has doubled since 1996, the first year that Roundup Ready crops were used. About 4.2 million lbs (1.9 million kg) of glyphosate and its salts were applied in 1996,



Glyphosate formulations can be toxic to frogs.

Photo courtesy Gary Nafis

and about 8.6 million lbs (3.9 million kg) were applied in 2010 (CA DPR 1996; 2010).

In 2008, 57% of the corn acreage and 73% of the cotton acreage in the U.S. had been planted in BT varieties (Benbrook 2009). In 2010, over 58 million acres (23.5 ha) worldwide were planted to BT crops, mostly cotton and corn (Gassmann 2012).

Monarch Butterfly

Habitat destruction of the monarch butterfly, *Danaus plexippus*, represents one of the first large scale environmental catastrophes due to GE crops. The monarch butterfly is one of the best known environmental icons (Brower and Malcolm 1991). Developing caterpillars of the monarch are dependent on wild stands of milkweed, *Asclepias* spp. From the milkweed they obtain the chemicals that give them a bad taste, and thus protect them from predators (Malcolm et al. 1989).

Milkweed is especially sensitive to glyphosate, and stands along crop edges have been destroyed by massive glyphosate applications associated with GE crops. There has been an 81-90% reduction of milkweed on farmland in Iowa. Similar reductions are found throughout the Midwest where GE crops are planted (Hartzler 2010; Pleasants and Oberhauser 2012).

From 1999 to 2010 disappearing milkweed insectary plants have led to an 81% decline in Midwest production of migrating monarchs. Partly due to this reduction, overwintering populations in Mexico have dropped by 65% (Pleasants and Oberhauser 2012; Brower et al. 2012).

Update

Frogs, Pathogens, Nutrients

Pesticides may be one of the causes of widespread amphibian decline seen over the last 30 years. More than one-third of amphibian species are now threatened with extinction. Glyphosate formulations containing various surfactants and inerts may cause amphibian toxicity, including birth defects (Paetow et al. 2012; Paganelli et al. 2010; Howe et al. 2004). Glyphosate formulations are toxic to tadpoles, and some studies have shown that glyphosate formulations kill tadpoles in natural settings (Relyea 2005a; Moore et al. 2012; Williams and Semlitsch 2010). Glyphosate formulations can reduce species diversity of frogs and other species in aquatic communities (Relyea 2005b). (See Box A)

Glyphosate binds to micronutrients in the soil, making them less available for plant nutrition. Low levels of glyphosate reduce root uptake of Fe, Mn, Zn, and Cu, making plants more susceptible to disease. The problem is worsened with the increased glyphosate application seen with GE crops (Johal and Huber 2009). Sprays of glyphosate increase populations of plant pathogens in soil (Cerdeira and Duke 2010; Duke et al. 2007). Roots of GR soybeans and corn are heavily colonized by *Fusarium* (Kremer and Means 2009). Roundup Ready seeds are now being treated with the fungicide pyraclostrobin (Acceleron®) to help deal with the disease problem. In 2010, 11% of corn was treated with fungicides. Less than 1% of corn had been treated in earlier years (Benbrook 2012; Antoniou et al. 2012).

Box A. Glyphosate Problems

Glyphosate herbicide was originally developed by John Franz at Monsanto in 1970. It works by inhibiting a key enzyme needed for plant growth. It is broadspectrum and will affect most higher plants. Differences in damage between plant species is due mainly to differences in absorption (Duke and Powles 2008).

Glyphosate has low acute toxicity, and a generally benign toxicological profile (Duke and Powles 2008; Mink et al. 2011). But some studies have shown that glyphosate or its formulations may cause birth defects and endocrine disruption problems in animals (Richard et al. 2005; Paganelli et al. 2010; Dallegrave et al. 2003). Reduced testosterone and delayed puberty has been seen in rats at relatively low concentrations (Dallegrave et al. 2007; Romano et al. 2010). Most of the controversy coming from these studies is centered on what is an environmentally relevant amount (Antoniou et al. 2011; Williams et al. 2012).

Applicators that use glyphosate often absorb it. One study showed that 60% of farmers that use it have traces of glyphosate in their urine (Acquavella et al. 2004; Battaglin et al. 2005). A large scale epidemiologic study of exposed farmers showed an association with multiple myeloma (de Roos et al. 2005). Another study showed a connection with non-Hodgkins lymphoma (de Roos et al. 2003; Cox 2004).

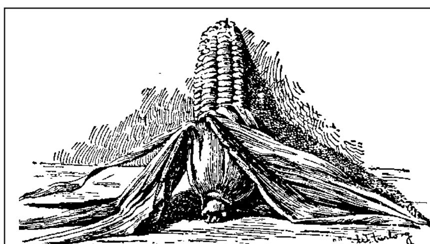
There is a large variation in environmental persistence. The soil half life of glyphosate ranges from 2-197 days, and the soil half life of the degradation product AMPA ranges from 76-240 days. Glyphosate binds to soil, but it still moves out into streams. Phosphate fertilizers displace glyphosate and increase runoff (Cerdeira and Duke 2010). Nearly every stream, river, and reservoir in heavily farmed regions contain glyphosate and its degradation products (Chang et al. 2011). In the Midwest, glyphosate or its degradation products were found in 69% of surface water samples tested. Concentrations measured in streams are low, but direct measurements of runoff from small watersheds can have amounts (5.1 mg/liter) that exceed drinking water standards of 0.7 mg/liter (Battaglin et al. 2005).

