The IPM Practitioner
Monitoring the Field of Pest Management
Volume XXXVI, Number 1/2 (Published February 2018)

Regenerative Agriculture Can Reduce Global Warming

By William Quarles

The average temperature of the earth has increased by about 0.7°C (1.3°F) over the last 100 years, resulting in climate change and extreme weather conditions, including drought and flooding. The warming is caused by greenhouse gases (GHG) produced mainly by industry, transportation, and agriculture (Edenhofer et al. 2014; UNEP 2013).

Up to one-third of global greenhouse gases come from agriculture. Synthetic pesticides and fertilizers lead to releases of carbon dioxide (CO_2), methane, and nitrous oxide (N_2O). Monocultures and tillage oxidize soil organic carbon, releasing carbon dioxide. Since 1750, carbon dioxide in the atmosphere has increased by about 40%. About 80% of the global warming is due to carbon dioxide, but methane, nitrous oxide and other gases also contribute to the effect. Over the same timespan, atmospheric methane has increased by 150% and nitrous oxide by 20%. Yearly emissions of all greenhouse gases in 2012 gave about the same warming as 50 gigatons (Gt) of CO_2 (50 Gt CO_2e) (Montzka et al. 2011; Edenhofer et al. 2014; UNEP 2013). [A Gt is a billion metric tons. A metric ton is 1000 kg.] Emissions in 2020 are projected to be 59 Gt CO_2e (UNEP 2013).

To keep global warming below 2°C (3.6°F) over the next hundred years, emission levels by 2020 should be reduced by 15-20% to 41-47 Gt CO_2e/yr. Accomplishing this by 2020 may be impossible. But this article shows how the methods of organic and regenerative agriculture, including cover crops, crop rotations, composts, organic fertilizers, no-till and strip till cultivation can help reach this goal over the next 20-30 years (Rogelj et al. 2013; Rodale 2014).


Photo courtesy USDA and NRCS

This farmer is planting no-till corn into a cover crop of barley. No-till production combined with cover crops can remove carbon dioxide from the atmosphere and trap it in the soil.

Agricultural Greenhouse Emissions

Direct global greenhouse gas emissions of nitrous oxide and methane from agriculture produce about 10-12% (5.1-6.1 Gt CO_2e) of the total warming effect. Nitrous oxide comes mostly from nitrogen fertilizers, and methane comes from livestock operations and rice production. But when GHG from agricultural machinery, fossil fuels used in production of pesticides and fertilizers, deforestation, and oxidation of soil organic carbon (SOC) due to tillage are included, agriculture produces 24% to 33% of the world's GHG (17 Gt CO_2e) each year (Niggli et al. 2008; Scialabba and M-Lindenlauf 2010; Edenhofer et al. 2014; Smith et al. 2014).

In This Issue

The IPM Practitioner
Monitoring the Field of Pest Management

The *IPM Practitioner* is published six times per year by the **Bio-Integral Resource Center (BIRC)**, a non-profit corporation undertaking research and education in integrated pest management.

Managing Editor William Quarles
Contributing Editors Sheila Daar
Tanya Drlik
Laurie Swiadon

Editor-at-Large Joel Grossman
Business Manager Jennifer Bates
Artist Diane Kuhn
Research Intern Erin Berg

For media kits or other advertising information, contact Bill Quarles at 510/524-2567, birc@igc.org.

Manuscripts
The IPMP welcomes accounts of IPM for any pest situation. Write for details on format for manuscripts or email us, birc@igc.org.

Subscriptions/Memberships
A subscription to the IPMP is one of the benefits of membership in BIRC. We also answer pest management questions for our members and help them search for information. Memberships are $60/yr (institutions/libraries/businesses); $35/yr (individuals). Canadian subscribers add $15 postage. All other foreign subscribers add $25 airmail postage. A Dual membership, which includes a combined subscription to both the *IPMP* and the *Common Sense Pest Control Quarterly*, costs $85/yr (institutions); $55/yr (individuals). Government purchase orders accepted. Donations to BIRC are tax-deductible.
FEI# 94-2554036.

Change of Address
When writing to request a change of address, please send a copy of a recent address label.

Update

Synthetic Fertilizers and Pesticides

Conventional agriculture increases GHG in several ways. Synthetic fertilizers and pesticides lead to increased consumption of fossil fuels. Global synthetic nitrogen fertilizer use is about 90 million tons, and production of this fertilizer consumes about 90 million tons of fossil fuel. Each kg of nitrogen requires 0.86 kg (1.9 lb) of C in fossil fuel, releasing about 3.2 kg (7 lb) CO_2. Herbicides, fungicides, and insecticides create about 18 kg (40 lb) of CO_2 for each kg of pesticide produced (Lal 2004a).

Excess nitrogen fertilizer applied in conventional production degrades into nitrous oxide, increasing greenhouse warming. Nitrous oxide is 300x times more potent than CO_2 as a greenhouse gas, contributing 2.8 Gt CO_2e/yr (5.6% of total warming) (Niggli et al. 2008; Scialabba and M-Lindenlauf 2010). Excess synthetic fertilizer also accelerates carbon dioxide release from the soil (Khan et al. 2007). The problem is exacerbated by GMO herbicide resistant crops that require increased applications of pesticides and 50-70% more synthetic fertilizer to maintain yields compared to conventional crops (Quarles 2016; Quarles 2017).

Loss of Soil Organic Carbon

Conventional agriculture releases CO_2 and leads to loss of soil organic carbon (SOC). Since 1850, about 42-78 gigatons (Gt) of carbon have been lost from the world's agricultural soil due to poor agronomy. From 1850 to 1998, 270 Gt of C were released by burning fossil fuels, and 136 Gt by land use change, including loss of carbon from agriculture. [Carbon is often used as the measuring stick for CO_2 emissions. One ton of carbon is equal to about 3.7 tons of carbon dioxide.] Until the 1950s, more CO_2 was released into the atmosphere from deforestation and soil cultivation than from burning fossil fuels (Lal 2004ab; Lal et al. 2007; Khan et al. 2007).

Conventional agriculture generally leads to a loss of soil organic carbon because of tillage, replacement of manure with synthetic fertilizers, and emphasis on monocultures instead of crop rotation and cover crops (Rodale 2014).

Where Does the Carbon Dioxide Go?

Where does the carbon dioxide produced by fossil fuels and soil degradation go? Since 1750, about 40% of CO_2 has remained in the atmosphere (880 Gt CO_2), 30% has been absorbed by the oceans and other water bodies (660 Gt CO_2), and about 30% has been absorbed in plant growth (660 Gt CO_2) (Edenhofer et al. 2014). The ocean is absorbing some of it, but the dissolved carbon dioxide is making the oceans more acidic. Ocean acidity will finally lead to release of carbon dioxide, as the calcium carbonate in marine animal shells and coral dissolves (Lal 2004a).

Removing Carbon Dioxide

Carbon dioxide can be removed from the atmosphere by encouraging plant growth. Planting trees will lead to absorption of CO_2 in photosynthesis and to a storage of carbon dioxide as biomass. Biomass in forests currently stores an amount of carbon equal to about 85% of that found in the atmosphere. Conversion of some agricultural land to tree plantations and good forest management practices offset 11.5% of the U.S. greenhouse gas emissions in 2014 (Hepperly 2007; USDA 2016a). Agroforestry can immobilize 50 tons of carbon/ha in trees and 7 tons/ha carbon in soil over a 20 year period (2850 kg C/ha/yr; 2538 lbs/acre/yr) (Niggli et al. 2008).

Working against this solution are the forest fires triggered by drought due to global warming. Dry forests caused by climate change nearly doubled the area burned by wildfire from 1984 to 2015 in the western forests—nearly 4.2 million ha (10.4 million acres) (Abatzoglou and Williams 2016).

