Getting the Bugs to Work for You: Biological Control in Organic Agriculture

Symposium Proceedings

November 12, 2004 – Portland, Oregon

Organized by:

Washington State University
Center for Sustaining Agriculture and Natural Resources

Oregon State University

TILTH PRODUCERS

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Making the Bugs Work for You: Biological Control in Organic Agriculture Symposium

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Bill Snyder, WSU David Granatstein, WSU
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- SARE Professional Development Program
- Small Farms
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Welcome and Symposium Introduction
Mark Musick, Chair, The Tilth Foundation, and Carol Miles, Symposium Chair, Washington State University Vancouver Research and Extension Unit

The WSU/OSU research symposium, “Getting the Bugs to Work for You,” is a fitting prelude to Tilth’s 30th Anniversary Conference. When the Tilth movement began in the summer of 1974 our nation was reeling from the impact of the Arab oil embargo, the Vietnam War still raged, Earl Butz was Secretary of Agriculture, and the “O” word was anathema in polite agricultural society. This symposium is a powerful symbol of the changing relationship between the scientific community and the sustainable agriculture movement. Those of you attending this symposium all contribute to what Wendell Berry calls “renewing husbandry.”

The Tilth movement grew out of a speech by Wendell at the “Agriculture for a Small Planet Symposium” in Spokane July 1, 1974. In his talk that day, Wendell decried what he saw as the wanton destruction of the culture of traditional agrarian communities:

"A culture is not a collection of relics and ornaments, but a practical necessity, and its destruction invokes calamity. A healthy farm culture can only be based upon familiarity; it can only grow among a people soundly established upon the land; it would nourish and protect a human intelligence of the land that no amount of technology can satisfactorily replace. The growth of such a culture was once a strong possibility in the farm communities of this country. We now have only the sad remnants of those communities. If we allow another generation to pass without doing what is necessary to enhance and embolden that possibility, we will lose it altogether. And then we will not only invoke calamity – we will deserve it."

A generation has now passed since Wendell spoke those words, and we are delighted to report that the necessary work is being done “to enhance and embolden” the possibility of healthy farm communities in this country. Your dedicated efforts – and this symposium – are the proofs.

As farmers, researchers and sustainable agriculture industry representatives gather in this room today, the focus of our discussion is how to build stronger, healthier farms through biodiversity. Our ultimate goal is to enable and support each other within our communities, be they farms or research institutions. If Wendell were here with us today, he would feel assured and encouraged that our agricultural communities are alive and well.
Current Status of Organic Research and Education in Washington and Oregon
David Granatstein, Center for Sustaining Agriculture and Natural Resources,
Washington State University

Organic farming has grown rapidly in Washington and Oregon over the past 15 years. Certified organic acreage in Washington alone increased 8-fold between 1993 and 2002. Yet the approximately 57,000 certified acres in the two states still comprises less than 1% of the total farmland base. With the growth of the organic sector in the region has come a commensurate expansion of research and education activities, which are described below.

Current Status of Organic Farming in the Pacific Northwest
Based on the most recent data from Oregon Tilth and Washington State Department of Agriculture Organic Food Program, the dominant certifiers in the region, in 2003 there were 25,928 certified acres and 854 transition acres in Oregon, and 30,640 certified acres and 1,914 transition acres in Washington. These numbers do not include farms certified by other certifiers. Oregon is a major producer of organic nursery plants, and accounted for nearly 50% of the national acreage of organic nursery/herbs in 2001. Organic dairy production is rapidly expanding today in Oregon and is not reflected in the above statistics. In contrast, Washington is a clear leader in organic acres of apples, pears, and cherries. Washington has 37% of the organic apple acreage in the U.S. and over 20% of that in the world (Granatstein and Kirby, 2002). Today large-scale vegetable production accounts for nearly 30% of the organic acres in Washington. Thus, while the two states have many agricultural similarities, the organic farming sectors are somewhat distinct in each state (Table 1).

Table 1. Certified organic cropland in Oregon and Washington in 2001 (USDA-ERS, 2002).

<table>
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<th>Crop Category</th>
<th>U.S. Total</th>
<th>OR</th>
<th>WA</th>
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<tr>
<td>Grain</td>
<td>454,598</td>
<td>1,100 (4)</td>
<td>2,739 (8)</td>
</tr>
<tr>
<td>Bean</td>
<td>211,405</td>
<td>nil</td>
<td>342 (1)</td>
</tr>
<tr>
<td>Oilseed</td>
<td>43,722</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Hay</td>
<td>253,641</td>
<td>4,400 (16)</td>
<td>5,136 (15)</td>
</tr>
<tr>
<td>Vegetable</td>
<td>71,677</td>
<td>2,475 (9)</td>
<td>7,190 (21)</td>
</tr>
<tr>
<td>Fruit</td>
<td>55,675</td>
<td>1,925 (7)</td>
<td>9,244 (27)</td>
</tr>
<tr>
<td>Herb/nursery</td>
<td>14,599</td>
<td>7,976 (29)</td>
<td>3,424 (10)</td>
</tr>
<tr>
<td>Other crop</td>
<td>197,085</td>
<td>4,125 (15)</td>
<td>3,081 (9)</td>
</tr>
<tr>
<td>Pasture</td>
<td>1,039,090</td>
<td>5,500 (20)</td>
<td>3,081 (9)</td>
</tr>
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</table>

¹ Number in ( ) is the % of the total organic land in this category in each state. ‘Nil’ is used for crops less than 1%.

Historically, organic farming in the Pacific Northwest had its roots on small farms that were commonly located near population centers. As the organic market has expanded, larger farms in the major agriculture production areas have become more common and more prominent. For example, western Washington has provided the philosophical, political and consumer base for the growth of organic farming in the state. However, in 2001, 82% of the certified organic acres and 98% of the acres in transition were in eastern Washington (Granatstein, 2002), which is the dominant commercial farming region in the state. In contrast, one-third of the organic farms
were in western Washington, and two-thirds were in eastern Washington. Farms in western Washington tend to be smaller than farms in eastern Washington. The two regions have quite different populations and biophysical environments, and correspondingly distinct research needs. The research community will need to track the demographic nature of organic farms in order to effectively serve them. The situation in Oregon is reversed, with western Oregon containing 79% of the organic farms, 42% of the certified acres, and 74% of the transition acres in 2003.

The Changing Land Grant University
Washington State University (WSU) and Oregon State University (OSU) are the land-grant institutions for their respective states, with the mandate to “to teach such branches of learning as are related to agriculture and the mechanic arts, …in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life” (Morrill Act of 1862). The Hatch Act of 1896 created the agricultural experiment stations at land-grant universities to “conduct original researches or verify experiments on the physiology of plants and animals; the diseases to which they are severally subject, with the remedies for the same; the chemical composition of useful plants at their different stages of growth; the comparative advantages of rotative cropping as pursued under a varying series of crops; the capacity of new plants or trees for acclimation; the analysis of soils and water; the chemical composition of manures, natural or artificial, with experiments designed to test their comparative effects on crops of different kinds; the adaptation and value of grasses and forage plants; the composition and digestibility of the different kinds of food for domestic animals; the scientific and economic questions involved in the production of butter and cheese; and such other researches or experiments bearing directly on the agricultural industry of the United States…”, and most of this mandate fits well with organic agriculture.

The Smith-Lever Act added the extension component in the early 1900s, creating the unique combination of teaching, research, and extension under one roof at land-grant universities. This system has proven very effective in solving specific problems and developing new technologies that are put in place on the land. And it can do the same for organic farming when resources are directed towards that end. Both WSU and OSU are increasingly investing in organic research and education through faculty time, courses, educational events, state research funding, and grants. Some 50 faculty at each institution have indicated current involvement or strong interest in organic farming, based on surveys done in the past two years (Stephenson et al., 2003; Miles et al., 2002a). Experiment station land is being certified organic in both states to provide a base for long-term studies. But it remains difficult to quantify the investment in organic agriculture research, as many ‘conventional’ research projects on such issues as biocontrol of insects or soil quality directly benefit organic growers but are not classified as organic research.

The increase in WSU and OSU involvement in organic research and education can be attributed to a number of factors including: the wide familiarity and acceptance of sustainable agriculture and conservation farming concepts; dramatic increases in organic acreage in the region; new sources of funding for organic research; and more receptive leadership within the universities. The entry of many mainstream farms and companies into the organic sector also helped to legitimize organic within the universities and provided support from stakeholders who have a long-standing university relationship.
CURRENT RESEARCH AND EDUCATION ACTIVITIES ON ORGANIC FARMING IN WASHINGTON AND OREGON

‘Modern’ organic agriculture research projects in the region can be tracked back several decades (Granatstein et al., 2003). A 1979 study by Kraten and Holland (WSU Agricultural Economics) compared the economics and energy performance of organic and conventional dryland grain farms, inspired by the oil crises of previous years. Studies by graduate students and faculty in the WSU Department of Crop and Soil Sciences during the 1980s compared soil fertility, soil biology, soil erosion, and crop rotation in conventional and dryland systems, and even included a study of some biodynamic treatments.

Since the mid-1990s, the number of “dedicated” organic research projects has increased. These are projects with a reference to organic farming in the title or main objectives, and include treatments or systems that would meet organic standards. Few have been conducted on certified organic land, and fewer yet on organic land that has gone through transition and is in “organic equilibrium.” Many other research projects on soil management and pest management were directly applicable to organic farms but are often not counted as organic research. Thus, numeric comparisons are fraught with the judgment factor of what should be considered organic research.

To illustrate the trend of increasing organic research at the national level, the USDA SARE (Sustainable Agriculture Research and Extension) program database was searched for projects that included “organic” in the title. Projects were grouped into two time periods, the first half and the second half of the life of the SARE program, which was initiated in 1988 (Table 2).

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<thead>
<tr>
<th></th>
<th>National</th>
<th>West</th>
<th>Northeast</th>
<th>North Central</th>
<th>South</th>
<th>WA</th>
<th>OR</th>
</tr>
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<tbody>
<tr>
<td>1988-1996</td>
<td>50</td>
<td>13</td>
<td>17</td>
<td>12</td>
<td>9</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1997-2004</td>
<td>141</td>
<td>16</td>
<td>53</td>
<td>32</td>
<td>39</td>
<td>3</td>
<td>0</td>
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The overall increase in organic projects is obvious, signaling that this public funding source was responding to the growth in the organic sector. However, the Western region, which includes Washington and Oregon, saw the smallest increase between the two time periods. Table 3 lists recent SARE funded organic projects for Washington and Oregon, some of which do not contain ‘organic’ in the title but that are taking place in organic systems. A similar search was done of the Organic Farming Research Foundation (www.ofrf.org) list of projects. For every year from 1993 to 2004, there were between one and three projects funded for Washington and Oregon, with a total of 13 projects in each state over the time period. Recently, funded projects include breeding for late blight resistance in tomato, organic wheat breeding, pastured turkey production, compost tea, and biocontrol of insect pests in organic vegetables.