Glyphosate was found in 60-100% of rain and air samples tested in Iowa and Mississippi by U.S. Geologic Survey (USGS) (Chang et al. 2011). Glyphosate or AMPA was found in 92% of rain samples in Indiana. Concentrations were low, but maximum concentrations of glyphosate were higher the maximum concentrations of other herbicides tested. About 0.7% of glyphosate applied to soil goes airborne and is removed from air by rainfall (Chang et al. 2011).

Gene Flow and Human Error

One of the problems of GE crops is the flow of the transgenes into the environment, causing genetic pollution. Transgenes can spread through seeds, pollen, and vegetative propagules. As an example, field trials of glyphosate resistant (GR) bentgrass, *Agrostis stolonifera* in Oregon led to gene escape into the wild bentgrass population (Bollman et al. 2012). Three years after the trials, "as much as 62% of the wild bentgrass population in the vicinity possessed the GR trait" (Duke and Powles 2009).

Movement of GE transgenes into organic crops is possible. One study showed half the samples from six conventional soybean cultivars had up to 1% GE contamination. Also, there was up to 1% GE contamination in half the samples from six conventional corn cultivars. GE corn pollen can contaminate nearby fields, but pollution drops with distance. GE transgenes in alfalfa pollen, however, can move 4 km (2.4 mi) or more. In one



GE crops can lead to genetic pollution, causing great economic damage.

study, 22% of seed tested from trap plants 1000 m (0.6 mi) away from alfalfa production fields had the transgene (Mallory-Smith and Zapiola 2008; Snow et al. 2005).

Geneflow is compounded by human error. To farmers and marketers, all corn looks alike. This fact may have led to the illegal sales of Starlink® corn in 2000. The corn was approved for animal use, but not for human food. Starlink was found in taco shells, and the resulting recall cost industry more than $1 billion. Traces of Starlink were still being found in the food supply in 2008. A similar mixup between approved BT11 corn and unapproved BT10 was discovered in 2005 (MacIlwain 2005; EPA 2008). Gene flow and human error may become dangerous with Pharm Crops that have been engineered to produce drugs (Mallory-Smith and Zapiola 2008).

All kinds of genetic traits are being incorporated into crops. But amylase corn may be the first crop that eats itself. As it grows, amylase is secreted that digests the starch produced. The result is a product easier to convert into ethanol. But even low amounts mixed into food supplies could lead to lower quality, such as sticky tortillas and gummy bread (Waltz 2011).

Safety of GE Crops

From the beginning there were regulatory difficulties with the introduction of GE crops. They were clearly novel, and millions of people would be exposed. Regulators had to decide whether GE crops should be treated as food or drugs. The pharmaceutical industry has to show through animal tests and clinical trials that a drug is effective and safe before it can be sold. Yet when the drug is sold, much larger numbers of people are exposed, and sometimes hidden toxic effects appear (Karha and Topol 2004).

The final GE regulatory model involves EPA, USDA, and FDA. Toxic effects of gene products are regulated by EPA. USDA approves production of GE crops. The FDA does a premarket preview of all GE food (Freese 2007). Industry has to show only that the GE food is “substantially equivalent” to the natural product. This is a very vague term. A living body might be “substantially equivalent” to a recently dead one, but there is still an obvious profound difference. Often substantially equivalent means only that nutritional analyses are done, not animal safety tests (Zobiole et al. 2010; Ridley et al. 2011; Antoniou et al. 2012).

A recent publication by Antoniou et al. (2012) reviews GE food safety. Possible food safety issues occur if the transgene product is toxic or allergenic, or if the transformation process itself is mutagenic, causing new toxins or allergens to be produced. According to Antoniou et al. (2012), GE BT crops fed to animals have caused toxic effects to the small intestine, liver, kidney, spleen, and pancreas. There was also reduced weight gain and immune system disturbances. According to Antoniou et al. (2012) animals fed GE soybeans showed “disturbed liver, pancreas and testes function.”

Farmers are losing their independence, as traditional seeds are disappearing.

Why are GE Crops Being Planted?

If there are environmental problems and uncertain safety, why are GE crops being produced? GE crops are supported by aggressive marketing, favorable government policy, and some cost advantages. A major problem is lack of traditional seeds. Most seed companies in the 1990s were purchased by pesticide manufacturers, as they saw vast profits could be made by monopolizing both seeds and pesticides. It is not in their interest to produce and promote traditional seeds (Mortensen et al. 2012; Gray 2011).

The simplistic agronomic systems of GE crops can make them easier to grow. Intially, GE crops led to larger profits for farmers. But profits may not be sustainable due to increased seed costs, weed resistance and other problems (Duke and Powles 2009; Gianessi 2008). According to Benbrook (2012), there has been a 30% shift of net income/acre in corn, soybeans, and cotton from farmers to seed and pesticide providers. Net profits in soybean and cotton have dropped since 2004 (Duke and Powles 2009).

Calculations showing the profit advantages of GE crops do not include the economic burden posed by pest resistance (Gianessi 2008; Buman et al. 2005). Glyphosate weed resistance may increase weed control costs in GE crops by $12-$14/acre ($30-$35/ha)(Owen 2010). Profit advantage simulations also do not include some environmental costs, such as loss of the monarch butterfly and reductions in frog populations (Pimentel et al 1992).

Favorable Government Policy

GE crops are being planted because of favorable government policy. From the beginning, the USDA has promoted GE crops. When the National Organic Program was being created, the USDA wanted to include GE products in organic agriculture. The agency relented only after large scale resistance by consumers and organic interests (Quarles 1998). USDA approval and deregulation has been granted to almost every GE crop application. Lawsuits, such as the case of GE alfalfa, are needed to reverse bad decisions (Duke and Powles 2008; Kimbrell 2011).