Update

Organic Crops Trap CO_2 in Soil

Organic crops can help reduce global warming by trapping carbon dioxide in soil. Cover crops soak up CO_2, then are buried in the soil. Biomass containing immobilized CO_2 is added to soil in the form of manure and composts. Crops release 10-40% of the carbon compounds they synthesize as root exudates. Soil microbes eat the root exudates, immobilizing carbon in their bodies, increasing soil organic carbon (SOC) (Rovira 1991; Rodale 2014). For instance, soil samples from 10 farms in North Carolina showed organic farms had larger concentrations of carbon and nitrogen, greater microbial activity, and microbial diversity (Liu et al. 2007).

In Pennsylvania, the Rodale Institute Farming Systems Trial (FST) compared organic with conventional production of corn and soybeans starting in 1981. Organic soil fertility methods were either legume cover crops or added animal manure. The annual increase in soil carbon in the organic systems were 2-3 times that of the conventional. After 21 years of production, soil carbon levels had increased by 27.9% in the animal manure system, 15.1% in the legume system, and 8.6% in the conventional system. On average, organic production sequestered about 1,123 kg/ha (1000 lbs/acre) of carbon each year, trapping about 3,500 lbs of carbon dioxide for each acre. Nitrogen levels in the organic soils increased 8-15%, while no change was seen in conventional production. Overall, organic farming reduced output of CO_2 by 37-50% compared to conventional production (Pimentel et al. 2005; Hepperly 2007).

The National Soil Project at Northeastern University studied 659 organic farming soil samples from 39 states and 728 conventionally farmed samples from 48 states. On average, organic farms had 13% more soil organic matter, 44% more humic acid, and 150% more fulvic acid. Humic acid and fulvic acid are stable carbon materials resulting from progressive oxidation of carbon substances. Humic acid for instance, is the end result of composting. So organic farms not only have more soil organic carbon, the carbon is stored in a form unlikely to be oxidized to carbon dioxide (Ghabbour et al. 2017).


Photo courtesy USDA and NRCS

A knife roller (crimper) is used to flatten and kill a cover crop before the economic crop is planted.

Conversion of conventional agriculture to organic methods would also eliminate GHG associated with production and use of synthetic fertilizers and pesticides. And organic management can lead to lower nitrous oxide and methane emissions (Ren et al. 2017; Stalenga et al. 2008; Niggli et al. 2008).

Amount That Can Be Trapped

Estimates of the amount of carbon that can be trapped by organic crops in extended field experiments vary from 100 to 2360 kg C/ha/yr (89-2100 lb C/acre/yr). Generally, application of composted manure increases soil carbon faster than incorporation of legumes. Trapping rates are calculated by subtracting the amount of carbon in the soil at the start of the experiment from the amount found at the end, and dividing by the number of years carbon was added to soil (Hepperly et al. 2009).

Longterm trials in Europe found that organic farms sequestered 100-400 kg C/ha (89-356 lb/acre) per year (Niggli et al. 2008). Freibauer et al. (2004) estimated that carbon sequestration up to 500 kg/ha/yr (445 lb C/acre/yr) was possible in Europe using incorporation of residues and manure, but excluding no-till and reduced till. Gattinger et al. (2012) did a meta-analysis of 74 studies with an average duration of 14 years, and showed that soils of organic farms had 18% more carbon. Organic farms sequestered 450 kg C/ha/yr (400 lb C/acre/yr) more than conventional farms.

Hepperly et al. (2009) added manure, composts, or cover crops to a corn-vegetable-wheat rotation in Pennsylvania. Maximum carbon was sequestered by composted dairy manure, 2360 kg C/ha/yr (2100 lb/acre/yr). Compost amendments increased soil carbon by 16-27% and nitrogen by 13-16%.

A large amount of carbon was trapped in specialized crops in Egypt (4100 kg C/ha/yr; 3649 lb/acre/yr), Iran (4100 kg C/ha/yr; 3649 lb/acre/yr) and Thailand (6380 kg C/ha/yr; 5678 lb/acre/yr) (Rodale 2014). The maximum amount of carbon that can be trapped may be even higher. David

Johnson of New Mexico State University has developed special composting techniques leading to incorporation of 10,721 kg C/ha/yr (9541 lb/acre/yr) (Johnson 2018).

Mitigation of Greenhouse Gases

Estimates of yearly greenhouse gas reductions for organic agriculture and soil sequestration range from 12% to 100%. But at least 17% of each year's GHG production can be trapped in the soil by organic methods. Smith et al. (2008) estimated that organic agriculture methods could offset 5.5 to 6.0 Gt CO_2e/yr, about 12% of total GHG emissions in 2012. Calculations included both croplands and grasslands, and included non-CO_2 gases.

Scialabba and Muller-Lindenlauf (2010) calculated that eliminating synthetic fertilizers would reduce GHG emissions by 1.26 Gt CO_2e/yr, 2.5% of total 2012 GHG. They estimated carbon sequestration could reduce total yearly GHG by 13-24%.

Estimates for carbon sequestration in organic crops range from 5-24% of each year's GHG emissions. Lal 2004a estimated that maximum sequestration rate for croplands was 1000 kg C/ha/yr (890 lb/acre/yr), giving 1.2 Gt C/year (4.4 Gt CO_2/yr). This number is about 8.8% of total 2012 GHG (50 Gt CO_2e). Lal 2004b estimated 0.9 Gt C/year (3.3 Gt CO_2/yr) over a 50 year period. That is about 6.6% of total GHG levels in 2012. Gattinger found cropland on organic farms sequestered 450 kg C/ha/yr (400 lb/acre/yr) more than conventional farms. Extrapolation to all arable land (1369 million ha) gives 0.616 Gt C/ha/yr (2.26 Gt CO_2/yr). This number is equal to 4.5% of 2012 GHG emissions. Rodale Institute (2014) using a sequestration rate of 2360 kg C/ha/yr for crops projected a total 3.27 Gt C/yr (12 Gt CO_2/yr), which is about 24% of total 2012 GHG emission levels. The Rodale Institute estimate may be overly optimistic, because they extrapolated the results of only one experiment in Pennsylvania. Amounts sequestered in tropical areas are lower than in temperate areas (Lal 2004a).

Farmers inspect young corn plants emerging from underneath a protective layer of crop residue.

Photo courtesy NRCS and USDA

Grasslands and pastures can trap an average of 13% and a maximum of 74% of the total greenhouse gas emission each year (see below) (Conant et al. 2001; Rodale 2014). Very conservatively, about 17% of the world's total greenhouse emissions could be trapped in the soil each year by organic methods. This number combines Gattinger's estimate for crops (4.5%) with an average estimate (13%) for pastures. Reductions are based on 2012 emission rates (50 Gt CO_2e). Paustian et al. (2016) found a similar number, 8 Gt CO_2e, or 16% of 2012 global emissions.

Organic Livestock Management

Major reductions in GHG can be made by organic livestock management. Because the world's pasturelands (3500 million ha) have 2.4 times the acreage of croplands (1464 million ha), the amount of carbon dioxide that can be trapped by organic pasture management is large (Panunzi 2008). A review of 115 studies showed that more sustainable pasture management could sequester an average 540 kg C/ha/yr (480 lb C/acre/yr) and a maximum of 3040 kg C/ha/yr (2705 lb/acre/yr). Average length of each study was 23.7 yrs and average sampling depth was 32.5 cm (12.8 in). Techniques included sowing legumes, improved grasses, less destructive grazing, and increased conversion of native and arable land to pastures (Conant et al. 2001).

Rodale Institute (2014), using the maximum figure of 3040 kg C/ha/yr (2705 lb/acre/yr), calculated that potential GHG reduction due to improved pasture management could be a maximum 37 Gt CO_2e/yr, about 74% of total GHG in 2012. An average increase (540 kg C/ha/yr) in sequestered carbon could remove about 6.6 Gt CO_2e/yr, about 13% of total GHG in 2012 (50 Gt CO_2e) (Rodale 2014; Edenhofer et al. 2014; Conant et al. 2001).

Organic livestock methods also reduce stocking rates, leading to less destructive grazing and a reduction in methane emissions. Organic farms integrate crop and animal production, converting livestock waste to crop fertilizer. Manure from animals is composted onsite and incorporated into soil, increasing soil organic carbon. Conventional agriculture is characterized by large feedlots and dairies that wash animal manure into storage lagoons. Storage lagoons produce large amounts of methane. Waste from lagoons is trucked away and sprayed onto croplands and pastures. Composted manure results in about 54% more incorporation of carbon into soil than liquid waste applied at the same nitrogen levels (Sharp and Harper 1999; Niggli et al. 2008; Diacono and Montemurro 2010; Lal 2004ab).