4
In an assessment of the number of WSU faculty involved in explicit organic research over the same time periods, 6, 8, and 30 faculty were involved in 1984, 1994, and 2004, respectively. This shows a dramatic increase in organic research in the region since the mid-1990s. More thorough assessments of organic research and education activities at WSU and OSU were recently conducted. In 2001, the WSU Center for Sustaining Agriculture and Natural Resources conducted an email survey of faculty in the College of Agriculture and Home Economics to determine past and current organic farming projects. Some 90 projects were identified by 58 faculty members, and the results were compiled into a publication (Miles et al., 2002a). A group of OSU Extension faculty produced the “Organic Farmer’s Guide to Oregon State University” in 2003 to familiarize organic growers with the faculty, units, labs, and publications at OSU that might be of assistance to them (Stephenson et al., 2003). Both publications are available on line.

Recent meetings at WSU and OSU indicated a need to showcase organic agriculture research. A joint organic farming research symposium was hosted, along with Washington Tilth and Oregon Tilth, in Yakima in November 2002 that attracted 220 participants, and even more surprising, some 48 posters on current research and education projects in the two states. These were catalogued in the proceedings (Miles et al., 2002b). A second symposium specifically on weed management in organic systems was presented in February 2004 (Miles et al., 2004), and the current symposium on insect biological control is the third effort along these lines.

In 2003, WSU received a special grant from the USDA for organic crop research. Five projects were funded – organic seed production, transition rotations in Northwest Washington, understory
management in organic orchards, weed control in organic dryland wheat, and development of statistics on the organic sector. Funding was received again in 2004, and new projects on organic crop breeding, biodegradable mulches for weed control, biocontrol of nematodes, and cover crop systems were added. Further funding is anticipated in 2005.

Other current studies at WSU include a comparison of nutritional and anti-oxidant qualities of organic versus conventional strawberries, a major trial on organic wheat production, organic soil nutrient management, cover crops in organic grapes, biocontrol with nematodes, and mustard green manures. At OSU, other studies include nitrogen management, soil health, strip-till, creating disease suppressive soils, weed control in organic vegetables, conservation biocontrol, protein sources for organic livestock, organic cherry production, and crop breeding for organic systems. Organic research is underway at the USDA Agricultural Research Service labs in both states, and is also being conducted by commodity groups, private organizations, and individual farmers.

Numerous educational activities are also occurring. One of the main trends is the inclusion of organic sessions within many of the mainstream agriculture meetings, such as the Washington State Horticulture Association, the Western Washington Horticultural Association, and the Pacific Northwest Vegetable Association. Both universities are offering more workshops with a focus on organic agriculture. New graduate student opportunities are opening at the universities to study and conduct research on organic systems. WSU is launching a B.S. major in organic farming within the next year. Recently, an organic farming website was developed at WSU (http://csanr.wsu.edu/organic) to make it easier to find the variety of organic resources at the institution. The web site will include a database of all past and current organic projects to better identify the various activities.

Both WSU and OSU were major participants in the organic agriculture training project funded by Western SARE. The project has conducted two national satellite broadcasts, the first on the National Organic Standards, and the second on organic livestock. A training workshop was held in Portland, Oregon, and a training binder was developed that will be available on-line in the near future.

With funding opportunities expanding from USDA (Organic Transitions, OREI, SARE, NRI), EPA, OFRF, and other sources, organic research and education should continue to expand in Washington and Oregon. Even traditional sources such as the Washington Commission on Pesticide Registration are funding some organic projects under its IPM/biocontrol mandate. As many organic research findings find a home within conventional systems, because they work and they may reduce cost and risk, the demand for organic research will grow stronger and will be broader-based. More important, perhaps, is continued research that will make organic systems more sustainable – economically, environmentally, and socially.

References


Mycoattractants & Mycopesticides: New Horizons for Biological Control of Insects
Paul E. Stamets, Fungi Perfecti, LLC, PO Box 7634, Olympia, Washington 98507,
Ph. 360-426-3146, Fax: 360-426-9377, www.fungi.com

Abstract
A patent has been awarded, with more pending, for a technique to deploy the pre-sporulating mycelium of the entomopathogenic fungus *Metarhizium anisopliae* as a natural agent to attract and kill termites and ants. Since spores of certain entomopathogenic fungi repel termites and ants, widespread commercialization by the pesticide industry has been limited. The novelty of this patent is the discovery by applicant that ants and flies are attracted to entomopathogenic fungi in their mycelial state, prior to sporulation. Cultures of fungi can be isolated from naturally infected insects, and through a selection process can be cultured in the laboratory to create strains that delay spore production for several weeks. The pre-sporulating entomopathogenic mycelia emit powerful attractants and feeding stimulants, drawing select pests to a chosen locus, from where they then spread the infectious fungi throughout the targeted nest and ultimately to the queen. In choice tests, termites prefer the pre-sporulating mycelium of *Metarhizium anisopliae* to wood as food. Research shows that diverse insect species share specific affinities to these fungi in their pre-sporulating state. This discovery may well lead to novel methods for controlling insect pests worldwide. This mycotechnology is economical, scaleable, and utilizes cell culture methods currently in practice.

Executive Summary
- Certain mold fungi kill insects and use their carcasses as platforms for disseminating spores. These species are called entomopathogenic fungi.
- With limited success, the pesticide industry has attempted to deploy entomopathogenic fungal spores to kill pests such as termites and ants, as well as non-social insects such as grasshoppers and flies. The spores of entomopathogenic fungi repel many of these insects. Insects have natural defenses against entomopathogenic fungi. Guarding the nest, soldiers intercept spore-contaminated foragers from entering in order to protect the queen and the colony from infection.
- My patent claims the discovery that entomopathogenic fungi in the pre-sporulating state emit powerful attractants to targeted insects. Although the pesticide industry knew that fungal spores repelled, it did not know the mycelium, before spore formation, attracted.
- The patented invention for mycopesticides describes how to selectively culture strains of entomopathogenic fungi for delayed spore formation in order to make the cultures attractive to targeted insects.
- Termites and ants carry the pre-sporulating mycelium to their nests, fatally infecting the queen and her entire colony since one dose to a small locus can kill a vast colony.
- The infected colony repels subsequent insect invasions, thus protecting the treated site from infestation.
• Some strains of fungi are target-specific in their attractancy and mortality.

• The natural genome offers a continual supply of insecticidal strains.

• Tests at Texas A & M University’s Entomology Dept. suggest this method works against Formosan Termites, Eastern Subterranean Termites and Fire ants. Subsequent field tests show positive results in treating Carpenter ants and Phorid (Dung) flies.

• Termites are attracted to and are stimulated to feed on the highly diluted extracts of the pre-sporulating mycelium-on-grain of entomopathogenic fungi.

• These mycopesticide techniques may restructure global pesticide policy. The economic impact of this technology as an alternative to traditional chemical pesticides may reach billions of dollars. The benefit to the environment and human health is incalculable. These “green” methods expand our armamentarium of non-toxic solutions to pest problems, while reducing harm to health and the environment.

**Project Description**

To protect crops and structures, pesticides were invented to fight destructive insects. However, many of these chemicals, especially the organophosphates, harm non-targeted organisms, pollute water, and impair human health. The EPA has recently banned many chemical pesticides and effective February 2004 more than 50 countries—signatories of the Rotterdam Convention—will also limit toxic pesticides. The toxicity of these chemical pesticides was not widely known until tons had been dispersed into the environment. Chemical pesticides permeate the food chain: most Americans, and indeed most people on the planet accumulate these compounds and their derivatives in their fatty tissues and bloodstream. The need for alternative non-toxic pesticides has reached a critical level. The medical and ecological impact of toxic pesticides poses a cascading health hazard and a global threat to our biosphere.

The search for ecologically rational methods to control insects has focused on biopesticides — nature-based remedies with negligible or no collateral damage to non-targeted organisms. Biopesticides, especially select fungi, do not pose a persistent threat to the environment after use, in contrast to the long-term effects of many conventional chemical treatments. The interrelationships between fungi and insects are complex and are only now being understood. Many insects use fungi as platforms for their larvae. Some insects, including many species of termites, harbor and even cultivate mycelium to their mutual benefit. However, certain strains of fungi are deadly to insects. We now know thousands of species of insects are attacked by entomopathogenic fungi.

In 1834 Agustino Bassi noticed spores of the fungus *Beauveria bassiana* caused the disease “muscardine,” a plague that imperiled the international silk trade. He is credited with first conceiving “germ theory,” a major tenet of modern medicine, well before Louis Pasteur’s discovery of the role of microbes in 1858. As more entomopathogenic fungi were observed, often isolated from the moldy carcasses of dead insects, the pesticide industry explored the use of fungal spores as natural insecticides.
In the past twenty years, several patents have been awarded to exploit these mold fungi, raising expectations for treatments based on the emerging specialty of entomopathogenic mycology. The previously issued mycopesticidal patents usually targeted an insect species with a fungus strain, with or without an effective delivery system. Species in the genus Metarhizium (esp. *M. anisopliae*) a green mold fungus, Beauveria (esp. *B. bassiana*), and Paecilomyces species, white mold fungi, earned the most attention from researchers. *Metarhizium anisopliae* is prevalent in soils, sometimes representing up to 25% of the soil fungal spore population. One estimate is that 90% of all soils harbor significant populations of this fungus. When insects come into contact with spores of these entomopathogenic fungi, the spores attach and germinate, boring hyphal pegs through their exoskeletons. Other portals of entry include the respiratory tracts, the anus and mouth. Once inside, the mycelium forks and runs through the internal organs, interfering in metabolism, causing malaise, necrosis, and death in a few days. The insects look mummified with fuzzy mycelium, and then become a launching platform for further sporulation. In the case of some species of Metarhizium, Beauveria and Paecilomyces, a tiny club-shaped mushroom classified in the genus Cordyceps sprouts from the dead insect carcass.

Problems with finding effective spore delivery systems soon became apparent to the pesticide industry. Although captive insects are easily infected with spores in the laboratory, insect communities in nature have developed sophisticated strategies for defending themselves from these infectious spores. Among social insects, spore-carrying workers are refused entry to the nest. Such colonies have been described as “factory fortresses” with several tiers of guards preventing disease-bearing insects from entering. In other words, the insects know the plague is nearby when they smell it, and mobilize to prevent infection of their colony.

Although patents have been issued for spore-based pesticides, many insects avoid entomopathogenic spores, blocking the commercialization of Metarhizium, Beauveria and Paecilomyces fungi as mycopesticides, especially for social insects such as termites and ants. Once a building is infected with termites, treating the whole structure with a spore method is impractical. (How do you find the queen? How can the treatment be carried to her?) Chemical treatments may work temporarily, but typically the structures are soon reinvaded.