Update

Government crop insurance programs favor GE crops. In 2008, The USDA's Crop Insurance Board lowered premiums for farmers who would plant at least 75% of their corn to an approved transgenic hybrid (Gray 2011).

As this issue went to press, various amendments were being added to U.S. Farm Bill legislation that would make it easier to get GE crops with multiple herbicide resistant traits (see below) approved. The House Farm Bill contains HR 872, Reducing Regulatory Burdens Act, which stops the EPA from reviewing new and expanded uses of pesticides, and speeds approval of GE crops (Baden-Mayer 2012).

Environmental Benefits

GE crops produce some environmental benefits, mainly due to no-till production, which conserves water and soil. But no-till methods can be used with conventional crops. GR crops have meant fewer applications of other herbicides, such as 2,4-D and atrazine. But this may be a short term phenomenon. Weeds resistant to glyphosate are driving farmers to increase tillage and apply other herbicides. The industry solution is to produce GE crops simultaneously resistant to several herbicides (see below). Due to pesticide pollution, planting of crops resistant to multiple herbicides will likely eliminate any environmental advantage produced by GR crops (Mortensen et al. 2012).

Palmer amaranth, *Amaranthus palmeri*, is resistant to glyphosate.

Photo courtesy Virginia Tech Weed ID Guide

Resistance to Glyphosate

Glyphosate was used for more than 20 years without a report of resistance. Problems started with the introduction of GE glyphosate resistant crops in 1996 and the resulting explosion of glyphosate use (Duke and Powles 2009). Conversion from IPM methods of weed control to no-tillage monocultures maintained by one herbicide has led to a shift in the agricultural weed spectrum in the U.S. Sensitive weeds are disappearing, tolerant weeds are proliferating, and evolved resistance of superweeds is a reality (Owen 2008; Webster and Nichols 2012).

Resistance can build quickly. Resistant waterhemp, *Amaranthus tuberculatus*; and horseweed, *Conyza canadensis*, were seen 2-3 years after the introduction of GR soybeans. Resistant horseweed in cotton is a problem that may require a partial return to tillage (Owen 2008; Heap 2011).

Resistance to glyphosate has evolved in many species and is widely distributed. In 2011, 21 weed species worldwide were resistant to glyphosate. About 8 resistant species have become problems in GR crops in the U.S., and they are listed in Table 1. Leading the list in infested acreage is Palmer amaranth, *Amaranthus palmeri*, and horseweed, *Conyza canadensis* (Owen 2010; Benbrook 2009; Powles 2008; Heap 2011; Riley 2010; 2011).

Resistant horseweed, *Conyza canadensis*, covers millions of acres of GE crops.

Photo courtesy of Bob Williams and Stewart Farm

Resistant species such as horseweed, *C. canadensis*, are hybridizing and spreading resistance to related species such as hairy fleabane, *C. bonariensis*. Other weeds such as lambsquarters, *Chenopodium album*; pokeweed, *Phytolacca americana*; field horsetail, *Equisetum arvense*; velvetleaf, *Abutilon theophrasti*; tropical spiderwort, *Commelina benghalensis*; wild parsnip, *Pastinaca sativa*; and others are becoming problems because they are either naturally tolerant or are encouraged by no-till production (Owen 2008; Owen 2010; Benbrook 2009; Duke and Powles 2009).

Resistance to BT

Bacillus thuringiensis is one of the most important tools of organic agriculture. It is applied to crops as

Table 1. Glyphosate Resistant Weeds in U.S. Crops

Weed	Scientific Name	Crops
Palmer amaranth	*Amaranthus palmeri*	Corn, cotton, soybean
Waterhemp	*Amaranthus tuberculatus*	Corn, soybean
Common ragweed	*Ambrosia artemisiifolia*	Soybean
Giant ragweed	*Ambrosia trifida*	Cotton, soybean
Horseweed	*Conyza canadensis*	Corn, cotton, soybean
Kochia	*Kochia scoparia*	Corn, soybean
Italian ryegrass	*Lolium multiflorum*	Cotton, soybean
Johnsongrass	*Sorghum halepense*	Soybean

From Owen 2008; 2010. Benbrook 2009

a spray. It leaves no toxic residuals, spares beneficial insects, and generally affects only pests that eat the crop. It degrades quickly in the field, and does not contaminate water (Glare and O'Callaghan 2000).

Several crops have been engineered with transgenes that express

Photo courtesy Peggy Greb USDA ARS

The western corn rootworm, *Diabrotica virgifera virgifera,* is resistant to effects of BT corn.

insecticidal BT proteins. BT corn insecticidal to the European corn borer, *Ostrinia nubilalis*, and the western corn rootworm, *Diabrotica virgifera virgifera*, have been planted. BT cotton insecticidal to the pink bollworm, *Pectinophora gossypiella*, and other Lepidoptera covers more than 6.7 million acres (2.7 million ha)(Benbrook 2009; Naranjo 2011).

Transgenes in BT crops produce insecticidal proteins that differ from the natural product used in organic agriculture. Organic consumers wash off any residual BT, those who buy the GE crop eat insecticidal BT proteins. BT proteins growing in the crops are always there, pests are constantly exposed, making resistance more likely (Benbrook 2008; Benbrook 2009).

Several insect species have developed resistance to BT in the laboratory, and organic farmers objected to BT crops because field resistance was likely (Tabashnik et al. 2009). As a result, the EPA made establishment of BT free refuges a labeled requirement. Up until 2008, BT corn labels required planting of 20% non-BT corn to help prevent resistance. It was a good idea, but grower compliance has been less than 80%, and in 2010 the EPA dropped the refuge requirement to 5% for SmartStax GE corn (Gray 2011).