According to the Rodale Institute, if we switched entirely to organic agriculture and managed pastures sustainably worldwide, nearly the entire 2012 output of GHG (50 Gt CO_2e) could be sequestered in the soil. [12 Gt CO_2/yr crops; 37 Gt CO_2/yr pastures.] This is probably an unrealistic assumption. Corporations have large areas of corn and soybean production locked in with genetically engineered crops, synthetic fertilizers and pesticides. But switching half of all available cropland and pastures worldwide to organic production could help keep global warming below 2°C (3.6°F) over the next 100 years (Rodale 2014).

Organic Yields

One argument against increasing organic production is that organic methods conserve and enrich soil, but produce lower yields. In the Rodale Institute FST experiment mentioned above, corn yields for the three methods were similar: 6431 kg/ha manure, 6368 kg/ha legume, 6553 kg/ha conventional. But under drought conditions, organic corn and soybean yields were higher than conventional. Organic crops do better in drought conditions because soil organic carbon can retain up to 20 times its weight in water, buffering crops against extreme conditions. Studies other than the FST have shown organic yields either to be less, similar to, or better than conventional production, according to conditions (Pimentel et al. 2005; Hepperly 2007; Badgley et al. 2007).


Photo by Andy Bayham courtesy USDA

Manure from conventional livestock operations is stored in large lagoons. Liquid waste sprayed onto fields and pastures produces more methane and less GHG mitigation than composted manure buried in soil.


Photo courtesy gpvec.edu

Large feedlots produce methane.

Yields can be site specific, and can depend on specific farming practices. Averaged over a large number of crops, organic yields are about 5-13% lower than conventional when good farming practices are used. Organic yields are less because they generally receive less soluble nitrogen fertilizers (Seufert et al. 2012).

Badgley et al. (2007) showed that organic farming methods could feed the world population using the land now under cultivation. They estimated that average yields of organic crops are about 92% of conventional in developed countries. This average underestimates organic yields, because transitional phase data from conventional to organic are included. In developing countries, organic yields are 180% of conventional production. This number overestimates differences because not all the new technology is available to farmers.

If agriculture switched entirely to organic production, any reduction in yields could be covered by better food preservation practices. Up to 33% of the food produced by agriculture is destroyed before it can be distributed (FAO 2018).

Regenerative Agriculture

GHG mitigation through organic agriculture has great potential. According to the USDA, only 0.6% of U.S. farmland (5.4 million acres) was in organic production in 2011. But some crops such as carrots (14% of carrot acreage) and lettuce (12% of lettuce acreage) were making significant inroads (USDA 2016b).

Quick conversion of all crop production to organic might be impractical, but conventional agriculture could incorporate some of the organic techniques. Environmentally destructive agricultural methods lie on continuum. The worst is herbicide resistant GMO crops that need more pesticides and fertilizers than conventional production (Quarles

2017; Benbrook 2012). Less destructive are conventional crops grown with synthetic fertilizers. When IPM or biointensive IPM is incorporated, environmental effects are less. Organic methods are the most benign, as they pollute less and regenerate soil with cover crops, manure and composts (Benbrook et al 1996; Rodale 2014).

Soil improvement and mitigation of global warming could be made part of conventional agriculture. Cover crops, no-till production, crop rotation, application of composts and manure could reduce net greenhouse gas emissions by sequestration of carbon in soil. For instance, organic amendments such as manure and compost can increase soil organic carbon and nitrogen by 90% and yields by 250% (Diacono and Montemurro 2010). Conventional agriculture could be converted into a form of regenerative agriculture (Muller et al. 2014).

No-Till Production

One of the easiest first steps toward regenerative agriculture is no-till production. Many publications show that tillage leads to increased oxidation of soil carbon and releases of carbon dioxide into the atmosphere. And historically, tilled soils have lost much of their carbon (Abdalla et al. 2013; Nair et al. 2015).

And there are many other publications that show no-till agriculture increases soil carbon. Instead of plowing, no-till production leaves at least 30% of crop residues on the soil surface. Seeds are drilled into the soil through the residues to produce crops. West and Post (2002) analysed 140 publications and found an average increase of 570 kg C/ha/yr (507 lb/acre/yr) with no-till or reduced tillage production. However, most of these publications investigated only the first 12 inches (30 cm) of the soil profile (West and Post 2002).

Applications of synthetic nitrogen fertilizers to fields with surface crop residues were thought to increase formation of humus. Longterm cropping experiments have shown this concept to be only partly true. No-till methods increase carbon only in the topsoil (0-30 cm). No-till soils have higher bulk density and larger soil aggregates, encouraging shallow root systems compared to tillage (Baker et al. 2007; Khan et al. 2007).

No-till agriculture is still a good idea because it prevents soil erosion, improves soil structure, conserves water, promotes microbial activity, and concentrates carbon in an area important for plant growth (Lal 2004ab).

Photo by Jon Gisleson courtesy USDA

In strip till production only the planting rows are tilled. Strip till can trap more carbon in soil than no-till.

Modifications of No-Till

No-till methods can be modified to increase the amount of carbon trapped. Deep carbon sequestration in no-till could be encouraged by deep rooted cover crops, earthworms, and applications of compost tea (Rodale 2014). Strip-till methods, where only the crop rows are tilled, can increase SOC over no-till, reduce bulk density of soil, and increase deep root penetration (Fernandez et al. 2015). And no-till production combined with legume cover crops can sequester soil carbon and mitigate greenhouse gas releases (Bayer et al. 2016).

Synergism with the Soil Microbiome

Carbon sequestration, regenerative agriculture, and the soil microbiome are interrelated. Regenerative and organic farming techniques can help shape the soil microbiome, the kinds and numbers of microbes growing in the soil (Lupatini et al. 2017). According to Six et al. (2006), “crop rotations, reduced or no-tillage practices, organic farming, and cover crops increase total microbial biomass, and shift the community structure toward a more fungal-dominated community...”

Increasing the fungus to bacteria ratio leads to increased net carbon sequestration. For instance, soil mycorrhizae (fungi) can secrete glomalin, a kind of glue that binds organic matter to clay and other soil components, preventing carbon loss (Rodale 2014; Wilson et al. 2009; Six et al. 2006). The microbiome is also shaped by the plants growing in the soil. Plants release 10-40% of their photosynthates into the soil to feed microbes (Quarles 1999; Rovira 1991). New scientific evidence now shows that plants are able to choose the microbes growing in the rhizosphere by the way they feed the soil (Tkacz et al. 2015).

Increasing soil carbon increases microbial diversity (Degens et al. 2000). Microbes in the rhizosphere can affect emission of nitrous oxide and methane greenhouse gases (Philippot et al. 2009). Rhizosphere microbes can increase plant yields and reduce amount of synthetic fertilizer needed through nitrogen fixation (Richardson et al. 2009; Tkacz et al. 2015).

Composts can contribute to plant disease suppression, by adding beneficial microbes to soil. And cover crops feed the soil with carbon substrates that can recruit disease suppressive microbes (Mazzola and Freilich 2017; Perez-Piqueres et al. 2006; Quarles 2001ab).

The reality is that soil feeds plants, and plants feed the soil. Root exudates from plants influence the microbial distribution in the rhizosphere. This soil rhizomicrobiome can promote plant growth, and trigger systemic resistance in plants, protecting against disease and insects. The result is a reduced need for synthetic fertilizers and pesticides and a more sustainable agricultural production system (McLeod 1982; Richardson et al. 2009; Mazzola and Freilich 2017).

Organic Matter and Climate Change

Application of organic material such as manure, straw, or compost will increase soil carbon. However, incorporation of the carbon from these materials into the soil will mitigate climate change only if the material otherwise would have been burned or destroyed. For instance, applying straw that would have been burned has an effect. Adding compost to soil rather than landfill has an effect because landfill disposal leads to methane production. Moving manure from one spot to another has no overall effect by itself. But soil incorporation changes soil structure, reducing carbon dioxide emissions (Powlson et al. 2011; Leifeld et al. 2012).