My interests in growing the Cordyceps form as a medicinal fungus led me down a path of discovery not taken by other researchers in the field. Our clean room laboratories at Fungi Perfecti are spore-free environments. Mold fungi are viewed as a threat to our medicinal mushroom strains so I pursued sectors of mycelium that delayed or lacked spore formation. I discovered that a form of mycelium emerges which is attractive to insects otherwise repelled by this fungus’ spores. In culturing these mold fungi, through successive generations of transfers, I isolated a non-sporulating mycelial phenotype. These sectors initially appear as white V-shaped wedges of growth that gradually lose the ability to produce spores. I pursued these pre-sporulating growth forms *in vitro*, and soon discovered that the sporeless mycelium emits attractants and feeding stimulants.

Given the spore-avoidance behavior of insects, the potential to attract insects to pre-sporulating, insecticidal fungi has obvious advantages. If the insects could be attracted to entomopathogenic fungi, the insects themselves could become vectors for the insecticide to be distributed throughout a colony. I did not need to go far to test my hypothesis. My wood-framed house in
western Washington was under attack by Carpenter ants. From a growth sector I grew some pre-sporeulating Metarhizium mycelium on sterilized rice and placed it on a foraging path of the resident Carpenter ants. That night, about four hours later, my daughter spotted a swarming of these ants at the site of the mycelium-covered rice. The ants became distribution vectors for the mycelium, and promptly infected their nest. A week or two later my old decomposing farmhouse was rid of Carpenter ants (*Camponotus modoc*) and has not been re-invaded in the four years afterward. I hypothesize that the house, once treated, repels future invasions as the insect carcasses become moldy, thus warning off future would-be invaders. Once a structure is treated, the fungi provide a protective shield of resistance. Inasmuch as Metarhizium does not harm mammals, does not cause human allergies, and is limited in the size of its colonies, this treatment does not present issues common with “sick house” syndromes caused by other fungi.

Soon after my pilot test, I initiated a series of research trials at Texas A & M University’s Entomology Dept. under the guidance of Dr. Roger Gold, a prominent entomologist, that showed Formosan termites (*Coptotermes formosanus*), Eastern Subterranean termites (*Reticulitermes flavipes*), and Fire ants (*Solenopsis invicta*) were attracted to the mycelium, fed upon it, and carried fragments back to the nest. In one to two weeks, they died from fungal infection. In choice tests, termites preferred the mycelium to wood, and in one alarming example Fire ants workers enthroned the queen to rest upon a bed of mycelium where she soon expired along with her kingdom. With termites, it appears that the mycelium kills the large protozoa in their digestive tracts, which prevents the metabolism of cellulose and starves them. The insects sicken and become susceptible to infection by the fungus. This escalating mycelial poisoning contrasts to contact chemical insecticide poisons, many of which have proven to be highly toxic.

Furthermore, we found that water/ethanol extracts of the pre-sporeulating mycelium-on-rice (called “FF1000”) yielded a powerful attractant and feeding stimulant. Through serial dilutions, we discovered that our baseline extract was optimized after several orders of magnitude of dilution with water, thus reducing production costs by similar orders of magnitude. Furthermore, we discovered that native-borne fungi from an already infected termite colony were more attractive to that species of termite than to others. In many cases Metarhizium strains from one insect species did not attract other insect species. This mycelial bait is placed only after a colony has been detected. After the colony is decimated, other insects naturally avoid contact because the carcasses become moldy with the repellant spores. *Metarhizium anisopliae* does not infect plants, mammals, fish, bees or other insects. The EPA has encouraged the study of *Metarhizium anisopliae* as a biopesticide because its mode of action targets pest insects and not beneficial ones.

The active constituents causing attractancy, feeding, dispersion, and eventual death have not yet been characterized despite attempts to do so. Rather than one molecular compound causing such diverse effects, suites of compounds may work in concert. We determined that only some strains of *Metarhizium anisopliae* produce species-specific attractants, which may lead to the design of products to target specific insect pests. This discovery of how to use the green mold Metarhizium is a splendid example of “green chemistry” at work: a fungus can entice an insect to carry and cache it as food before the fungus is recognized as a pathogen. Chemically characterizing these behavior-modifying agents may not be as simple as discovering, for instance, a single antibiotic.
The benefits of this discovery can easily be imagined. The economic and ecological impact may prove extraordinary, and may:

- Replace toxic pesticides with an effective treatment for termites, ants, and flies.
- Protect ground water and habitats from contamination by toxic pesticides.
- Recruit the pestilent insects to expedite their own destruction.
- Use the genome as an indigenous source of new strains, thus limiting tolerance.
- Minimize potential harm to non-targeted insects, while precisely targeting unwanted insects.
- Provide attractants to the pesticide industry that allow insect contact with spore and chemical based treatments, overcoming repellent properties of other insecticides. Thus the extracts may function as masking agents.
- Afford long-term protection of treated sites.
- Allow use of structural building materials otherwise susceptible to insect destruction, reducing the market, for instance, for termite-resistant tropical hardwoods from rainforests, while retaining jobs and helping the US wood products industries.
- Save diverse biological communities, including our own.

I received approval from the US Patent Office for this biotechnological breakthrough (Patent # 6,660,290), on December 9, 2003 for attracting and killing Formosan termites (Coptotermes species), Eastern Subterranean termites (Reticulitermes species), and Carpenter ants (Camponotus species). I have pending an expanded set of divisional patents within the Continuation-in-Part (“CIP”) application. Recent trials show that dung flies (Phorid species) and blow flies (Calliphora species) are attracted to this mycelial extract, suggesting that this technique will also be effective against non-social insects. Several entomopathogenic fungi, in addition to *Metarhizium anisopliae*, show similar activity using the patent-pending techniques in the expanded CIP patent. The future of this green mycotechnology looks highly promising for treating insects that undermine structures, decimate crops and carry diseases.

**Acknowledgements**

The following are gratefully acknowledged for their contributions to this mycopesticide project: Dr. Roger Gold, Grady Glenn, Jim Gouin, Greg Grochoski, William Hyde, Bill Nicholson, David Sumerlin, Dave Van Andel, and Dusty Yao.
Farm-scaping for beneficials: a community-based biological control program
Gwendolyn Ellen, Mario Ambrosino, Nick Andrews*, Paul Jepson
Integrated Plant Protection Center, 2040 Cordley Hall, Oregon State University, Corvallis, OR
97331-2915
Oregon Tilth*, 470 Lancaster Drive NE, Salem OR 97301

Background

• OSU and Oregon Tilth have initiated a partnership to develop a grower-based program in conservation biological control (CBC).
• This partnership will be based upon the principles of Community IPM. Community IPM incorporates IPM in a strategy for local, sustainable agricultural development where farmers:
  - act on their own initiative and analysis;
  - identify and resolve relevant problems;
  - conduct their own local IPM programs that include research and educational activities;
  - elicit support from local institutions;
  - establish or adapt local organizations that include farmers as decision makers;
  - employ problem-solving and decision-making processes that are open and egalitarian;
  - create opportunities for all farmers in their communities to participate and benefit from the IPM activity;
  - promote a locally sustainable agricultural system.
• The program will consist of:
  - Grower to grower information exchange
  - Farm walks and demonstrations of techniques
  - On-farm research and development
  - Emphasis on farm planning as well as the techniques themselves

Current CBC Practices

• CBC techniques are widely practiced. Jeff Falen and Elanor O’Brien (Persephone Farm, Lebanon, OR) provided a brief summary of the practices that they use:
  - bird and bat houses;
  - plantings of sunflowers for birds and minute pirate bug (assumed to be a predator of cucumber beetle larvae);
  - plantings of dill, cilantro, fennel, Agastache, Alyssum, Calendula and orache interspersed with cash crops, to attract and sustain various beneficial insects;
  - emphasis on cover-cropping fields not in cash crops, many with flowering plants such as vetch and clover;
  - pastured poultry flock which hopefully consumes potentially harmful soil invertebrates;
  - vigorous wild population of mustards, radishes, chickweed, speedwell etc., to sustain a vibrant wasp community;
  - formerly: release of purchased ladybugs and lacewing larvae (no longer needed).
• Discussions on a Persephone Farm walk resulted in the suggestion that experimental beetle banks might be introduced to enhance ground predators

Future events

Bugscaping 2004
Practical Conservation Biological Control for Your Farm
Thursday, December 2nd
at
Benton County Fairgrounds Auditorium, Corvallis, OR
10:00 – 3:00 P.M.

Contact Details
Paul Jepson, jepsonp@science.oregonstate.edu,
(541) 737-9082

Three farm walks in 2003/4 have exposed more than 80 growers to diverse farming types and to a variety of CBC techniques that are practiced by the farm owners, managers and interns. Initial walks have been for organic vegetable producers, but the program will expand to include conventional growers, and other crop types

Farm Walks, 2003/4

Three farm walks in 2003/4 have exposed more than 80 growers to diverse farming types and to a variety of CBC techniques that are practiced by the farm owners, managers and interns. Initial walks have been for organic vegetable producers, but the program will expand to include conventional growers, and other crop types.
Insectary Plantings

Insectary Plants Defined

‘Insectary plantings’ refers to the use of flowering plants which contain resources in the form of nectar and pollen for natural enemies of crop pests and other beneficials. In addition to floral resources, these plantings can provide alternate prey or host food and shelter for certain natural enemies.

Types of Natural Enemies which Make Use of these Plantings

If carefully selected, the floral resources of insectary plants can potentially attract, retain, and/or enhance the reproduction, longevity and effectiveness of a wide range of natural enemies, especially:

- ladybird beetles
- hoverflies
- parasitoid tachinid flies
- predacious wasps
- soldier beetles
- green lacewinas
- parasitoid wasps

Other common natural enemies can also be attracted and enhanced by the alternate prey or host food and shelter found in some insectary plantings, such as:

- bio-eyed bugs
- minute pirate bug
- predacious stink bugs
- damsel bugs
- assassin bugs
- rove beetles
- around beetles
- spiders

Some photos above are from the collections of Ken Gray and Nigel Cattlin.
How to Choose the Plant Type and Method of Planting

If insectary plants are selected or planted haphazardly, the overall outcome for a crop or farm may not be optimal, or could even be negative. It is therefore important to plan for the biological and farm management factors outlined in Table 1 when selecting an insectary plant type or method.

For more detailed comparisons of insectary plant types and planting methods, the selection can be fine-tuned to the existing system by assigning a rating one of the factors. If any of the answers to the questions in the table are not available from the onset, they may have to be obtained with farm experimentation if the risk in unknown.