Despite the general success with refuges, pests are growing resistant. From 1996 to 2006, no resistance was seen. However, seven species have developed resistance within the last four years. These include pink bollworm, corn earworm, *Helicoverpa zea*; fall armyworm, *Spodoptera frugiperda*; corn stalk borer, *Buseola fusca*; cotton bollworm, *H. armigera*; Australian bollworm, *H. punctigera*; and western corn rootworm. In some cases, the BT crop is no more effective than untreated crops (Gassmann 2012).

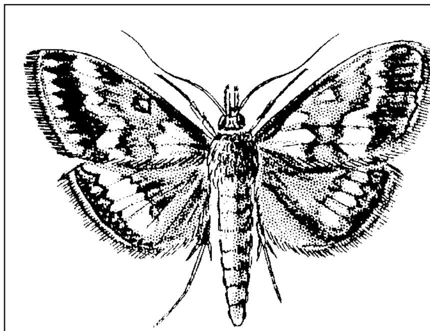
Resistance to BT and invasion of secondary pests not affected by BT have led to widespread seed treatments with systemic neonicotinoid insecticides (Benbrook 2008; Quarles 2011; Stokstad 2012).

BT Effects on Beneficials

According to Naranjo (2011), more than 360 published studies have examined the possible effect of BT crops on non-target organisms. Since beneficial insects do not eat the crop, most of the negative effects are indirect, due to reduced prey or consumption of herbivorous pests full of BT proteins. Thus fewer predators are found in BT cotton

Photo courtesy Peggy Greb USDA ARS

The pink bollworm, *Pectinophora gossypiella,* is resistant to effects of BT cotton.



European corn borer, *Ostrinia nubilalis*

crops, fewer parasitoids specific for European corn borer are found in BT corn (Marvier et al. 2007; Naranjo 2011).

Secondary pests in BT crops have led to systemic seed treatments. Reduction of the beneficial ground beetle, *Harpalus pensylvanicus*, in BT corn treated with neonicotinoids was due either to direct toxicity from the systemic pesticide or lack of prey due to BT (Leslie et al. 2009).

Stacked Traits and Multiple Herbicides

No lessons have been learned from the past about pesticide treadmills (van den Bosch 1978; Olkowski et al. 1991). To deal with glyphosate resistant weeds, the corporate solution is to engineer crops simultaneously resistant to several herbicides (Green et al. 2008; Benbrook 2009).

One of the first was SmartStax® corn, which was resistant both to the herbicides glyphosate and glufosinate, and simultaneously insecticidal to the western corn rootworm, and various Lepidoptera. Others waiting approval include crops simultaneously resistant to glyphosate, 2,4-D, and dicamba (Gray 2011).

Approval of these "stacked trait" crops with resistance to multiple herbicides will lead to large increases of 2,4-D and dicamba similar to those already seen with glyphosate. One estimate is that herbicide use in soybeans will approximately double by 2020 if these crops are approved (Mortensen et al. 2012).

This might be a conservative estimate. According to the manufacturer, applications of 2,4-D would be 560-2240 g/ha (227-907 g/acre) (Mortensen et al. 2012). Application of the minimum rate of 2,4-D to 54 million acres (22 million ha) of GE corn would be 27 million lbs (12.3 million kg). Application of the minimum rate to 132 million acres (53 million ha) of herbicide tolerant, corn, cotton, and soybeans would be 66 million lbs (30 million kg) of 2,4-D. Total agricultural use now is about 30 million lbs (14 million kg). Crops resistant to 2,4-D could at least triple the amount of 2,4-D applied in agriculture (EPA 2005; Benbrook 2009).

Though there are questions about glyphosate safety, other herbicides may actually be more toxic (see Box B). Water is already contaminated with herbicides, and crops resistant to multiple herbicides will result in major increases (USGS 2008; Benbrook 2012).

Box B. Toxicity of 2,4-D

The herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) has been used since 1940. It is more acutely toxic than glyphosate. Subchronic oral exposure causes damage to the thyroid, kidney, adrenal glands, ovaries and testes of laboratory animals. Damage occurs when kidneys are not able to excrete the toxin fast enough. This fact means 2,4-D might be more toxic to older people with impaired renal clearance. Because of the damage to reproductive organs in animals and widespread exposure, 2,4-D is being screened as a possible endocrine disruptor by the EPA. Occupational exposure in humans has been associated with reduced sperm motility and viability. Large doses led to birth defects in rats (NPIC 2012).

There is scientific disagreement about its carcinogenic effects. The EPA classifies it as "not classifiable as to human carcinogenicity." The International Agency for Research on Cancer (IARC) calls it "possibly carcinogenic to humans." One of the confounding problems is that commercial preparations can vary in purity, and older formulations were contaminated with carcinogenic dioxins. Some epidemiologic studies have associated 2,4-D with non-Hodgkins lymphoma (NPIC 2012).

2,4-D is soluble in water. It moves in soil and has been found in surface water and groundwater. The EPA has found traces in 49.3% of finished drinking water samples, but well below the 70 ppb (0.07 mg/liter) maximum contaminant level. Exposure is widespread and "2,4-D was detected in urine samples from all age groups in a large study of the American public." The No Observed Effect Level (NOEL) dose in rats is 5 mg/kg/day. The reference dose (dose below which no toxic effects are expected) in humans is 0.01 mg/kg/day (NPIC 2012; CDC 2005).