Photo by Markus Dubach courtesy USDA

Carbon incorporation into soil encourages beneficial soil microbes.

Cover crops remove carbon dioxide from the atmosphere as they grow. When legume crops are turned under, they increase soil carbon and nitrogen. Cover crops can truly mitigate climate change, as the carbon dioxide they absorb is stored in the soil as carbonaceous plant material. Soil microbiome changes induced by soil incorporation improve soil structure, reducing carbon loss by oxidation. And cover crops can reduce needed fertilizer through nitrogen fixation, reducing nitrous oxide emissions (Pimentel et al. 2005; Franche et al. 2009).

Cover crop biomass can also be converted to biochar before it is added to soil. [Biochar is similar to charcoal.] The overall effect is to trap carbon dioxide in soil as biochar. Conversion of biomass to biochar requires large capital investments in new technology to prevent GHG emissions during production. It is a promising concept, but it seems like an unnecessary complication with many unanswered questions. More research may clarify its importance (Paustian et al. 2016; Gurwick et al. 2013; Nair et al. 2017; Woolf et al. 2010).

Conclusion

Organic and regenerative agriculture can remove carbon dioxide from the atmosphere and sequester it in the soil. Conversion of the world's crops to organic production could trap 5-24% of annual carbon dioxide releases in the soil. Incorporation of cover crops, composts, and reduced tillage methods into conventional agriculture could improve soil structure, and reduce synthetic fertilizers and pesticides. Organic management of pastures and livestock could remove an additional 13% to 74% of yearly greenhouse gas emissions. Conservatively, regenerative agriculture techniques could reduce greenhouse gases by at least 17% each year. These reductions are possible, and we should implement them before it is too late.

William Quarles, Ph.D., is an IPM Specialist, Executive Director of the Bio-Integral Resource Center (BIRC), and Managing Editor of the IPM Practitioner. He can be reached by email, birc@igc.org

References

Abatzoglou, J.T. and A.P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western U.S. forests. *PNAS* 113(42):11770-11775.

Abdalla, M., B. Osborne, G. Lanigan et al. 2013. Conservation tillage systems: a review of its consequences for greenhouse emissions. *Soil Use Manag.* 1-11. Doi: 10.1111/sum. 12030

Badgley, C., J. Moghtader, E. Quintero et al. 2007. Organic agriculture and the global food supply. *Renewable Agric. Food Sys.* 22(2):86-108.

Baker, J.M., T.E. Ochsner, R.T. Venterea et al. 2007. Tillage and soil carbon sequestration: what do we really know? *Agric. Ecosys. Environ.* 118:1-5.

Bayer, C., J. Gomes, J.A. Zanatta et al. 2016. Mitigating greenhouse gas emissions from a subtropical Ultisol by using longterm no-tillage in combination with legume cover crops. *Soil Tillage Res.* 161:86-94.

Benbrook, C., E. Groth III, J.M. Halloran et al. 1996. *Pest Management at the Crossroads.* Consumers Union, Yonkers, NY. 272 pp.

Benbrook, C. 2012. Impacts of genetically engineered crops on pesticide use in the U.S.—the first sixteen years. *Environ. Sci. Eur.* 24:24.

Conant, R.T., K. Paustian and E.T. Elliott. 2001. Grassland management and conversion into grassland: effects on soil carbon. *Ecol. Appl.* 11(2):343-355.

Degens, B.P., L.A. Schipper, G.P. Sparling et al. 2000. Decreases in organic C reserves in soils can reduce the catabolic diversity of soil microbial communities. *Soil Biol. Biochem.* 32:189-196.

Diacono, M. and F. Montemurro. 2010. Longterm effects of organic amendments on soil fertility. A review. *Agron. Sustainable Devel.* 30(2):401-422.

Edenhofer, O., R. Pichs-Madruga, Y. Sokona et al. eds. *Climate Change 2014: Mitigation of Climate Change.* Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. pp. 811-922.

FAO (Food and Agriculture Organization of the United Nations). 2018. *Save Food: Global Initiative on Food Loss and Waste.* Fao.org/save-food/resources/keyfindings/en

Fernandez, F.G, B.A. Sorenson and M.B. Villamil. 2015. A comparison of soil properties after 5 years of no-till and strip-till. *Agron. J.* 107(4):1339-1345.

Franche, C., K. Lindstrom and C. Elmerich. 2009. Nitrogen fixing bacteria associated with leguminous and non-leguminous plants. *Plant Soil* 321:35-59.

Freibauer, A. M.D.A. Rounsevell, P. Smith et al. 2004. Carbon sequestration in the agricultural soils of Europe. *Geoderma* 122:1-23.

Gattinger, A., A. Muller, M. Haeni et al. 2012. Enhanced top soil carbon stocks under organic farming. *Proc. Natl. Acad. Sci. USA* 109(44):18226-18231.

Ghabbour, E.A., G. Davies, T. Misiewicz et al. 2017. Chapter one—national comparison of the total and sequestered organic matter contents of conventional and organic farm soils. *Advances Agron.* 146:1-35.

Gurwick, N.P., L.A. Moore, C. Kelly et al. 2013. A systematic review of biochar research with a focus on stability in situ and its promise as a climate mitigation strategy. *Plos ONE* 8:e75932.

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

Hepperly, P., D. Lotter, C.Z. Ulsh et al. 2009. Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. *Compost Sci. Utilization* 17(2):117-126.

Johnson, D.C. 2018. A greener revolution and a no-regrets carbon capture mechanism for New Mexico. NMSU Inst. Sustainable Agricultural Research. 42 slide Presentation.

Keister, D.L. and P.B. Cregan, eds. 1991. *The Rhizosphere and Plant Growth.* Beltsville Symposia in Agricultural Research. Kluwer Academic Publishers, London. 382 pp.

Khan, S.A., R.L. Mulvaney, T.R. Ellsworth et al. 2007. The myth of nitrogen fertilization for soil carbon sequestration. *J. Environ. Qual.* 36:1821-1832.

Lal, R. 2004a. Soil carbon sequestration impacts on global climate change and food security. *Science* 304:1623-1627.

Lal, R. 2004b. Soil carbon sequestration to mitigate climate change. *Geoderma* 123:1-22.

Lal, R., R.F. Follett, B.A. Stewart et al. 2007. Soil carbon sequestration to mitigate climate change and advance food security. *Soil Sci.* 172(12):943-956.

Leifeld, J., D.A. Angers, C. Chenu et al. 2012. Organic farming gives no climate change benefit through soil carbon sequestration. *Proc. Natl. Acad. Sci. USA* 110(11):E984.

Liu, B., C. Tu, S. Hu et al. 2007. Effect of organic, sustainable and conventional management strategies in grower fields on soil physical, chemical, and biological factors, and the incidence of Southern blight. *Appl. Soil Ecol.* 37:202-214.

Lupatini, M., G.W. Korthals, M. de Hollander et al. 2017. Soil microbiome is more heterogeneous in organic than in conventional farming system. *Frontiers Microbiol.* 7:article 2064.

Mazzola, M. and S. Freilich. 2017. Prospects for biological soilborne disease control: application of indigenous versus synthetic microbiomes. *Phytopathol.* 107:256-263.

McLeod, E. 1982. *Feed the Soil.* Organic Agriculture Research Institute, Graton, CA. 137 pp.

Montzka, S.A., E.J. Dlugokencky and J.H. Butler. 2011. Non-CO$_2$ greenhouse gases and climate change. *Nature* 476:43-50.

Muller, A. and C. Aubert. 2014. The potential of organic agriculture to mitigate the influence of agriculture on global warming – a review. In: S. Bellon and S. Penvern, eds. *Organic Agriculture, Prototype for Sustainable Agricultures.* Springer Verlag, 492 pp.

Nair, R., C.R. Mehta and S. Sharma. 2015. Carbon sequestration in soils: a review. *Agri. Rev.* 36(2):81-99.