How to Assess the Effectiveness of Insectary Plantings

It is then necessary to assess the effect of these plantings in order to justify their use, as well as to fit them within the overall farm plan. After learning how to identify the main pests and natural enemies, compare potential differences between the number of pests and natural enemies that:

| Timing of flowering | - Will the floral resources be present when needed?  
| - Will the flowers attract beneficials away from desired predatory or pollination activities at certain times? |
| Characteristics of the beneficials | 3. What is the relative preference that key beneficial and pest species have for the flowers?  
| 4. What are the different requirements for nectar, pollen, shelter, and alternate hosts food among these organisms?  
| 5. What are the relative foraging ranges and dispersal abilities of these organisms? (see adjoining poster on ‘scale considerations for insectary plantings’) |
| Agronomic considerations | 6. How competitive are the plantings with the crop or other weeds?  
| 7. Do the plantings have the potential to be weeds, or harbor weeds in the system?  
| 8. Can the plantings serve as an alternate host for crop disease?  
| 9. Are the plants toxic to any livestock or other local animals? |
| Economic & Management considerations | 10. Can the planting be harvested as an additional crop?  
| 11. What are the costs of seed, establishment, and maintenance?  
| 12. How do these costs compare to other management options?  
| 13. Are plantings compatible with the main pest management plan? |

Other Considerations:  
- Learn about the biology of the organisms to know:  
  - when and where to monitor  
  - which natural enemies act on which pests  
B) Keep accurate records and a written description of the methods used each time so that comparisons between dates can be made  
C) Keep track of other factors that can affect pests and natural enemies and note these on sampling records.  
D) Visual observation works well, other appropriate sampling methods vary by plant and organism, and you may need to consult a manual or an expert for these.

1) visit the plantings  
2) appear in crop areas near the plantings  
3) appear in crop areas away from, or without plantings  
4) visit other farm areas that may contain resources or habitat
Insectary Plantings – Scale Considerations

Why Scale is Important

It is generally difficult to tell if insectary plantings are influencing the overall abundance versus the redistribution of a given natural enemy population in a given situation. But it is still necessary to know what the potential zone of influence of an insectary planting may be, relative to the zone for the target pest. Consideration of the dispersal and foraging abilities of each natural enemy type, relative to pest location and insectary resources already present in the landscape, can help guide the placement of insectary plantings.

Varying Dispersal Abilities

The maximum potential dispersal and foraging ranges around an area with crop pests can vary for the adult stage of different natural enemies.
**Beetle Banks Defined**

*Beetle banks* are graded low banks that are placed in fields to enhance populations of predatory beetles and spiders. They are planted with tussock- or mat-forming grasses to provide high quality, over-wintering habitat, from which these invertebrates disperse in the spring. Beetle banks compensate for the loss or absence of traditional hedgerows, for isolation from natural over-wintering habitats, including riparian zones, and for fragmentation of farmland, and loss of connectivity between habitats in the farming landscape. Beetle banks take two to three years to become established. They can harbor 1,500 invertebrates/m². Predatory invertebrates colonize the centers of fields more rapidly and in greater numbers when they are used.

**Types of Natural Enemies which Make Use of Beetle Banks**

Beetle banks provide over-wintering habitat for predatory invertebrates that complete their life-cycles within the field. These tend to be generalist species, with a wide range of invertebrate prey. Many of these species evolved in riparian zones, and they are adapted to seek high, dry locations over the winter to avoid seasonal flooding. They colonize fields for the same reason they colonize stream banks; because of high abundance of invertebrate prey. Research has shown that the abundance of these species on farmland may be limited by lack of over-wintering habitat. Over-wintering predators colonize the beetle banks in the early fall, and migrate into the field in early spring. They include:

- **Rove beetles** (Staphylinidae): spring/summer active winged insects, that feed on fungal spores, aphids, and other plant and soil-borne prey. Also common in compost mounds and decaying vegetation. One to

- **Ground beetles** (Carabidae): night or day active, winged or wingless insects, mainly on the soil surface. They include spring and fall-breeding species, some of which may be active throughout the growing season. They only have one generation a year, and they are susceptible to local extinction following use of broad spectrum insecticides. Adults and larvae feed on insect eggs (e.g. cabbage maggot eggs), slugs and worms, and ground active prey, including the many pests that fall from the plant. Some species climb plants and

- **Spiders**, that may be ground active hunters, sheet web producers on the ground, or web-forming species in the plant canopy. May have several generations a year. Very susceptible to natural

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**Beetle Bank Construction**

- September and October are the best months to establish the grass sward on beetle banks. The bank should be about 0.4m high and 2m wide, cutting across the middle of the field, leaving space at either end for machinery

- The bank is created by careful two-direction ploughing, with furrows ploughed against each other, during autumn cultivation.

- Machine drill or hand sow with a mixture of perennial grasses including at least 30% tussock- and mat-forming species (in the UK, these include orchard grass (*Dactylis glomerata*) and Timothy grass). The rest of the mixture can consist of fescues and bents.

- For good establishment these can be sown at a rate of 70 kg/ha.

- Three cuts may be necessary in the first year (when the sward reaches 10cm) to encourage grasses to tiller and control invasive annual weeds.

- Once established, cuts are needed only to encourage dead tussocks to regenerate, and to control woody species (approx. once in three years).

- Beetle banks are particularly susceptible to pesticide drift.

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Information from Game Conservancy Trust, Royal Society for the Protection of Birds, Hampshire and Isle of Wight Naturalists Trust, Personal communications from Steve Wratten, Lincoln University NZ, UK-based research by Paul Jepson (now OSU, IPPC)

Some photos above are from the collections of Ken Gray and Nigel Cattlin
Beetle Bank Evaluation

• Soil samples can be taken each season, in mid-winter, from the root zone of the beetle bank grasses to demonstrate the presence of predatory species. Numbers of species and individuals grow over 2-3 years.
• Simple pitfall traps can be laid in the spring, to determine the timing of beetle emergence, and the distance they penetrate into the field.
• Evaluation of plant composition on and off the bank, will let you know if cutting is needed to manage bank grasses, or if bank species are escaping into the field.
• Comparisons of records of pest outbreaks and numbers over time, with fields that do not have beetle banks, may help to determine effectiveness, but total impact is difficult to quantify without detailed research. We can say that for high beetle populations to persist, they must be consuming large amounts of prey.

Pitfall traps can be as simple as a plastic drinking cup, sunk into the ground. The lip must be flush with the soil surface to catch and insects, and the sides must be shiny and clean to prevent escape. Make small drainage holes in the bottom, and add some leaves and stones as shelter, and

What Researchers Do!

Construct cages and barriers over and alongside beetle banks, to compare pest numbers in the crop with and without access to the bank, and to different groups of predators. These experiments quantify the separate roles of plant climbing and soil active generalist predators, and compare these with the contributions made by better-understood predators and parasites, including ladybugs and

The left-hand cage includes wheat plants only, the right-hand cage also includes a section of beetle bank. This permits comparison of pest populations when they are exposed to soil surface predators only (left), or to the soil surface species, and the species that overwintered in the beetle bank (right). Both cages exclude aerially-

Plastic barriers permit access to the plants by flying predators and parasites, while also allowing researchers to manipulate numbers of ground-active, non-flying species.

Beetle banks now extend to tens of thousands of kilometers in European farmland, and growers receive financial rewards for including them within their farm conservation plans. The benefits of beetle banks to predatory invertebrate populations have been repeatedly demonstrated, but (as you can see from these techniques) it is very difficult to precisely quantify the

All photo's from Mauremootoo, Jepson, Wratten and Joyce (in prep)
Successful Farmscaping: Experiences from an Organic Farm in the Willamette Valley
Elanor O’Brien, Persephone Farm, Lebanon, OR

The farmscaping techniques used at Persephone Farm are simple and compliment our philosophy of diversity in a balanced eco-system. Once we started to think about what practices we could employ to attract and sustain beneficial insects, we realized we already had a few things going for us.

Many natural aspects of the farm landscape and its surroundings affect local beneficial insect populations. The farm, surrounded by forested and riparian areas, benefits from beneficial insect activity in these border areas.

Our cover crops, planted for soil health, are also useful for farmscaping. The blooms of alfalfa, buckwheat, various clovers, fava, phacilia, vetches, peas, etc are all attractive sources of nectar and pollen for beneficiais. Even weeds are helpful. Various wild mustards and radishes are favored by parasitic wasps. Tall grasses provide shelter for many beneficial bugs, especially ladybugs. Mulching with straw, leaves, bark, or compost not only inhibits weeds and conserves moisture, but also provides fantastic habitat for spiders, a general predator.

What practices have we adopted specifically for the purpose of farmscaping for beneficiais? We seed and transplant a variety of insectary species along with each mechanical transplanting of cash crops (ten transplantings, each 2 weeks apart throughout the season). The insectary plants we currently use for this are alyssum, agastache, fennel mix, calendula, and orache. We are always seeking ideas for new plants to add, but for now, we feel this mix provides a variety of bloom times throughout the season, and the succession planting distributes the blooms among different fields and locations.

We use sunflowers in several ways. In an effort to attract minute pirate bugs and bug eating birds for control of cucumber beetle larvae, we transplant sunflowers in rows bordering crop fields. This season we began transplanting dwarf sunflowers among our onion plants in hopes of controlling western flower thrips. Next season we will also transplant dwarf sunflowers among our other mechanically transplanted crops, as this seemed to fit into our routine pretty easily.

Several crops that we direct seed for market, such as dill leaf and cilantro, provide insectary benefits when allowed to stand and bloom past harvest time. Growers who sow and sell salad mix may consider letting mustard greens, arugula, and Asian greens bloom after harvest. In many cases consideration is a moot point…bloom happens.

One past project, which we plan to repeat, was an attempt at planting a hedgerow of shrubs and ground cover to offer habitat to beneficiais. The problems we encountered with this project were perennial weed pressure around the shrubs, gopher and vole damage to roots, and frost damage to newly planted shrubs. Our goal is to establish a new hedgerow, this time with better attention to planting site, advance weed control, and the type of shrubs that survived the previous effort.
This fall we established two “beetle banks”. This farmscaping method incorporates raised beds seeded with mat-forming grasses, to provide habitat for ground beetles. Having established the beetle banks only one month ago, we haven’t much to report yet.

We have lots more ideas and plans for future farmscaping projects. How successful are our farmscaping efforts so far? We find the results difficult to quantify for many reasons, not the least of which is our vegetable-driven existence during the growing season. However, in several instances we have seen reductions in specific pest problems, and we see a wide range of beneficials present in all fields.