About 46 million lbs (21 million kg) a year of 2,4-D are currently applied—30 million lbs (14 million kg) in agriculture. Since 2,4-D is used on lawns as well as agriculture, aggregate exposure is a problem. The Food Quality Protection Act requires that aggregate exposure must be considered. Because of this law, the EPA had to require a reduction in application rates for urban uses in 2005 (EPA 2005). The new and expanded herbicide use proposed for GE crops would normally trigger a re-evaluation. However, as this article went to press, HR 872, Reducing Regulatory Burdens Act, an amendment added to the U.S. Farm Bill, will stop the EPA from reviewing new and expanded uses of pesticides (Baden-Mayer 2012).

Multiple Resistance

Further implementation of this simplistic approach to weed management will lead to multiple herbicide resistance, and other problems. One of the expected problems is misapplication. To a professional applicator, all soybean crops look the same. Unmodified or glyphosate resistant crops may be sprayed by mistake with 2,4 D or dicamba, with resulting crop destruction.

Since herbicides in these crops are applied aerially, another problem will be pesticide drift. After application, pesticides can volatilize, and ester formulations of 2,4-D are especially volatile. These risks might drive farmers to convert to multiple resistant crops in self defense (Mortensen et al. 2012).

Companies promoting multiresistant crops suggest applying glyphosate and other herbicides simultaneously. Repeated application of these other herbicides will lead to the same weed resistance seen with overuse of glyphosate. There are 28 weed species already resistant to 2,4-D. There are 38 weed species already simultaneously resistant to two or more herbicidal modes of action—44% of these have appeared since 2005 (Mortensen et al. 2012).

Integrated Pest Management

Herbicide resistant crops are not needed to provide effective weed control in agriculture. Weeds can be controlled by using the principles of integrated pest management (IPM) (Stern et al. 1959). A combination of cover crops, competitive cultivars, restricted tillage, and spot treatments with herbicides can produce profits and effectiveness similar to an all herbicide regime (Liebman et al. 2008; Pimentel et al. 2005). For instance, resistant horseweed can be controlled by tillage, crop rotation, and cover crops (Shaner et al. 2012). Even if GE herbicide resistant crops continue to be used, they should be combined in an IPM program with other methods to reduce resistant weeds and maintain a sustainable system (Mortensen et al. 2012).

Conclusion

GE food should have been regulated in the same way as drugs. As it is, GE crop consumption is a vast, uncontrolled experiment, with no oversight, no monitoring for adverse reactions, and no real way to assess liability. Gene flow and genetic pollution can be tracked only after it occurs. If we remember the problems with Starlink corn, the whole industry is one catastrophe away from total meltdown.

If we overlook safety and environmental issues, GE crops have not been used wisely. Monolithic plantings of one cultivar increase the potential for total crop failure. Relying almost entirely on glyphosate and BT for pest management has increased pest resistance, and current GE crops may become ineffective. Seed monopolies are also causing farmers to lose their independence.

We should learn from the pesticide treadmills of the past. GE crops that tolerate several herbicides are not the answer to resistant weeds. The result will be massive applications of herbicides that are more toxic than glyphosate. Weeds will become resistant to multiple herbicides. The answer is a return to IPM principles that allow both sustainable crop production and environmental protection.

For now, the only sure way to avoid eating GE food is to buy organic products. Maybe if more people vote in the marketplace, producers will make some changes.

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Conference Notes

Special Pheromone Report from the ESA 2011 Annual Meeting

By Joel Grossman

These Conference Highlights are from the Nov. 13-16, 2011, Entomological Society of America (ESA) annual meeting in Reno, Nevada. ESA's next annual meeting is November 11-14, 2012, in Knoxville, Tennessee. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

Cigarette Beetle Mating Disruption

Pheromone mating disruption can create false trails for males to follow, mask natural female pheromones, or overwhelm natural mating scents, said Rizana Mahroof (South Carolina State Univ, 300 College St NE, Orangeburg, SC 29117; rmahroof@scsu.edu). One advantage of pheromone mating disruption is that no residues are detectable in end products such as stored grain, spices, and tobacco. Disadvantages include the need for government regulatory approval and the need for other methods if pest densities are too high.

In 2010 and 2011 mating disruption was tested against the cigarette beetle, *Lasioderma serricorne*, in three South Carolina feed mills, one flour mill, and a seed warehouse. The pheromone was synthetic serricornin (4,6-dimethyl-7-hydroxynonan-3-one) in Trécé mating disruption dispensers.

Trécé and Insects Limited pheromone sticky traps monitored the cigarette beetle mating disruption experiments. In 2010, two mills had only mating disruption treatments. Two other mills were fumigated and did not have mating disruption treatments. In 2011, a seed warehouse was added to the experiment, with one cigarette beetle mating disruption dispenser per 225 ft^2 (21 m^2).

Cigarette beetle larvae can chew through packaging to infest various stored commodities. Food stations with oviposition (egg-laying) cups were used to assess larval cigarette beetle populations. The food stations were brought into the lab biweekly and incubated; microscopes were used to identify the species of larvae.

In 2010, after two weeks no differences were noted between pheromone treated and fumigated facilities. After eight weeks, the mating disruption treatments had significantly fewer cigarette beetles than the fumigated facilities. A year later, the benefits of the mating disruption treatments were still evident. Larval populations trapped in the oviposition cups were lower in the mating disruption treatment facilities than in the fumigated facilities.

The pheromone mating disruption experiments in South Carolina warehouses and food and feed processing facilities were "successful in disrupting cigarette beetle populations both short-term and long-term," said Mahroof. But there are potential complications. For example, cigarette beetles can co-exist with other pests, such as drugstore beetles, *Stegobium paniceum*. Fumigation interventions for other issues add another layer of potential complications to the mating disruption strategy.