Nair, V.D., P.K.R. Nair, G. Dari et al. 2017. Biochar in the agrosystem-climate-change—sustainability nexus. *Front. Plant Sci.* 11(8):2051. December 11, 2017.

Niggli, U., H. Schmid and A. Fliessbach. 2008. *Organic Farming and Climate Change.* International Trade Center, Geneva. 38 pp.

Panunzi, E. 2008. Are grasslands under threat? Analysis of FAOSTAT data by Eleonora Panunzi, July 2008.

Paustian, K., J. Lehman, S. Ogle et al. 2016. Climate smart soils. *Nature* 532:49-57.

Perez-Piqueres, A., V. Edel-Hermann, C. Alabouvette et al. 2006. Response of soil microbial communities to compost amendments. *Soil Biol. Biochem.* 38:460-470.

Philippot, L., S. Hallin, G. Borjesson et al. 2009. Biochemical cycling in the rhizosphere having an impact on global change. *Plant Soil* 321:61-81.

Pimentel, D., P. Hepperly, J. Hanson et al. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *BioScience* 55(7):573-582.

Powlson, D.S., A.P. Whitmore and K.W.T. Goulding. 2011. Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. *Eur. J. Soil Sci.* 62:42-55.

Quarles, W. 1999. Plant disease biocontrol and VAM fungi. *IPM Practitioner* 21(4):1-9

Quarles, W. 2001a. Composts and plant disease. *Common Sense Pest Control Quarterly* 16(3):3-20.

Quarles, W. 2001b. Compost tea for organic farming and gardening. *IPM Practitioner* 23(9):1-7.

Quarles, W. 2016. Glyphosate toxicity: smoke or fire? *IPM Practitioner* 35(5/6):1-7.

Quarles, W. 2017. Glyphosate, GMO soybean yields and environmental pollution. *IPM Practitioner* 35(11/12):1-9.

Ren, F., X. Zhang, L. Liu et al. 2017. A synthetic analysis of greenhouse emissions from manure amended agricultural soils in China. *Sci. Rpt.* 7:article 8123.

Richardson, A.E., J.M. Barea, A.M. McNeill et al. 2009. Acquistion of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. *Plant Soil.* 321:305-339.

Rogelj, J., D.L. McCollum, B.C. O'Neill et al. 2013. 2020 emissions levels required to limit warming to below 2°C. *Nature Climate Change* 3:405-412.

Rodale Institute. 2014. *Regenerative Organic Agriculture and Climate Change.* Rodale Institute, 611 Siegfriedale Road, Kutztown, PA 19506. 26 pp.

Rovira, A.D. 1991. Rhizosphere research—85 years of progress and frustration. In: Keister and Cregan, pp. 3-13.

Scialabba, N. El-Hage, and M. Muller-Lindenlauf. 2010. Organic agriculture and climate change. *Renewable Agric. Food Sys.* 25(2):158-169.

Seufert, V., N. Ramankutty and J.A. Foley. 2012. Comparing the yields of organic and conventional agriculture. *Nature* 485:229-232.

Sharpe, R.R. and L.A. Harper. 1999. Methane emissions from an anaerobic swine lagoon. *Atmospheric Environ.* 33:3627-3533.

Six, J., S.D. Frey, R.K. Thiet et al. 2006. Bacterial and fungal contributions to carbon sequestration in agroecosystems. *Soil Sci. Soc. Am. J.* 70:555-569.

Smith, P., D. Martino, Z. Cai et al. 2008. Greenhouse gas mitigation in agriculture. *Phil. Trans. Royal Soc. B.* 363:789-813.

Smith, P., M. Bustamante, H. Ahammad et al. 2014. *Agriculture, Forestry and Other Land Use (Afolu).* In: O. Edenhofer, R. Pichs-Madruga, Y. Sokona et al. eds. *Climate Change 2014: Mitigation of Climate Change.* Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. Pp. 811-922.

Stalenga, J. and A. Kawalec. 2008. Emission of greenhouse gases and soil organic matter in different farming systems. *Intl. Agrophys.* 22:287-290.

Tkacz, A., J. Cheema, G. Chandra et al. 2015. Stability and succession of the rhizosphere microbiota depends upon plant type and soil composition. *ISME J.* 9:2349-2359.

USDA. 2016a. *Agriculture and Climate Change.* USDA Economic Research Service. October 14, 2016.

USDA. 2016b. *Documentation of Organic Production.* USDA Economic Research Service. September 22, 2016.

UNEP (United Nations Environment Programme). 2013. *The Emissions Gap Report 2013.* United Nations Environment Programme, Nairobi. 45 pp.

West, T.O. and W.M. Post, 2002. Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. *Soil Sci. Soc. Am. J.* 66:1930-1946.

Wilson, G.W., C.W. Rice, M.C. Rillig et al. 2009. Soil aggregation and carbon sequestration are tightly correlated with abundance of arbuscular mycorrhizal fungi: results from longterm field experiments. *Ecol. Lett.* 12(5):452-461.

Woolf, D., J.E. Amonette, F.A. Street-Perrott et al. 2010. Sustainable biochar to mitigate global climate change. *Nature Comm.* 1:Article 56.

ESA 2017 Meeting Highlights

By Joel Grossman

These Conference Highlights were selected from the Denver, Colorado (Nov. 5-8, 2017) Entomological Society of America (ESA) annual meeting. The next ESA annual meeting, November 11-14, 2018 in Vancouver, British Columbia (BC), Canada is a joint meeting with the Entomological Societies of Canada and BC. For more information contact the ESA (3 Park Place, Suite 307, Annapolis, MD 21401; 301/731-4535; http://www.entsoc.org).

Spotted wing drosophila (SWD), *Drosophila suzukii*, caused $133 million of crop damage in 31 USA states in 2014, said Yan Feng (USDA-ARS, 10300 Baltimore Ave, Beltsville, MD 20705; yan.feng@ars.usda.gov). Methyl benzoate, a volatile aroma compound naturally found in fermented apple juice and produced commercially in bulk quantities for foods and cosmetics in the USA and EU, has all the earmarks of an inexpensive reduced-risk botanical insecticide. In cage tests, a 1% aqueous emulsion dip of methyl benzoate protected harvested blueberries from SWD for 10 days. Methyl benzoate dips also prevented egg and nymph development of brown marmorated stinkbug, *Halyomorpha halys*; and egg development of diamondback moth, *Plutella xylostella*, and tobacco hornworm, *Manduca sexta*.

Potatoes Respond to Beneficial Nematodes

Potato plants somehow perceive the below-ground presence of entomopathogenic nematodes (EPNs), and respond in above-ground ways that deter egg laying of Colorado potato beetle (CPB), *Leptinotarsa decemlineata*, and result in lower-weight CPB larvae consuming less potato leaf mass, said Anjel Helms (Penn State Univ, 501 ASI Bdg, University Park, PA 16802; amh468@psu.edu). "Plants respond to beneficial nematodes by inducing systemic defense responses, and herbivores respond by avoiding EPN cues. This has important implications for pest management in agroecosystems, as EPN natural enemies both directly protect plants by killing insect pests, and indirectly reduce herbivore damage through chemical warning cues to plants and herbivores."

EPN exposure measurably increases salicylic acid in plants and "expression of the pathogen-resistance gene PR1," said Helms. In 3-way choice tests, female CPB adults lay fewer eggs when exposed to EPNs. There are multiple reasons beyond pest mortality for applying beneficial nematodes: induced plant resistance to plant pathogens and insect pests; reduced pest egg laying; less fit pest larvae; pest avoidance or repellence; and attraction of additional natural enemies.

Kaolin Clay Alternative to Neonics

Seedless watermelons grown in California's southeastern desert valleys are typically treated at planting time with soil applications of imidacloprid, a neonicotinoid insecticide, although a kaolin clay foliar particle film coating the foliage white works equally well, said Vonny Barlow (Univ California, Briggs Hall Rm 367, Davis, CA 95616; vmbarlow@ucdavis.edu). The goal is preventing sweetpotato whitefly, *Bemisia tabaci*, from vectoring cucurbit yellow stunting disorder virus (CYSDV). Even with imidacloprid, watermelons succumb to the virus when whitefly populations are high.