Farmscaping for beneficials fits well into our overall farming philosophy, that diversity is important for a balanced ecosystem. We do not need to control every weed or react to every pest problem with an insecticide. Tall grass is okay, even though it does not look tidy. We do not know everything. We just try to look out for opportunities to learn more.
Ecological Challenges for Conservation Biological Control
Bill Snyder and Renee Priya Prasad, Department of Entomology, Washington State University, Pullman, WA 99164, (509) 335-3724, wesnyder@wsu.edu

Pest outbreaks occur in agricultural monocultures at a scale and frequency rarely seen in natural systems. This has led agroecologists to suggest that what we need for a more sustainable agriculture is to re-incorporate the biological diversity of nature into farming systems. This idea, that biodiversity helps restore a natural balance and thus reduce pest problems, has been central within the organic movement.

However, for the many biological control agents that are generalists (feed on many different prey species), spiders for example, the relationship between biodiversity and effective pest control may not be a simple one. This is because generalists feed not only on pests, but also on other beneficials such as other predators, detritivores and pollinators. While we would like to assign species to being “good” or “bad” bugs, nature is not so simple and often the role of a species, beneficial or harmful, depends on the particulars of the situation – what’s the pest, or, what are we trying to accomplish? Despite all of this complexity there are common patterns for how species interact, and so by getting to know our bugs well we can begin to have realistic expectations of what they can, and cannot, do for us.

In this paper I will focus on a case study that demonstrates some of the ecological complexities associated with one common predator conservation technique, the establishment of beetle banks. Beetle banks are strips of undisturbed vegetation within crop fields, typically planted in perennial grasses, which provide a place for predatory ground beetles and spiders to spend the winter and to get out of the way of cultivation or other disturbances. Working with our grower cooperators, we established beetle banks on three organic mixed vegetable farms in the vicinity of Mount Vernon, WA, in the summer of 2002. We found that densities of predatory ground and rove beetles greatly increased in fields with beetle banks, compared to nearby fields lacking these refuges.

To better understand the impacts of the predators conserved using beetle banks, we have been studying interactions between our ground-dwelling beetles, other predators, and pests in large field cages. What we have found suggests to us that beetle banks can help control some pests, in some situations, but not all pests in all situations. The first complication we have encountered is that the larger ground beetles eat the smaller ones. This can be a problem when the pest is small, because smaller predators are more likely to eat smaller pests. The second complication is that the ground beetles prefer to eat some pests, but will ignore others, when they have a choice in prey species. This means that when some very tasty pests are present, such as aphids for example, the predators will switch to eating aphids when we would rather have them eating something else (root maggots in our case, which apparently do not taste very good). In summary, our experiments have revealed that the specific predator species conserved, the type of pest being targeted, and what other prey are in the crop for predators to eat all will affect whether beetle banks “work” in controlling a particular pest.

So, can we ever generalize about conservation biological control, or instead will everything always be on a case-by-case basis, different for each farm? To some extent the answer to both
questions is “yes”. Predictions with 100% certainty will always be difficult. However, I suggest that we can apply some basic principles to many situations, following a short checklist of questions to ask when trying to find a predator conservation technique that (might) work. First, what is the pest being targeted? Where does this pest live, what stages are causing injury or might be most vulnerable, and how big is the pest? Our answer here leads us to the second question, what natural enemies do (or are most likely to) attack this pest, based on the size, seasonality and habitat preferences of that predator? Third, what resource are these important predators finding in short supply on our farm? Is it a place to spend the winter, somewhere to avoid tillage or other disturbance, or a source of alternative prey or other food? With a hint as to what our predators need, we can identify a strategy to provide the needed resource to the predator(s) most likely to be effective against our worst pest(s). Increasing biodiversity on the farm in and of itself is not likely to be a cure-all for pest problems. Rather, our chances for success may be best when we target conservation efforts by providing specific, limiting resources to particularly important natural enemies.
The benefit to organic farmers of having pest-eating insects, spiders, birds and bats as resident allies on the farm seems obvious enough, at least to organic farmers. Less obvious is the exact amount of benefit, as measured in yield, quality, and net profit. The uncertainty about these benefits keeps a farmer skeptical about the usefulness of dedicating good ground to farmscaping for better bug ranching. After all, any loss of crop ground to insectary plantings can be figured as a percentage of crop lost to a defensive posture against pests.

Our approach at Shoulder to Shoulder Farm has been to integrate the farm crop scheme with the naturally overlapping cycles of weed and native species to keep consorts of blooming communities active throughout the year. The same crop species that are intended for the fresh vegetable or seed market, and some weeds that are their normal seasonal associates, are also good nectar and pollen sources for crop-beneficial insects. It's clear that these beneficial species are abundant in our fields, presumably due in part to the ample presence of their ecological cohorts. The context of the Shoulder to Shoulder Farm observations are not typical of commercial organic production systems (being 3-acres and non-mechanized), but more recent observations at Gathering Together Farm (a 45-acre multi-tractor diversified organic vegetable and seed operation with 20 summer workers) suggest that the same principles and strategies are effective at the larger scale, possibly more so. In either example, the simple guiding principle is to encourage blooming of any kind in and around the fields. Bolted salad and vegetable species, cover crops, and benign weeds are all tolerated at least through their flowering period. The practice appears to increase insect biodiversity, especially among species of lady beetles, syrphid flies, wasps, bees, and predatory true-bugs. The beneficial effects of extended bloom on the farm can usually be achieved with little loss to additional labor, materials, fuel, or land opportunity, since no special plantings need be made.

**Room for Bloom**

Uncultivated areas are among the most cost effective sources of biodiversity on the farm. Trees and brush species are recognized as valuable sources for pollen and nectar, as are native perennial herbs naturally comprising the understory, especially in riparian zones. Willow species are among the earliest sources for pollen and nectar, along with Indian plum and Bigleaf maple. Cascara, *Spirea*, Roses and *Rhubus*, Serviceberry and Oak are common and valuable attractors of pollinators and predators, including honeybees and native bees, parasitic wasps, lacewings, and snakeflies. Perennial bunchgrasses surrounding crop fields are refuges and breeding sites for a diversity of groundbeetle species that are effective generalist predators of some signature pests for organic vegetable farmers, including slugs and *Brassica* root maggots. Within these grassed borders and alleys we find several perennial weed species (Ox-Eye daisy, Sheep sorrel, dandelion) and occasional natives (asters, yarrow) that are known hosts for Minute piratebug, Big-Eyed bug, syrphid flies, and parasitic wasps. These areas get periodic mowing that tends to prevent rampant reseeding while extending the blooming period. This biodiversity resource requires minimal management and removes no land from production.
These extant sources of floral support for insect allies can be looked upon as “background biodiversity” in the context of organic farms, and simple choices related to timing of mowing or discing can enhance or diminish the impact of the background ecology on the primary crops. There is also the possibility to enhance this background counterbalance to pest outbreaks by extending the blooming period of borders through irrigation overspray, high mowing to prevent seed set and restimulate blooming, and adding autumn-blooming species (a typical rarity) to the mix of “rough” species.

**Blooming With Intention**

Strategies for going beyond the background level of biodiversity may include attempts to attract beneficials directly into the field among pest-sensitive crops. At Gathering Together Farm, where onions are an important part of the crop mix, sunflowers are planted alongside and among the beds to specifically attract minute pirate bugs that prey on onion thrips. Perhaps the sunflowers attract thrips *away* from the onions, as well, and provide an effective meeting place for predator bugs and their prey. Other Sunflower family species may work as well, including the common weed species Ox-Eye daisy that volunteers in synchrony with spring planted crops.

Seasonal insectary hedgerows that divide large fields into rotational blocks are a predictable and effective means to get a diversity of beneficials into the heart of the crops. Components of such hedgerows are chosen to assure blooming before and during the pest-vulnerable period of the crop(s), and are generally fast-growing annuals that will be tilled in along with the crop residues. One current rule of thumb estimates that a blooming insectary bed spaced every 200' across large fields will provide reasonable habitat to ensure good biodiversity “coverage” for the crop. We aren't aware of any documentation for such estimates. Designing seasonal insectary hedgerows requires some experience with the growth rate and bloom cycles of candidate species, and how blooming is effected by day length; that is, spring, summer and fall require different species and varieties. The chief advantage of these short lived insectary hedges is that they can fit with convenience into the annual planting scheme then plowed down at season's end with the rest of the crop. Flexibility is the strong point here.

Perennial insectary hedgerows provide some distinct advantages over the annual approach, including savings of tillage time and money, greater habitat stability, more botanical and arthropod diversity, more birds, and conservation of tillage-sensitive species like ground beetles and snakes. Perennial bunch grasses and native species can also fit into the mix. A special version of this insectary strategy (pioneered in England) is referred to as a “beetle bank”, and is intended specifically to enhance ground beetle reproduction and overwintering success. The soil for the beetle habitat strip is “banked” by plowing up soil from opposing directions to create a slightly raised bed. This bank is sown to densely bunching grasses that help encourage beetle success. Because ground beetles can't fly it is particularly desirable to provide them with undisturbed ground within large fields, otherwise their activity is mostly limited to field margins within range of un-tilled grasses. Woody species may be included in these beetle bank designs, providing additional biodiversity and windbreak benefits, but this precludes the ease of management by high mowing, and may create shade effects across the field. Another option is to include herbaceous perennials like Alexanders, angelica, *Lomatium* spp, lovage, *Agastache* spp, peppermint, fennel, yarrow, aster and the like. These have the advantages of perennial dependability and vigor, seasonal functionality (this list blooms sequentially from early spring
through late fall), bunch grass compatibility, the ability to regenerate through self-sowing, and management can be limited to mowing once or twice a year. Native grasses and flowers are compatible with this regime, and may provide on-farm habitat for native butterflies and pollinators specifically reliant on endemic species.

**Double-Cropping the Bug Range**

Any number of seed crops from the Umbel family, the Crucifers, Composites, Mints, and Legumes may provide secondary benefits to farm ecology and pest control as they pass through their blooming phase prior to seed set. There are also some diversity enhancement double-cropping strategies that are a regular part of the organic seed production program for Wild Garden Seed (WGS) at Gathering Together Farm (GTF). Biennials like kale and parsley are both important fresh vegetable crops for GTF and seed crops for WGS, and both crop species attract and feed syrphids, beneficial wasps, lady beetles, and bee pollinators. Such crops provide farm-wide opportunities to stack functions of biodiversity enhancement with double income production and all the savings and benefits of reduced tillage in the cropping cycle.

The typical double-use crop is a leafy vegetable whose leaves are cut for bunching or salad without serious loss of vigor for seed production. These are planted along with other fresh market crops of the season, and positioned in the field with the knowledge that the seed crop will be left to stand after the vegetable crops have been harvested and their beds re-tiled for another planting. Sometimes the double-crop may be positioned along the edge of the field to keep it out of the way of the replanting, in other cases the seed crop may divide a large field like a seasonal hedgerow, a blooming sanctuary of undisturbed ground amidst the new crop. We have no documentation that this strategy provides a demonstrable benefit to the vegetable crops in the field, but there are clearly a large number beneficial species in attendance of the bloom. Regardless, it costs the farm nothing to manage the cash crops in this manner, and the potential for benefits are there, including the potential for scientists to do research on farm ecology.