Vine Mealybug Mating Disruption

"Vine mealybug (VMB), *Planococcus ficus*, has emerged as a serious pest of vineyards in California," said Ashfaq Sial (Univ of California, 130 Mulford Hall #3114, Berkeley, CA 94720; ashfaqsial@yahoo.com). "Besides infesting the grape clusters and accumulating honeydew on various parts of vines, VMB is a vector of several viral diseases. It is therefore considered an economic pest at very low infestation levels and is often treated with multiple insecticide applications. Effectiveness of insecticides is limited because VMBs are usually protected under the bark or on roots. Repeated insecticide use also adversely impacts VMB natural enemies. In this situation, use of female sex pheromone-based mating disruption is a safe, effective, and species-specific control tool to work in combination with or as an alternative to insecticides."

CheckMate® puffer dispensers were applied at the rate of 2 puffers per acre (0.4 ha) in each of the 10 acre (4.05 ha) treatment plots in a grid pattern, and a perimeter of CheckMate® VMB-XL dispensers was established around each treatment plot and compared with the untreated control. "The number of male VMB catches significantly decreased over time in the mating disruption treatment plots as compared to the untreated plots...The percentage of (grape) clusters that displayed any VMB damage was higher in the control as compared to mating disruption treatment."

The conventional grower insecticide program was compared with the "effectiveness of the VMB mating disruption program using Meso-emitters at 25 per acre (0.4 ha) and CheckMate® plastic dispensers at 250 per acre (0.4 ha)," said Sial. "The male VMB counts in both of the mating disruption treatments was similar to those in the grower standard insecticide treatment. However, the male VMB trap catches started numerically increasing in August, which could be attributed to the fact that CheckMate® standard plastic dispensers might have run out of pheromone by then." Grape cluster damage was similar in both mating disruption treatments, but slightly higher than the conventional insecticide program.

The area of impact of a single puffer unit (i.e. pheromone plume effect) was calculated using a 64-trap grid (8x8) in two 1-acre (0.4-ha) plots. "A single puffer unit programmed to puff every 15 minutes from 2:00 AM to 2:00 PM daily was placed in the center of the pheromone treatment plot," said Sial. "Trap captures were significantly reduced in pheromone treatments compared to the untreated control... For the pheromone puffers, a clear local suppression was observed which appeared to range from a very narrow band of 50 feet (15 m) to beyond the plot boundaries of 200 feet (61 m)."

Grape Root Borer IPM and Mating Disruption

Grape root borer, *Vitacea polistiformis*, larvae live for two years in the soil, complicating the evaluation of pheromone mating disruption, said Douglas Pfeiffer (Virginia Tech, 205C Price Hall, Blacksburg, VA 24061; dgpfeiff@vt.edu). Grape root borer larvae can be invisible under the root bark; root softness indicates their presence. Pupation lasts a month, with emergence in late June to early July.

When grape root borer surveys began in Virginia in 2002, this underground pest often went unnoticed until the vines were about to die. One vineyard lost vines only 2-3 years old; and another had 16 borer exuviae in one vine. One grower found large grape root borer infestations when pulling out wine grape vines. Indeed, 7 of 8 survey sites in the North Piedmont grape area were infested in 2002; with the worst infestations near wild vines, which were a possible infestation source. By 2003 it was evident that the pest was established in Virginia vineyards.

Mounding soil around the vines after borer pupation in summer, and pulling the mounds down in fall is a labor-intensive control tactic that must be well timed, and does not work in all soils. Grape root borer IPM also includes a weed-free area around the vine that creates a dry environment reducing early instar larvae by 95%. Irrigation tends to counter the weed control and favor the pest by eliminating the arid zone that dries out the pest.

Chlorpyrifos (Lorsban®), the only registered chemical for control, is hard to apply, is disliked by growers, and is not used much because of a 35-day post-harvest interval. Entomogenous nematodes show promising results, and may be used more in the future.

Pheromone mating disruption provides good results against other clearwing moth (Sesiidae) species such as peach tree borer, *Synanthedon exitiosa*, and dogwood borer, *S. scitula*. Pheromone mating disruption ropes used against clearwing moths are typically a two-component blend.

In 2004-2006, 200 pheromone ropes per acre (0.4 ha) had one grower very happy because his vines stopped dying. In 2007-2010, the rate was reduced to 100 ropes per acre (0.4 ha), as the lower cost could lead to wider acceptance. In heavily infested Northhampton County, there was a highly significant reduction in the pest and improved vine health. Regulatory approval for Isomate-GRB in the U.S. is expected. In 2013, data should be available for a further reduced rate of 75 ropes per acre (0.4 ha). Minimum treatment area is 5 acres (2 ha).

Grape Berry Moth Pheromone

Grape berry moth, *Paralobesia viteana*, is one of the principal grape pests in northeastern and central North America. "Different insecticide use patterns depend more or less on the phenology of the insect, which can be monitored using pheromone traps," said Timothy Jordan (Virginia Tech, Blacksburg, VA 24061; tajordan@vt.edu). "Septa lures contain a synthetic sex pheromone of the female, *P. viteana*, reported by manufacturers as a 9:1 blend of Z9-12Ac and Z11-14Ac. The E-isomer of the primary component (Z9-12Ac) is considered a potential contaminant. A similar tortricid moth, sumac moth, *Episimus argutanus*, is attracted to *P. viteana* pheromone baited traps and is active around the same time."

There is a danger that lures attracting species other than grape berry moth may result in moth species misidentification, leading to flawed IPM decisions. A two-year experiment with large delta traps compared four commercial pheromone lure catches for grape berry moth and sumac moth in wooded and open vineyards.