Experimental treatments were: 1) imidacloprid applied at planting, 2) kaolin clay (particle film) applied every 14 days, 3) untreated controls. Neither kaolin clay nor imidacloprid affected floral nectar or honeybee behaviors such as pollen deposition and number of flower visits. Watermelon fruit numbers and weights were the same with imidacloprid and kaolin, supporting "the use of kaolin clay particle film as a reduced risk alternative to neonicotinoids on watermelon."

Creating Insect Suppressive Soils

"Plant pathologists have for a long time studied the concept of 'suppressive soils', and "we propose to expand the concept to 'pest insect suppressive soils'," said Heikki Hokkanen (Univ Helsinki, Box 27, Latokartanonkaari 5, Helsinki, Finland; heikki.hokkanen@helsinki.fi). Agricultural fields usually have very low numbers of beneficial entomopathogenic nematodes (EPN) and fungi (EPF), and thus little effect on pests. Yet simple improvements in field and crop management can quickly increase their numbers to levels that will impact pest populations.

Oilseed Brassica or pulses, important worldwide crops, are attacked by *Sitona* spp. weevils. EU (European Union) oilseed cropping systems are "antagonistic to high levels of soil EPNs and EPFs," which is unfortunate, as "*Sitona* weevils are very susceptible to EPNs and EPFs," said Hokkanen. Weevil natural enemies include beneficial fungi such as *Metarhizium anisopliae*, whose soil levels can be increased by ecostacking. Ecostacking simply means applying multiple ecological farming practices in additive or synergistic combinations. Examples are avoiding inversion tillage and herbicide applications. Tillage exposes beneficial nematodes and fungi to lethal UV light and desiccation, and herbicides kill beneficial fungi. Ecological farming practices provide alternative soil hosts for EPNs and EPFs.

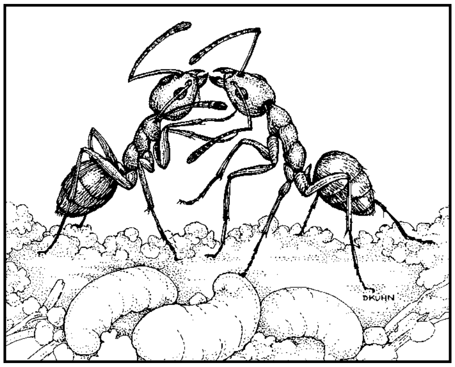
The goal is building a microbial soil buffer against *Sitona* weevils, including endophytes, mycorrhizal fungi, *Rhizobium* bacteria, plant growth–promoting rhizobacteria (PGPR) and fungi (PGPF). Crop rotations can introduce alternative soil hosts for EPNs and EPFs. Beneficial microbes can be reintroduced through legume cover crops. These multiple methods of insect suppressive soil creation can be synergistic. Even if additive, "little percentages add up." IPM techniques such as trap crops and biopesticides can also be integrated with ecostacking. For example, pheromones can attract *Sitona* weevils, which are then infected with EFNs and EPNs for introduction into crop soils.

Argentine Ant Gel Baits

Invasive Argentine ants, *Linepithema humile*, are ubiquitous in Southern California, inhabiting 89% of citrus groves and making up to one million ant visits per day per tree, often to tend honeydew-producing insects such as Asian citrus psyllid (ACP), *Diaphorina citri*, which spreads the tree-killing citrus greening disease, huanglongbing (HLB), said Kelsey Schall (Univ California, 900 University Ave, Riverside, CA 92521; kscha008@ucr.edu). Honeydew-seeking Argentine ants disrupting ACP biocontrol are costly: "California growers are already bearing the burden of increased ACP-HLB management costs, and economic forecasts predict that pesticide and nutrition costs may rise to $220 million per year in the next five years."

Argentine ant control is a key part of "integrated, sustainable strategies for improving biological control of ACP and other ant-tended hemipteran pests," such as mealybugs, aphids, whiteflies and scales, said Schall. Indeed, 87% of honeydew-producing citrus pests have a mutualistic relationship with ants, exchanging honeydew for ant protection from natural enemies. Liquid baiting programs for ants are labor-intensive and expensive in citrus orchards. Hydrogel baits work well against Argentine ants in urban areas. Alginate hydrogel baits, derived from algae or seaweed, contain 0.0001% thiamethoxam, a dose 100-fold less than standard urban ant gel baits.

Gel baits were applied in six plots in three commercial navel orange orchards in Redlands, California. Argentine ants were rapidly attracted, feeding for 3 days until the alginate hydrogels dried up. After the first bait application, ants on citrus trees were down 45%; but swiftly rebounded one week later. Hydrogels lost over 90% of their water in two days, and irrigation was insufficient for rehydration. After a third bait application, Argentine ants were down 70% after 3 weeks; which was on par with other baiting systems, including chemical industry standards and boric acid. Three weeks between baiting with 250 mg (0.0088 oz) per tree is "an effective alternative tactic," reducing Argentine ant activity nearly 90%.



Drawing by Diane Kuhn

Argentine ant, *Linepithema humile*

Stink Bug Trap Crops

Organic bell pepper crops were protected from brown marmorated stink bug (BMSB), *Halyomorpha halys*, by sorghum and sunflower trap crops in Maryland, Pennsylvania, New Jersey, West Virginia and other mid-Atlantic and southeastern states, said Clarissa Mathews (Redbud Farm, 942 Tabler Station Rd, Inwood, WV 25428; cmathews@shepherd.edu). Trap crop borders consisted of two rows of sorghum and two rows of sunflowers surrounding five rows of bell peppers planted into plastic mulch. The control treatment (no trap crop) had more BMSB than trap crop treatments. BMSB numbers declined over time in trap crop treatments, in contrast to control treatments. Sorghum and sunflower trap crops had 500% to 5,000% more stink bugs per unit area than "protected" bell pepper cash crops.

During the 8 weeks in which trap crop flowers and seed heads were most attractive to BMSB, the bell pepper cash crop suffered only minor damage. Trap crops provided the best stink bug protection late in the mid-June to September growing season. BMSB populations peaked in week 5, which is when 80% of stink bugs were trapped. High stink bug damage to peppers mostly occurred during early weeks of the growing season, which is when IPM programs might use flaming or selective sprays to kill BMSB in trap crops.

Fungicides Induce Insecticide Resistance

First reported as a major problem near Omaha, Nebraska in 1859, Colorado potato beetle (CPB), *Leptinotarsa decemlineata*, is now a major worldwide pest causing 50% yield losses and is resistant to almost every major class of insecticide, a phenomenon driven in part by heavy exposure to common potato fungicides such as boscalid and chlorothalonil, said Justin Clements (Univ Wisconsin, 1630 Linden Dr, Rm 840, Madison, WI 53706; jclements2@wisc.edu). "Many non-insecticidal compounds can mimic insecticidal chemistries and may unintentionally drive insecticide resistance," which appears to be the case with boscalid and chlorothalonil, a pair of fungicides heavily used in commercial potato production. Chlorothalonil has been sprayed on 150 CPB generations since 1966. Boscalid use dates to its 2003 registration. "Exposure to either fungicide induced a phenotypic and genetic response in *L. decemlineata* which correlated with known mechanisms of insecticide resistance," including target site insensitivity and enhanced enzyme degradation.

For instance, both boscalid and chlorothalonil interact with the neonicotinoid insecticide imidacloprid to induce generalized chemical resistance. In field rate tests, both boscalid and chlorothalonil showed insecticidal activity, causing 2nd instar CPB to struggle and manifest reduced growth. Both insecticide and fungicides induced the same resistance enzyme, glutathione-S-transferase; genetic studies confirmed the similar mechanisms of resistance. The fungicides activate a non-specific enzyme, with cross-resistance between insecticide and fungicide the subject of ongoing multi-generational CPB studies.