**Conclusions**

As farmers of diverse species of fresh vegetables and specialty seed crops, and as field observers of organic farm ecology, we see numerous opportunities to enhance biodiversity and crop profitability by encouraging bloom in and around our fields. Strategies that can integrate ongoing cycles of flowering natural vegetation, including trees, shrubs, native species, and weeds (as well as bolting salad crops) may be the most cost effective for small farmers. Additional benefits can be expected from strategies that enhance habitat for flightless general predators like ground beetles, spiders, and snakes, especially in fields larger than two acres. Beetle banks and perennial insectary hedgerows that divide large fields into crop rotation blocks are efficient means to spread biodiversity on the farm. Certain species provide special “double-cropping” opportunities for both vegetable and seed production, and unique seasonal insectary benefits as well.

The following are lists of insectory crop and weed species and insects commonly found on these species on organic vegetable farms west of the Cascades.
Table 1. A list of insectary species.

<table>
<thead>
<tr>
<th>Bloom Period</th>
<th>Weed and Crop Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td><em>Weeds:</em> Bittercress, Chickweed</td>
</tr>
</tbody>
</table>
| Spring       | *Weeds:* Dandelion, Chickweed, Shepherd's Purse, Speedwell, Wild Mustard  
               *Crops:* Arugula, Cilantro, Chervil, *Brassica* spp., Radish, Fava, Common Vetch, Clovers, Phacelia, Angelica |
| Summer       | *Weeds:* Ox-Eye Daisy, Lamb's Quarter, Wild Carrot, Yarrow, Smartweed(?)  
               *Crops:* Sunflowers, Shungiku, Endive, Chicory, Lettuce, Dill, Carrot, Parsnips, Celery, Parsley, Radish, Mints, Basil, Quinoa, Orach, Sorrel, Lovage, Buckwheat |
| Autumn       | *Crops:* Fennel(!), *Agastache* spp., Shungiku, Chicory, Dill, Orach, *Chenopodium* spp., Asters, Yarrow |

Table 2. Insects commonly observed on these crop and weed species.

<table>
<thead>
<tr>
<th>Insect Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syrphid Flies</td>
<td>The larvae are aphid predators found on crop leaves; adults commonly seen on all flower types. Adults require pollen for egg production, nectar for food. Especially significant for autumn aphid control, when <em>Chenopodium</em> spp. are common pollen source.</td>
</tr>
<tr>
<td>Wasps</td>
<td>Microwasps are often parasitic on larval pests, or eggs. Macrowasps like hornets and yellowjackets are efficient predators of caterpillars and flies.</td>
</tr>
<tr>
<td>Lady Beetles</td>
<td>Aphid predators, especially during larval stage. Adults common on flowering umbels, chickweed, and <em>Brassica</em> Family.</td>
</tr>
<tr>
<td>True Bugs</td>
<td>Generalist predators and egg eaters, Minute pirate bugs are found on Sunflower Family blooms; energetic consumers of thrips. Big-Eyed bug is found on buckwheat flowers. Damsel bugs are found eating aphids in heads of endive and chicory during winter.</td>
</tr>
<tr>
<td>Lacewings</td>
<td>Generalist predators of pests and their eggs. Observed feeding at flowers of Rose Family fruit trees and shrubs at night. Snakeflies are a distinct Order, but bear a resemblance to lacewings and share their highly Predatory habits. They are born in the bark crevices of trees, notably Oregon oak, but are mobile and active against many pest species.</td>
</tr>
</tbody>
</table>
Organic agriculture is changing as some farmers and researchers are exploring more ecological systems approaches to organic farming (Leffroy et al. 1999, Soule and Piper 1992). The goal of ecologically based organic farming is to design cropping systems that more closely mimic natural systems. These systems strive to reduce tillage, increase species and genetic diversity, close nutrient cycles, enhance system resilience (stability), and create more complex habitats (Gliessman 2000).

Reducing Tillage
When we plow or till the soil to produce crops, soil organic matter levels and microbial populations decrease. In grassland soils, huge drops (from 9% down to 4% soil organic matter) have been recorded during the first years following tillage (Doran 1980, Hooker and Black 1995, Cambardella and Elliot 1992, Kay 1990, Doran et. Al. 1998, Gliessman 2000). Exposed bare soil between crop plants and between cropping seasons (winter fallow) causes leaching of mobile nutrients like nitrate-nitrogen that had formerly been recycled by permanent vegetative cover (Hooker and Black 1995; Atthowe 1996, Swift 1997, Allmaras 2000, Gliessman 2000). Leaked nitrate can end up in surface waters and riparian areas (Randall et al. 1997). Adding organic residues can help overcome some of the negative effects of tillage on soil health. However, in a Central California study, conventional organic cultivation and cropping significantly reduced soil organic matter when compared to an unfarmed grassland, even when high levels of organic matter were added through winter cover crops and composts (Waldon 1994).

Further, organic residues are not all the same. Phillips (2001) reports that when nitrogen-fixing legumes are used in rotations less than 25% of the time (i.e. only grown 1 in every 4 years), then soil organic matter decreases over a 10-year period. Drinkwater et al. (1998) found that total amount of residue input alone did not account for changes in soil carbon and nitrogen. They report that plant species composition and litter quality play important roles in soil organic matter increases and decreases. At Biodesign Farm we have found differences in carbon:nitrogen ratios and macro- and micro-nutrient levels due to a clover living mulch mowed at different times of the season (spring vs. summer vs. fall) (Atthowe 1996).

Reducing tillage and maintaining soil cover helps to close nutrient cycles. In general, soil management techniques that provide permanent soil cover result in higher levels of microbial biomass and potentially mineralizable nitrogen, and lower levels of late fall and early spring nitrate-nitrogen and thus decreased nitrogen leaching (Doran and Parkin 1994, Atthowe 1996, Doran et al. 1998, Allmaras et al. 2000). Lower levels of early spring nitrate-nitrogen can mean later crop maturity and reduced warm season crop yield (Doran and Parkin 1994). Corn yield was reportedly decreased in a ridge tillage system on the Thompson Farm in Boone, Iowa, as a result of reduced available nitrate-nitrogen in early May and cooler temperatures in the residue-filled alleys between cornrows (Doran et al. 1994). It was suggested that subsurface tillage (to aerate and warm soil between corn rows) might improve corn yield by enhancing mineralization of crop residues and soil organic matter and by reducing denitrification losses of available nitrogen (Doran et al. 1994). At Biodesign Farm we have overcome potential soil nitrate-
nitrogen deficiencies in our permanent cover soils during the cool spring period by utilizing soil warming techniques such as plastic mulch.

**Species Diversity**

Traditionally, organic farming has received high marks for enhancing species diversity and creating more complex habitats, at least when compared to chemical farming. However, when compared to undisturbed plant systems (such as grasslands or native plant communities), conventional organic farming significantly diminishes habitat complexity. Tillage diminishes the habitat of many beneficial organisms, including earthworms, spiders, insects, and soil microorganisms (Dennis and Fry 1992, Thomas et al 1992, Hooker and Black 1995, Atthowe 1996). Permanent groundcover, specifically perennial grasses that form thick sod layers, have been shown to support higher densities of ground-dwelling predators such as spiders and beetles by providing stable microclimates and improving their overwintering success (Denys and Tscharntke 2002, Dennis and Fry 1992, Thomas et al 1992, Hassall et al. 1992, Desender 1982). Undisturbed, perennial grass habitats known as "beetle banks" are areas of mixed perennial grasses that are planted along agricultural borders to increase predator carabid beetle populations (Thomas 1992). Unfortunately, in the study by Thomas (1990) there was no correlative decrease in pest populations due to increased predator beetle populations, except in areas that were closest to the beetle banks. Based on this work I asked the question: “Why not include beetle banks within my cropping systems and not just along the outside borders?”

As vegetation within a crop field is diversified and tillage is reduced, parasitoid populations are increased. Parasitic wasps and flies lay eggs in crop pests and their young feed on the pest after hatching, a little like invasion of the body-snatchers. Populations of fly and wasp parasitoids also increase in habitats that provide season-long pollen and nectar sources (Baggen and Gurr 1998, Hagley and Barber 1992, Idris and Grafius 1995, Stapel et al. 1997, Takasu and Lewis 1993, Altieri and Whitcomb 1979, Altieri and Letourneau 1982). The availability of season-long parasitoid food plants has been shown to translate into higher parasitism rates in cropping systems (Grossman and Quarles 1993, Leius 1967, Stapel et al. 1997, Zandstra and Motooka 1978). The proximity of pollen and nectar plants to cropping systems and their pests affects parasitism rates. As the distance between food plants and hosts (pests) increases, so too does the time and energy required for parasitoids to travel between these two resources (Lewis et al. 1998). Maintaining diverse, undisturbed vegetation borders alongside and within cropping systems can provide an economic benefit for farmers by increasing the populations of predators and parasitoids thereby increasing natural pest control.

Researchers have begun to study how "islands" or "alleyways" of uncultivated vegetation or native plant communities can bring predators and parasitoids into cropping systems and thereby enhance insect pest management (Altieri and Schmidt 1986, Atthowe 1996, Altieri 1999). Populations of generalist predators such as spiders are particularly enhanced by vegetation between crop rows (Dr. Susan Rierchert, VPI and Dr. John Luna, OSU, personal communication, Atthowe 1996). It has been suggested that a greater diversity of plant species within crop land may provide the best predator enhancement (Leius 1967, Altieri and Whitcomb 1979, Altieri 1999). There is also evidence that providing habitat for native bees within cropping systems can significantly enhance crop pollination and yield (Dr. David Stickler, Univ. Of NV, personal communication).
Permanent soil cover and reduced tillage have also been associated with enhanced disease suppression. In several studies, undisturbed leguminous under-story cover crops resulted in lower levels of *Phytophthora* root rot (Malajczuk 1979, Shea and Malajczuk 1977, Malajczuk 1983) and *fusarium* wilt (Abadie, Edel, and Alabouvette 1998). Bacterial Spot of radish was also significantly reduced in no-till compared to cultivated plots (Zhang 1997). In another study, undisturbed soils were 82% *Pythium* suppressive while newly cultivated soils were only 31% suppressive. In soils that had been intensely cultivated for annual cropping over an extended period, *Pythium* suppression dropped to only 7% (Lourd and Bouhot 1987). However, in some non-organic no-till grain production systems, increased disease has been reported. In these systems only one kind of plant residue is usually added, that is wheat straw. Disease suppression may require a diversity of residue type and decomposition quality. Darby and Stone (2002) compared raw and composted dairy manure application effects on corn root rot disease and found that composted manure provided the best disease suppression 2 months after incorporation. However, after 12 months, composted manure provided no more disease suppression than the control or the raw manure treatment. Stone suggests that carbon quality plays a significant role in the disease suppressiveness of particular soils and organic residue amendments.