"Separate experiments with the same methodology were completed in two table grape (Concord) vineyards," said Jordan. Pheromone lures from Alpha Scents, Inc. (West Linn, OR), ISCA Technologies (Riverside, CA), Suterra (Bend, OR), and Trécé, Inc. (Adair, OK) had less than 7.6% of the impurity, E9-12Ac when measured using gas chromatography-mass spectrometry (GC-MS). Lower levels of the impurity are believed linked to higher grape berry moth trap catches.

"Pheromone monitoring for *P. viteana* is impractical in wooded vineyards, while *E. argutanus* attraction does not appear different between environments," said Jordan. "Additional research should determine the origin of E9-12Ac in lures to maintain quality control and attraction."

NOW California Nut Pheromone Traps

"The navel orangeworm (NOW), *Amyelois transitella*, is the primary pest of almonds and pistachios, California crops collectively worth $5 billion in 2010," said Charles Burks (USDA-ARS, 9611 S. Riverbend Ave, Parlier, CA, 93648; charles.burks@ars.usda.gov). "Population growth of this pest varies greatly depending on the host, cultivated variety, and stage, and abundance is greater in mature pistachios compared to mature almonds. Seasonal trends in abundance also differ between these crops. Despite advances in characterizing the pheromone blend of this species, there is still no pheromone lure available for this species with sufficient field stability for practical use." [Note: Puffer formulations, however, have been used successfully for areawide mating disruption of *Amyelois transitella*. See *IPMP* 30(7/8):11]

"Unmated navel orangeworm females are used as a pheromone source for lures in research, and are also in limited commercial use," said Burks. "Mating in this species occurs in the last 2 hours before dawn above 17°C (62.6°F), and begins earlier in the night as temperatures fall closer to the 12°C (53.6°F) threshold for mating activity."

Abundance and sampling range are important considerations with pheromone traps. "Sampling range is the maximum distance from which the target species is known to be captured by an attractive trap over a given time," said Burks. "Distance over which mutual interference between traps can be demonstrated has been used to estimate sampling range. Several studies have shown that fewer males are captured in pheromone traps with more calling females in the area. Such demonstrations imply that the number of calling females would affect the sampling range of a pheromone trap."

"Sampling range varied with abundance," said Burks. "At low to moderate adult density, the sampling range for navel orangeworm adults using female-strength lures is over 400 m (1,312 ft): i.e. greater than 40 acres (16 ha)."

"Unmated females used as a pheromone source were from a USDA laboratory colony," said Burks. "Females were isolated as mature larvae, and placed in plastic mesh cages shortly after eclosion for transport to the field where they were placed in wing traps. Grids of 9 pheromone traps were hung from trees in the center and 402 m (1,319 ft) and 805 m (2,641 ft) in each cardinal direction in 3 almond and 3 pistachio orchards, each of approximately 256 ha (633 acres)." Orchard rows were north-south; light nighttime winds were from the west and southwest.

Each pheromone trap was baited with sleeve cages of 3 unmated females in late May, and monitored weekly into early September. "There was a trend of more males in peripheral traps in each cardinal direction, although this trend was stronger in the north-south direction (with the rows) than in the east-west direction (across the rows)," said Burks. "Across rows the upwind trap captured the most males, but along rows the downwind trap captured the most males."

Dogwood Borer Pheromones Protect Apples

Dogwood borer (DWB), *Synanthedon scitula*, a clearwing moth (Sesiidae) wood-boring pome fruit pest in eastern North America, feeds "on burr knot and vascular tissue on the trunks of apple trees, reducing tree vigor and potentially killing young trees," said David Epstein (USDA-ARS, 1400 Independence Ave SW, Washington, DC 20250; David.Epstein@ars.usda.gov). The DWB sex pheromone was identified by Zhang et al. in 2008, enabling pheromone mating disruption, attract and remove technology (mass trapping), and monitoring of DWB phenological development.

"Attract and remove differs from traditional use of mass trapping by deploying pheromone-baited trapping devices in quantities usually associated with the number of mating disruption dispensers required to achieve disruption."

"Male DWB were captured in significantly higher numbers in traps baited with the Alpha Scents DWB lure and in traps with red septa lures loaded with 1 mg pheromone extracted from Isomate®-DWB lure dispensers," said Epstein. "Video footage of male moths responding to pheromone sources also show that males frequently approached and made contact with high load lures (>10 mg), but had few approaches to 1 mg and smaller load lures. Male moths had a mean retention time of 30 seconds on 10 mg lures."

Emerald Ash Borer Biocontrol Pheromones

"The emerald ash borer (EAB), *Agrilus planipennis*, is a serious pest of ash trees, *Fraxinus* spp. in the U.S. and Canada," said Allard Cossé (USDA-ARS, 1815 N University St, Peoria, IL, 61604; allard.cosse@ars.usda.gov). "Biological control with natural enemies is the only sustainable method for managing EAB at the landscape level in forests, woodlots, and riparian zones. *Spathius agrili* (Braconidae) has been isolated from EAB in China and was approved for U.S. field release in 2007. Recently, a native parasitoid, *S. floridanus*, was identified attacking EAB larvae, suggesting it may also be an effective EAB biocontrol agent."

"Pheromones could be useful in monitoring systems to evaluate the establishment and spread of populations of EAB biocontrol agents," said Cossé. "Current practices require a laborious process of felling EAB infested ash trees and the removal of EAB larvae, in the hope of detecting the presence of the parasitoids."

Septa with a *Spathius agrili* 3-component pheromone blend (1 mg of major component) were tested in large field cages with 8 potted evergreen ash plants and yellow sticky traps. "Approximately 45% of the males and 50% of the females were recaptured in three replicated 24-hour experiments, demonstrating the attractiveness of the synthetic pheromone in a more natural setting," said Cossé. Septa "stayed attractive after 4 weeks in the field."