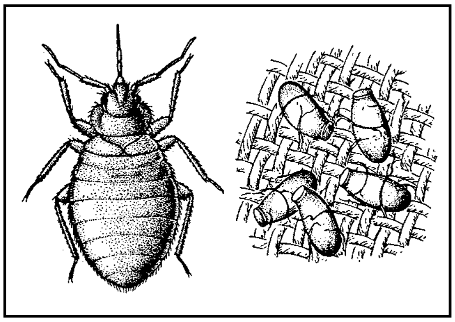
Specialty Crop Insectary Plants

"Flowering hedgerows and insectary plants can support beneficial insects in agricultural landscapes, but the associated establishment and maintenance costs can deter some growers," said Tessa Grasswitz (Cornell Univ, 12690 St Rt 31, Albion, NY 14411; tg359@cornell.edu). "Small-scale farmers in particular have expressed interest in insectary plants that also produce marketable products to help offset such costs. *Ziziphus jujuba* (jujube or Chinese date) has the potential to meet this need, since its flowers are attractive to many beneficial insects and its fruits can command high prices in niche markets."

Jujube flower samples in New Mexico contained mostly (68%) Hymenoptera, of which 14% were pollinators and 44% biocontrol agents, particularly predatory wasps. Flowers also contained 11% syrphid and tachinid flies, and 19% beetles, mostly ladybugs. Other natural enemies frequenting jujube flowers included green lacewings, *Chrysoperla* spp., and minute pirate bugs, *Orius* spp. "Where the climate is suitable, *Ziziphus jujuba* may therefore have potential as a dual-purpose specialty crop and insectary plant, particularly for small-scale diversified farms where land is at a premium," said Grasswitz.

Bed Bug Botanicals

"Active components of essential oils such as thymol, eugenol, and carvacrol, exhibit a broad spectrum of insecticidal, repellent, antifeedant and growth disruption activity" potentially useful against insecticide resistant bed bugs, *Cimex lectularius*, said Sudip Gaire (Purdue Univ, 901 West State St, West Lafayette, IN 47907; sgaire@purdue.edu). "Plant derived essential oils are considered safer for humans, have limited persistence in the environment and are exempted from registration by the U.S. Environmental Protection Agency." Essential oil and botanical products such as EcoRaider® and Bed Bug Patrol® have proven effective against bed bugs. But "there is a significant gap in knowledge and controversy about the effects of essential oil constituents on the insect nervous system."



Bed bug, *Cimex lectularius*

Saturated aromatic compounds such as thymol and carvacrol were more effective than unsaturated compounds and hydrocarbons such as eugenol, geraniol, and *alpha*-pinene against adult male bed bugs of the Harold Harlan strain in topical and fumigant bioassays. Citronellic acid has neuroexcitatory effects. Thymol (in thyme oil) acts on chloride channels. Carvacrol (in oregano oil) acts on nicotine acetylcholine receptors. Eugenol (in clove oil) acts on octopamine receptors and has neuroinhibitory effects on insect nervous systems.

EcoRaider, an essential oil-based product containing 1% cedar oil, 1% geraniol and 2% sodium lauryl sulfate, was effective in lab and field tests against both susceptible (Harlan strain) and pyrethroid-resistant bed bugs, said Fang (Rose) Zhu (Washington State Univ, 166 FSHN, Pullman, WA 99164; fang.zhu@wsu.edu). EcoRaider suppressed bed bug feeding and reproduction capabilities, though susceptible bed bugs survived sublethal exposures in a dose- and time-dependent manner.

A pyrethroid and EcoRaider mixture "significantly enhanced" bed bug mortality. "Our data suggests that the toxicity of EcoRaider on pyrethroid resistant bed bugs is partly due to down-regulation of metabolic genes that contribute to the pyrethroid resistance," said Zhu. EcoRaider suppressed 75% (3 of 4) of overexpressed genes associated with pyrethroid resistance in pyrethroid-resistant bed bugs. But "further studies are required to reveal the mode of action of EcoRaider, which is very likely different from that of pyrethroids."

Winter Rye for Iowa

"Implementation of cover crops on the 23 million acres (9.3 million ha) of harvested corn and soybean in Iowa has the potential to decrease soil erosion, nitrate leaching and weed competition," and over the long term improve soil health, said Andrew Lenssen (Iowa State Univ, 2104 Agronomy Hall, Ames, IA 50011; alenssen@iastate.edu). "Despite many positive attributes, farmer adoption of cover crops remains low in Iowa with less than 3% of annual row-crop acres cover cropped. Farmers express concerns over the lack of short-term economic benefits and increased farm management complexities when cover crops are included in corn-soybean systems." However, "overall system profitability" is boosted when winter rye is grown for mid-May forage harvest before soybean.

Corn and soy grain yields are similar with and without cover crops. "When cover crops are planted in Iowa, winter rye, *Secale*

Calendar

January 24-27, 2018. 38th Annual EcoFarm Conference. Asilomar, Pacific Grove, CA. Contact: Ecological Farming Association, 831/763-2111; info@eco-farm.org

January 29-February 1, 2018. Annual Meeting Weed Science Society of America. Arlington, VA. Contact: www.wssa.net

February 22-24, 2018. 29th Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

February 26-March 1, 2018. 28th Annual University of California Vertebrate Pest Conference. Rohnert Park, CA. Contact: www.vpconference.org.

March 5-9, 2018. BPIA Biopesticides Conference. San Diego, CA. Contact: BPIA, www.bpia.org

March 19-22, 2018. 9th International IPM Symposium. Renaissance Baltimore Harborplace Hotel. Baltimore, MD. Contact: Michelle Marquat, 217-244-8174; mmarqua2@illinois.edu

April 3-5, 2018. SARE Sustainable Agriculture Conference. St. Louis, MO. Contact: https://ofof.sare.org

June 20-23, 2018. Annual Meeting, Pest Control Operators CA, South Lake Tahoe, NV. Contact: PCOC, 3031, Beacon Blvd, W. Sacramento, CA 95691; www.pcoc.org

June 27-28, 2018. North America Biopesticides Conference. Agricultural Institute of Canada. Vancouver, BC. Contact: rbaryah@acieu.net

July 29-August 3, 2018. American Phytopathological Society Conference, Boston, MA. Contact: APS, 3340 Pilot Knob Road, St. Paul, MN 55121; 651-454-7250; aps@scisoc.org

August 5-10, 2018. 103rd Annual Conference, Ecological Society of America, New Orleans, LA. Contact: ESA, www.esa.org

November 4-7, 2018. Annual Meeting, Crop Science Society of America. Baltimore, MD. Contact: https://www.crops.org

November 4-7, 2018. Annual Meeting, American Society of Agronomy. Baltimore, MD. https://www.acsmeetings.org

October 23-26, 2018. NPMA Pest World, Orlando, FL. Contact: NPMA, www.npmapestworld.org

November 11-14, 2018. Annual Meeting, Entomological Society of America, Vancouver, BC. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; www.entsoc.org

January 6-9, 2019. Annual Meeting, Soil Science Society of America. San Diego, CA. Contact: www.soils.org

Conference Notes

cereale, is the choice on nearly all acres," said Lenssen. "Corn following winter rye sometimes has reduced yield due to increased early season root disease." But overall in terms of biomass and added nitrogen, winter rye is superior to hairy vetch, *Vicia villosa*; turnip, *Brassica rapa*; canola, *B. napus*; camelina, *Camelina sativa*; and fall/spring cover crop mixtures.

Birds, Bees and Berries

Pest control strips are rows or strips of flowering plants adding vegetative diversity to crop ecosystems to boost pollinators and biocontrol agents, though they may also increase some pests, such as *Lygus hesperus* and cucumber beetles, which means weighing the pluses and minuses, said Amber Sciligo (Univ California, 130 Mulford Hall, Berkeley, CA 94720; amber.sciligo@berkeley.edu). Pest control strips are under investigation on 15 salad bowl (lettuce) and 15 organic strawberry farms in California's central coast area. Pest control strips can be simple, such as 10% non-strawberry plants or native habitat around fields; or polycultures with 30% to 90% vegetative diversity.