**Systems Management**
Managing permanent soil cover without significant yield reduction is the challenge. This is especially true in annual grain and vegetable farming systems that rely on extensive and repeated tillage for weed control. An added benefit of increased soil organic matter levels is increased soil water-holding capacity. Studies at Montana State University indicate that after years of drought, better wheat yields are coming from no-till fields. However, soil-building takes time and permanent vegetation may steal water from crops in the short term.

One way to mimic natural systems in annual vegetable cropping is to include a semi-permanent vegetative cover within the crop. This living mulch system reduces tillage and increases species diversity within the field by creating more complex habitat. Legume living mulches have been used successfully in vegetable production to control weeds and provide added organic matter (Kass 1979, Macrae and Mehuys 1985, Lanini et al. 1989) and nitrogen to the soil (Lanini et al. 1989, Eaglesham et al. 1980). Several studies have investigated the choices of leguminous cover crops and living mulches for particular climates, soil types, and the impact on yield crop (Vrable 1981, Nicholson and Wein 1983, Schmid and Klay 1984, and William 1986, Abdul-baki 1997, Abdul-baki et al. 1996, Abdul-baki et al. 1997).

Researchers have evaluated methods to reduce the competition between living mulches and the crop. It has been suggested that mowing or harvesting legume cover crops enhances senescence and degradation of nodules and results in the release of nitrogen into the soil system (Vance et al. 1982). Nitrogen release from cover crop incorporation into the soil is generally thought to be from 2-10 weeks depending on climate, soil type, and developmental stage of the cover crop (Schmid and Klay 1984). Work done at Cornell University indicates that living mulches perform best in regard to both weed suppression and warm season crop yield when they are shallowly cultivated during the summer (Vrable 1983, Wyland 1986, Grubinger and Minotti 1990). Studies at Biodesign Farm in 1995 and 1996 suggest that periodic mowing is the best way to manage a living mulch in an intensive vegetable cropping operation in order to achieve an optimum
combination of weed control, nutrient contribution, long-term soil improvement, biological control, and adequate yield (Atthowe 1996).

Another benefit of organic matter addition is that it increases the general level and diversity of microbial activity (Cook and Baker 1983, Curl and Truelove 1986, Workneh and Van Bruggen 1994, Doran 1998). Plant residues increase available carbon, nitrogen, phosphorus, sulfur, and other nutrients required by plants and most soil microorganisms (Parnes 1990). Microbial action is required before plant residues can be converted into nutrient forms that plants can readily take up (Mengel and Kirkby 1982). Soil microorganisms, including the bacteria, actinomycetes, and fungi responsible for decomposition of plant residues, show a marked seasonal activity (Hassink et al. 1991) that depends on soil temperature, moisture, organic matter, structure, aeration, and pH (Tate 1995). It has been reported that soil microbe populations increase in reduced tillage systems, however, cultivation results in a temporary increase of soil biological activity and a predominance of one bacterial species over another (Doran 1980, Atthowe 1996, Hauttori 1973, Allison 1973, Mekhtiev 1957.).

Summary
Living mulch systems enable organic farmers to reduce tillage while increasing vegetative and soil microbiological diversity. Optimum species and management systems still need to be worked out for each environment crop and climate. The Land Institute in Salina, Kansas, is investigating another way to reduce tillage, increase species diversity, close nutrient cycles, and mimic natural systems. The Land Institute is selecting for perennial grains to be part of a “perennial polyculture” production system that mimics the tall-grass prairie. This system is 50 or more years away from economic practicality, but the concept of looking at natural ecosystems to find patterns for agriculture can begin to impact our research questions today.

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Breeding and Genetic Studies of Perennial Wheat
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By acreage, wheat is the major crop grown in Washington State, and some regions of the state are considered among the most productive wheat growing regions in the world. Wheat yields on the Palouse are among the highest in the world, but the steep topography and winter rainfall pattern combine to make the Palouse one of the most highly eroded crop lands in the United States. Constant plant cover is the most effective barrier to erosion. Additionally, many physical, chemical, and biological properties of soil actually improve under perennial grass cover. We envision perennial wheat as a complementary strategy to CRP and the ultimate form of no-till agriculture. To meet these ends, we have employed a breeding strategy to incorporate the agronomically favorable traits of modern wheat cultivars with the perennial growth of wild wheat relatives. Additionally, we are engaged in genetic studies to determine the molecular and physiological factors that delineate these two different life cycle strategies.

Perennial wheats are hybrids between hexaploid bread wheat or tetraploid durum wheat, and perennial wheatgrasses in the closely related genus *Thinopyrum*. We are currently conducting field trials of hybrid lines in which *Thinopyrum* chromatin is introduced into competitive wheat cultivars. Agronomic quality, perennial vigor and karyotypic stability are our primary selection criteria. To characterize the genetic basis of perennial habit, we are performing physical mapping of chromosome 4E, which by itself is sufficient to initiate successive rounds of growth in greenhouse-grown plants.

We have evaluated hundreds of perennial wheat hybrids to select germplasm for breeding new lines adapted to Washington State. Historic lines with sufficient agronomic promise are crossed to elite annual wheat varieties better adapted to local conditions. We are evaluating other perennial relatives of wheat for drought tolerance, disease resistance, winter hardiness, grain yield and agronomic characteristics at two locations in the state for 32 species from 9 different genera of perennial relatives of wheat. The most promising accessions are now being used to produce new hybrids with adapted annual varieties in the greenhouse. We primarily utilize a bulk selection strategy in which progeny from several thousand lines are grown as mixed populations in three agronomic zones in Washington State. Seed is advanced after the second harvest from each field. We maintain forty lines selected from these populations for karyotypic and genetic studies, agronomic studies, and for disease resistance studies.

To physically map chromosome 4E, we have generated deletion stocks of the chromosome using gametocidal chromosome 4E from *Aegilops cylindrica*. Using PCR-based markers isolated in our laboratory, we are screening ~1500 individuals for missing 4E segments and visualizing deleted chromosomes via genomic in situ hybridization (GISH). In our physical mapping initiative, of ~400 individuals screened via PCR, 46 have demonstrated marker profiles consistent with deleted chromosome segments. GISH has demonstrated translocations of chromosome segments to wheat chromosomes in some of these lines; analysis is ongoing.

Our ultimate goal is to produce lines in the soft white market class with 3 to 5 years of productive stand life. Identification of the gene for regrowth will isolate an essential trait which must be incorporated into perennial breeding and will provide considerable insight into plant life cycle mechanisms.
Cereal leaf beetle (CLB) was first identified in Michigan in 1962 as an introduced pest from Europe. Since then it has spread to most states east of the Mississippi River. In 1986 it was found for the first time in the Western United States near Salt Lake City, Utah. It quickly spread to the neighboring states of Wyoming, Montana, and Idaho. CLB was first found in Oregon in 1999 in Malheur County and now infests 19 Oregon counties.

Eggs are laid by overwintered adults in the spring on the upper leaf surface, parallel to the veins. Larvae generally feed only on the upper leaf surface removing the chlorophyll containing layer. They secrete a mucous layer to which they add their fecal matter for protection. Pupal cases are formed in the soil from bits of sand, dirt and debris. Adults emerge and feed for a short time in late summer on crops like corn. They overwinter as adults, emerge in early spring, and begin to feed on winter grains. Egg laying begins shortly thereafter. Adults usually chew strips completely through the leaf. Larvae, however, are the most economically damaging life stage on grains. Heavily infested fields have a “frosted” appearance. Larvae typically strip the upper flag leaves, the main energy producers, thereby reducing grain yield.

Spring grain plantings of oats, barley and wheat have been the most commonly treated crops. CLB is also starting to impact grass seed fields and occasionally impacts sweet corn. Over 1000 acres of sweet corn were treated to meet California’s quarantine requirements and at least one field of perennial ryegrass was treated in 2003. Acres treated have continually increased from none in 1999 to 38,309 acres (a) treated in 2003. The most frequently used chemicals were Malathion and Mustang. Lorsban, Warrior, Asana, Sevin, and Dimethoate were also used. Poor CLB control was reported with Dimethoate. Cost estimates for these chemicals range from about $4-5/a for Malathion to $6-8/a for Warrior. Application costs run approximately $10-12/a for aerial, and $4-6/a for ground application. By using a weighted average cost of $5.50/a for the chemical, plus an application cost of $5.50/a, the estimated cost to treat CLB in Oregon in 2003 was $421,399.

Biological control has proven to be an effective weapon against CLB in the Midwest and Eastern U.S. where the beetle first became a serious problem. It controls CLB to below economic thresholds, eliminating the need for pesticide application. Oregon’s CLB biological control program started immediately after the beetle was detected in 1999. The first dedicated CLB field insectaries in the state were established in 2002. The insectaries will allow us to raise two parasitic wasp species, Anaphes flavipes and Tetrastichus julis, in large numbers for redistribution throughout CLB-infested areas in the state. Insectary fields have been established in Benton, Malheur, Jefferson, Union, and Washington counties. The larval parasitoid, T. julis, was first recovered in 2003 in Malheur and Union counties and again in 2004 in much higher numbers in Union and Baker counties. Overwintering recovery of the egg parasitoid, A. flavipes, was achieved for the first time in 2004 in the Washington County insectary.
Developing Bait Stations Against Alfalfa Looper and Corn Earworm Using Floral Chemical Attractants
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The pestiferous status of noctuid moths in North America is widely understood. Crops attacked by larvae are diverse and include corn, alfalfa, soybeans, cotton, numerous vegetables crops and others. Traditional chemical pesticides and genetically engineered plants are the most common methods for controlling these caterpillars. The need of “organic-friendly” control techniques, the Food Quality and Protection Act, growing environmental issues, and worker safety concerns have led scientists to explore alternative management approaches. Although the use of lures and pheromones in attract and kill programs is relatively old, few uses of this method have proven to be effective against these species. The inability to attract females is one of the main reasons for its repeated failures. Most studies have shown that larval numbers are not negatively affected by the removal of males alone. Recently a series of floral chemical lures have been developed using compounds that are odorants from “moth-visited” flowers. Both sexes of several pest species of pestiferous noctuid moths are attracted to these floral lures.

Our objective is to reduce the larvae population of alfalfa looper and corn earworm in alfalfa and corn fields respectively, by applying bait stations that attract and kill female adult moths. By reducing female activity the number of eggs laid in the field is expected to be lowered.

Experiments were conducted in the 2003 and 2004 alfalfa growing seasons and the 2004 corn season. Lures were dispensed from polypropylene vials that were modified to provide controlled release rates for extended periods of time. A killing station was developed and tested for use in combination with these lures as a lure and kill system that can be field-implemented to decrease numbers of female moths. Fifty bait stations per acre were placed in treated plots and monitoring for moth activity was done every other day using commercial sex pheromone traps and floral chemical attractant traps. On corn fields a black light trap was also used. Alfalfa looper larvae infestations were assessed by a sweep net sampling schedule during each experiment.