"Males and females of both species (*S. agrili* and *S. floridanus*) are attracted to their respective pheromone and all listed compounds have a behavioral function," said Cossé. Both biological control agents share the lactone pheromone component (E)-11-tetradecen-4-olide; but each species is attracted to a different chiral version of the molecule. Indeed, racemic and chiral variations of pheromone components are of major importance in these closely related biocontrol species. Since "for *S. floridanus* both natural lactones have to be present in the blend for a positive behavioral response...it will be unlikely that *S. floridanus* will be attracted to the *S. agrili* pheromone."

Chestnut Weevil Semiochemicals

"The most successful use of semiochemicals controlling agricultural pests combines host-plant volatiles with insect-produced pheromones." said Bruce Barrett (Univ of Missouri, 3-22I Agric Bldg, Columbia, MO 65211; BarrettB@missouri.edu). "The level of attractiveness of herbivorous insects towards constitutive plant volatiles is critical in understanding their dispersal and how such phytophagous insects might be managed. The lesser chestnut weevil. *Curculio sayi*, infests the nuts of trees within the genus *Castanea* throughout the United States, and it has not been reported to feed or oviposit on any other group of plants."

"Chestnut weevils (fall and spring collected) were tested behaviorally by placing them in a glass holding chamber at the base of a Y-tube olfactometer and then recording if and when they moved into the arm of either the compound or the control air source," said Barrett. "The Y-tube was surrounded by white cardboard to obscure visual cues and lighted by an overhead light source centered to prevent its influence on beetle choice." EAG (electroantennogram) responses to plant volatiles were recorded from excised weevil antennae.

Of the compounds tested, lesser chestnut weevils were attracted only to (*E*)-2-hexanal and *beta*-pinene. They were repelled by a number of ketones, esters, and alcohols.

"No studies of the preference of *C. sayi* adults based on chestnut cultivar have been conducted, and such studies may affect the suggested plantings of chestnut trees in Mid-Missouri," said Barrett. "Future research should also examine the VOCs (volatile organic compounds) emanating from *C. sayi* adults, in an effort to determine the presence and identity of any sex or aggregation pheromone."

RHYFER Lure for Red Palm Weevil

The red palm weevil is an invasive species from the Middle East that has been discovered in California (see *IPMP* 32(7/8) New Invasives Threaten California Crops and Ornamentals). "The discovery of the male-produced aggregation pheromone (4-methyl-5-nonanol and 4-methyl-5-nonanone) for the red palm weevil (RPW), *Rhynchophorus ferrugineus*, made the implementation of pheromone-based monitoring and trapping of the weevil possible for its management," said ESA poster exhibitor AlphaScents (1089 Willamette Falls Dr, West Linn, OR 97068; sales@alphascents.com). "RHYFER, an innovative new pheromone lure, is a highly efficient alternative to chemical control of the most dangerous insect pest on date palm in the Arab Gulf countries."

"The active ingredients of RHYFER are clear liquids with slight musty color," said AlphaScents. "These very high purity pheromones are preloaded on an absorbent matrix (special paper) and enclosed in an inert, permeable plastic bag...Pheromone is released from the lure at a controlled rate over a period of time. Basically, the release rate of RHYFER, after reaching equilibrium (usually 48-72 hours), will remain constant throughout most of the life of the lure and will diminish over time. RHYFER is formulated using high quality plastic to assure a constant release rate." Lure replacement is recommended every 65 days for lures with 700 mg (0.025 oz); and every 20 days for lures with 200 mg (0.007 oz).

"For optimal weevil catch, place traps on the ground with the lower half of the trap inserted in the ground between date palm trees," said AlphaScents. "One trap per hectare (2.47 acres) or one trap per 100 date palm trees is a common application to detect peak emergence periods and to estimate insect populations. For best results, and to locate the source of infestation, we recommend adding one more trap per farm." That is, place 3 traps in a 200 tree farm, 4 traps in a 300 tree farm.

Lady Beetles and Aphid Pheromones

"Newly hatched aphidophagous (aphid-eating) lady beetle larvae are poor hunters, making their first meal particularly important," said Thomas Whitney (Univ of Kentucky, S-225 Agric Sci Center N, Lexington, KY 40546; thomas.whitney@uky.edu). "By laying their eggs in clusters, females are thought to improve their sexual fitness by way of 'social feeding'. Under this hypothesis, lady beetle hatchlings will use the aphid alarm pheromone, (E)-*beta*-farnesene, as an olfactory cue to locate its meal when a fellow clutchmate is already preying. If one larvae captures an aphid, others can share and avoid starvation."

"We examined social feeding in the two-spotted lady beetle, *Adalia bipunctata*, and tested the hypothesis that increased initial larval density increases predation success and larval survivorship," said Whitney. "Our results confirm that lady beetle larvae are attracted to cues from damaged aphids and also suggest that larger groups are more likely to capture an individual aphid. We found no support, however, for the prediction that being part of a group improves the survival of larval lady beetles."

"We suggest that increased (larval lady beetle) egg consumption can explain why survival of individual hatchlings was greater when more eggs in their cluster remained unhatched," said Whitney. "Feeding on unfertilized eggs and unhatched siblings can prolong lady beetle survival. When the opportunity for feeding on eggs was removed, however, we found no support for the social feeding hypothesis. This suggests that two-spotted lady beetles from varying cluster sizes can be equally successful, which holds implications for augmentative biological control."

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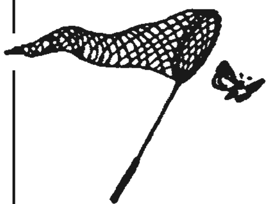

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