In organic strawberries, pest control strips boosted pollinator abundance, adding 15% to strawberry fruit growth. Pest control strips also boosted numbers of beneficial big-eyed bugs, *Geocoris* spp., which are predators of the key strawberry pest, *Lygus hesperus*, whose numbers fell 10%. Insect-eating birds were more abundant with pest control strips. Pest birds eating strawberries declined in number. On balance, strawberry farms with carefully added vegetative diversity reaped net benefits. They had more strawberry growth via pollinators; more insect and bird biocontrol; and fewer plant-eating insects and birds.

CLIMBUP®
INSECT INTERCEPTOR

DETECTS BED BUGS

- people are the best bed bug bait...use under furniture legs where people are sleeping
- early, reliable detection of bed bugs
- all stages are clearly visible against the white surface
- talc-coated interior makes surface too slick to climb out...it is not acting as a pesticide
- easy to clean and easy to retalc
- bed bugs are attracted to the fibrous exterior surface to climb up
- tells if bed bugs are going to or coming from furniture
- aids in protecting furniture from reinfestation
- Furniture slides easily to reinspect and retreat
- can be reused for months
- made in USA
- patent pending

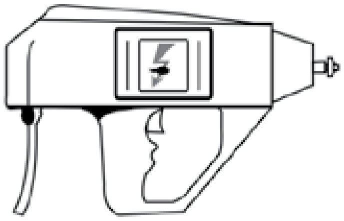
Manufactured by: Susan McKnight, Inc.
P.O. Box 11406 Memphis, TN 38111
www.insect-interceptor.com • susan@insect-interceptor.com
901-848-3831

"Pest Controls *Mother Nature* Would Use"
NATURE'S CONTROL

Specializing in Beneficial Insects and Organic Pest Controls for Over 20 Years!

- Ladybugs, Spider Mite Predators, Nematodes, Lacewings, and many more "Hired Bugs".
- Mighty Myco Mycorrhizae.
- Magnifiers, Yellow & Blue Traps.
- Quantity Discounts.
- Orders Arrive in 1-2 Days.
- Live Delivery Guaranteed!
- Friendly, Knowledgable Staff.
- Check our website for the distributor nearest you, or call for your free "Hired Bugs" brochure.

NATURE'S CONTROL
PHONE: (541) 245-6033
FAX: (800) 698-6250
P.O. BOX 35
MEDFORD, OR 97501
www.naturescontrol.com



ETEX®
ELECTRO-GUN®
Termite Treatment System

Your customers are asking for it by name!
Don't delay! Call for your 1st full year discount!

Etex Ltd.
(800) 543-5651
www.etex-ltd.com | salespcoc@etex-ltd.com
Established February 1979
Leased to Licensed Pest Management Companies

MADE IN USA
CA DPR REG #55850-50001-AA

The Ultimate in
Biological Pest Control

Guardian Nematodes™
Lawn Patrol™

(*Steinernema* spp. & *Heterorhabditis* spp. beneficial nematodes)

Application rate: 1 million per 2,000/3,000 sq.ft. of greenhouse
24 million per acre

Pests: Controls over 250 root zone pests including:

- Cutworms
- Black vine weevils
- Sod webworms
- Fungus gnats
- White grubs
- Strawberry root weevil
- Corn rootworm
- Thrips
- Japanese beetle grubs

Other beneficial items: Encarsia formosa, Phytoseiulus persimilis, Mesoseiulus longipes, Neoseiulus californicus, Aphidoletes aphidimyza, Aphidius, Amblyseius cucumeris, Chrysopa carnea (lacewings), Hippodamia convergens (ladybugs), Nosema locustae (Nolo Bait), Orius, Mealybug predators, etc. Sticky ribbons, Sticky cards, Insect Screens and much more!

HYDRO-GARDENS, INC.
COLORADO SPRINGS, CO

Call TOLL-FREE 1-800-634-6362
for a FREE Catalog

HYDRO-GARDENS, INC.
Your Total Greenhouse Supplier!
http://www.hydro-gardens.com
email: hgi@hydro-gardens.com

8765 Vollmer Road, Colorado Springs, CO 80908 * FAX 719-495-2266

BioQuip®
PRODUCTS SINCE 1947
69 Years Leader in the Field 1947 - 2016

Serving entomology for 69 years
1947 - 2016

BioQuip provides a wide selection of equipment for IPM practitioners including traps, protective clothing, magnifiers & microscopes, forceps, cages, nets, and books, plus live and preserved arthropods. We also provide thousands of other products and books for entomology and related sciences.

Visit our web sites to view products, books, arthropods, and monthly specials.

www.bioquip.com
www.bioquipbugs.com

BioQuip Products
2321 Gladwick St.
Rancho Dominguez, CA 90220
Ph: (310) 667-8800
Fax: (310) 667-8808
Email: bqinfo@bioquip.com

pestec
www.pestec.com

East Bay: 925-757-2945
San Francisco: 415-671-0300
South Bay: 408-564-6196

LOCAL & TRUSTED
CERTIFIED SERVICES
INNOVATIVE SOLUTIONS
AWARD WINNING

Providing certified Integrated Pest Management solutions, consulting and education to residential, commercial and government clients in the San Francisco Bay Area.

RODENTS
BED BUGS
ANTS
WASPS
COCKROACHES

SCAN TO LEARN MORE!

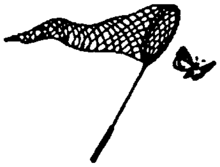
Bio-Integral Resource Center
B • I • R • C
P.O. Box 7414, Berkeley, California 94707

ADDRESS SERVICE REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
Berkeley, CA
Permit #442

Please renew your membership and help support BIRC. THANK YOU!

COMMUNITY PRINTERS



Classified Ads

Products

Beneficial Nematode Products for:
Lawn & Garden Insects
Greenhouses & Horticultural Insects
Termites, German Roaches
Turf Insects
Bulk Nematodes Available

BioLogic
For full information see
www.biologicco.com

PO Box 177
Willow Hill, PA 17271
Tel. 717-349-2789

Products

RINCON-VITOVA
INSECTARIES, INC.
Biological Solutions Since 1950

Aphid Control *Mealybug Control* *Fly Control*

800-248-BUGS - 805-643-5407 - Ventura, CA - **rinconvitova.com**

Canadian Producer of Nematodes

NIC®
NATURAL INSECT
C•O•N•T•R•O•L

BENEFICIAL NEMATODES
Canadian and "Organic"

BENEFICIAL INSECTS
Distributor for Applied Bionomics
Largest Variety Available

Monitoring Tools and Traps

3737 Netherby Road, Stevensville, ON, L0S 1S0
905-382-2904; 905-382-4418(fax)
nic@niagara.com

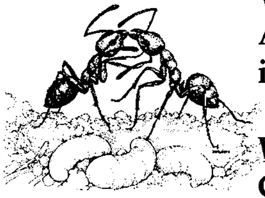
www.naturalinsectcontrol.com

FRESH BENEFICIALS GUARANTEED
Shipping from the Northeastern United States

- Beneficial Insects
- Beneficial Mites
- Beneficial Nematodes

Controlling plant pests & manure pests

IPM Laboratories Inc
ipminfo@ipmlabs.com
315.497.2063
FREE CONSULTATION
www.ipmlabs.com



Want to Order a Back Issue?
A BIRC Publications Catalog
is Online at www.birc.org

Want to Advertise?
Call 510/524-2567 or
Email birc@igc.org

Garlic Barrier
Aphids, Spider Mites, and Earwigs
are quickly controlled by OMRI listed
Garlic Barrier.

See our website:
www.garlicbarrier.com

CLASSIFIED AD RATES—1x rate: $1 per word. 2x-3x: 80¢ per word. 4x or more: 80¢ per word. Write ad, calculate the cost. **BUSINESS CARD AD RATES** (2 x 3.5")—1x rate: $55. 2x-3x: $45 each time. 4x or more $40 each time. Business card ads must be camera-ready; or BIRC will typeset your ad for $40. **ALL ADS MUST BE PREPAID**. Send ads and payment to ***IPMP* Classified Ads**, PO Box 7414, Berkeley, CA 94707. Ads must be received five weeks prior to date of issue in which it is to appear. We reserve the right to refuse materials we feel are inappropriate.