We observed that the number of female alfalfa looper adults captured per trap was significantly reduced from plots treated with bait stations compared to untreated plots in both the 2003 and 2004 seasons. Density of alfalfa looper larvae were reduced in treated plots. Corn earworm female and male adult numbers were reduced when comparing treated plots against the untreated plots. Reductions in corn earworm adults were observed in both the black light trap and the commercial sex pheromone trap.

Field research demonstrated efficient control of female alfalfa looper adults and by consequence reduction of larvae activity in the field. Bait stations demonstrated great potential for row corps with similar architectural type as alfalfa against alfalfa looper. Other attractants are being developed to broaden the spectrum of application. More replications of corn earworm control using bait stations are necessary however. Results of the 2004 season demonstrated reduction of female moth activity. Development of this system and different kinds of noctuid pest attractants will be useful for a variety of important crops as an alternative method of controlling these insects.
Noxious weeds are destroying biological diversity throughout the state of Washington, decreasing forage and habitat for wildlife and livestock, increasing erosion, and decreasing land values. Many years of manual and chemical control are often required to have any impact on infested areas, which can be costly for landowners and public agencies. For such situations, biological control offers an inexpensive, long-term weed suppression option, as site-appropriate insects will self-perpetuate. The mobility of biocontrol agents also allows them to disperse to new and unknown weed infestations that may be difficult to reach with other control practices.

Biological control is not a quick fix; agents may take several years to establish and perhaps longer to have significant impacts on weed infestations. Even so, some agents have proven to be extremely effective over time at bringing weed infestations down to a manageable level, and are in many cases the best management option. In eastern Washington, knapweed seed head weevil (*Larinus minutus*) has proven to be very effective against diffuse knapweed (*Centaurea diffusa*), a widespread and aggressive weed of range and natural areas. The weevil is already visibly affecting an estimated 8100 hectares, with beneficial vegetation beginning to reoccupy sites. Forage and habitat values are improving, while herbicide use for knapweed control has decreased. Purple loosestrife (*Lythrum salicaria*), a riparian invader, is a primary target for biocontrol in western Washington. Several years after their initial release, golden loosestrife beetle and black-margined loosestrife beetle (*Galerucella pusilla* and *G. calmariensis*) are established in many sites and are making significant impacts on loosestrife infestations.

The Washington State Invasive Species Bioagent Enhancement Program, led by WSU Ferry County Extension and funded by the US Forest Service, is designed to increase the use and integration of biological weed control into weed management programs across the state. The program works directly with property owners, county noxious weed control boards, and land managers to establish biological agents and manage them on a statewide scale.
Protecting Salmonid Habitat in Agricultural Drainage Watercourses with the Evaluation and Development of Best Management Practices

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King County is funding Washington State University (WSU) and the University of Washington (UW) to conduct a 5-year research project on the effects of maintenance of agricultural waterways on water quality, fish habitat, vegetation, and sediment transport. The long-term goal of this project is to identify effective ways to maintain agricultural watercourses while protecting fish habitat and water quality. We are still in the early stages of this research, and the conclusions presented here are based on a limited amount of data and should thus be viewed as tentative. This poster highlights results from the vegetation, water quality, and fish habitat utilization components of the research project.

The objectives of the riparian vegetation component of this project include a) developing a BMP protocol for the effective control or eradication of reed canarygrass (RCG), and b) identifying methods for establishing vigorous stands of native herbaceous and woody riparian vegetation that produce shade, fish cover, and habitat for insects that constitute prey for salmonids.

Initial pilot field studies determined that an allelopathic mulch of red cedar hog fuel and shade material suppressed RCG growth more effectively than the other treatments tested (salal or clover plantings and nitrogen reduction), regardless of whether steam was used to kill the RCG prior to applying the shade material or mulch. Current research is investigating a combination of shade and allelopathic mulch treatments, along with a multi-species planting design intended to increase the likelihood of native riparian vegetation establishment and eventually out-competing the RCG. These experiments will compare willow only plantings to multiple species plantings consisting of black twinberry, Pacific ninebark, oceanspray, Indian plum, small-fruited bulrush, and other species and are replicated at three farms.

Water quality research done in 2003 focused on two main topics: a) developing a working model for predicting the effects of agricultural watercourse maintenance on water temperature, and b) evaluating the effects of different types of vegetation on water temperature. Pre-project water temperatures were lower in watercourses lined with a mixture of willows and blackberries than in channels dominated by RCG. These data indicate that a riparian zone composed of mixed vegetation is more effective in moderating water temperatures than RCG alone. Data collected at 10 field sites in King County, representing four distinct bank vegetation types (RCG, blackberries, willows, and a mixture of blackberries and willows) were used to develop and calibrate a model used to predict water temperature following channel maintenance coupled with various vegetation planting scenarios. Research is beginning on the impacts of ditch maintenance practices on dissolved oxygen.

During four fish sampling events conducted in 2003, nearly 1,500 fish were collected, representing at least 14 different species. Over half (806) of these were juvenile salmon or trout, the vast majority of which were coho salmon (757). Although only some of our data have been analyzed so far, the coho salmon collected in these agricultural watercourses appeared to be healthy and in very good condition. Growth rates (length at age) appear similar to those of coho salmon collected in natural stream channels elsewhere in the Puget Lowlands.

Studies have been set up to evaluate sediment control methods in terms of cost and effectiveness. Eight erosion control treatments will be evaluated in this experiment; they include peat moss, Coir mat, woodchips at 2” and 4” depths, sod, hydroseeding at 100% and 150% of the standard application rate, and hand seeding at 100% of the standard application rate. The effectiveness of erosion control from “first flush” sediment mobilization, as well as long-term cumulative erosion, will be measured by an index which includes rill formation on the banks of drainage watercourses, sediment from “first flush” erosion, and cumulative sedimentation on the bottom of the watercourse. Particle size distribution will also be measured to help estimate sediment transportation within the watercourse.
Currently, the demand for organic arugula in the Puget Sound region is well in excess of what can be supplied, likely due to the difficulty in growing the crop in the presence of a high flea beetle population. Flea beetles can decimate an arugula crop, and producers who can avoid or prevent flea beetle damage would gain substantially in the market place.

We are conducting a study to test the efficacy of a trap crop with or without 3 organic treatments to prevent flea beetle damage in arugula. This study is being conducted at Full Circle Farm near Carnation, WA. The study is a split plot design where the whole plot treatment is the presence or absence of a trap crop bordering the arugula beds. Within each whole plot, four subplot treatments were applied in a random complete block design, for a total of 8 treatments per block (see figure to left). Each block consisted of one bed of arugula and one whole plot treatment bed. Beds measured 500 feet long by 5.5 feet wide and contained 30 rows of baby arugula (spacing between rows was 2 inches). The experiment was replicated across 4 plantings, one in June and three in August. We used Green Wave Mustard as the trap crop, based on research results reported in the Organic Farming Research Foundations newsletter (Smith, Summer 2000). The subplots consisted of 4 treatments: Pyganic, garlic spray, Brix Mix, and a control (no application). We placed a 4-foot tall fabric barrier between each subplot treatment to minimize the movement of insects between treatments (Bergelson & Kareiva, 1987).

Each subplot was sampled once a week from seedling stage to harvest for flea beetle numbers. Sampling consisted of collecting flea beetles present in each subplot over a 20-foot section with a portable D-Vac sampling device. In addition, flea beetle feeding damage to leaves was measured twice for each replicate, 14 days after planting (DAP) and prior to harvest (usually 28-30 DAP). A 1/3-meter diameter quadrat was the sampling unit and all leaves on selected plants were inspected for flea beetle damage and scored based on damage where: 0 = no damage; 1 = 1-5 feeding holes; and 2 = >5 feeding holes. The threshold of 5 feeding holes represents the cut-off between commercially marketable and un-marketable product. Five quadrats were sampled per treatment–sampling day.

Data has been collected on this project and final results will be presented on the poster.
Dirty Cropping and Insect Community Structure: Can Relaxed Weed Control Benefit Pest Control in Brassicaceae Crops
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Currently, the Puget Sound region is experiencing an explosion of direct marketing of organic vegetables to local consumers with over 40 different Farmers Markets serving the region. Commonly grown vegetables are from several plant families, e.g. Brassicaceae, Chenopodiaceae, Umbelliferae, Faberaceae, Solanaceae, and Gramineae. To exploit direct marketing opportunities, growers continually plant each crop type (relay planting) to ensure marketable produce throughout the summer. This results in planting crops at less than ideal times for crop growth and pest populations. The primary pests associated with crucifers (e.g. broccoli, cauliflower, cabbage, mustard greens) in this region are: a suite of aphids (Homoptera: Aphididae) *Brevicoryne brassicae*, *Myzus persicae* and *Aphis fabae*; flea beetles (Phylloctreta cruciferae, Chrysomelidae: Alticidae); and a lepidopteran complex consisting of *Pieris rapae* (Pieridae), *Plutella xylostella* (Plutellidae) and *Trichoplusia ni* (Noctuidae).

One cultural pest control strategy is modifying the vegetational habitat, either in structural complexity or species diversity, causing a change in the pest’s behavior or abundance. From a production standpoint, the easiest way to increase diversity in a crop is to allow the native background vegetation (i.e. weeds) to grow. This will increase diversity at no direct cost to the farmer (compared to undersowing or intercropping) while reducing normal costs associated with controlling weeds. However, decreases in herbivore abundance and damage must offset the competition between the weeds and the crop.

To assess the impact of increased vegetational diversity and complexity on insect abundance, mechanical weed control was relaxed on four commercial organic farms in western Washington during the summer of 1999. The experiments were conducted as part of the farm production system with treatment plots ranging between 484 and 3,292 square feet (treatment plots were of equal size on a specific farm) growing a mixture of brassica crops. Insect abundance was measured every two weeks for the major pests listed above by visual inspection of plants in a repeated measures design. The overall feasibility of this pest control strategy was measured by yield (broccoli head weight).

In this study, the four farms varied in the degree of relaxed weed control, resulting in different densities of weeds in the “dirty” plots on each farm (two farms with about 15% ground cover and two farms with near 100% ground cover). In general, the impact of the weed control level on pest populations varied depending on the pest species. Specifically, adult flea beetle abundance was reduced at all levels of relaxed weed control (as the percent of weed ground cover increased, flea beetle abundance decreased). Any level of relaxed weed control did not affect abundance of the lepidopteran complex. Aphid populations were reduced for all levels of relaxed weed control except on the farm with the least difference between weeded and non-weeded treatments. Possible behavioral mechanisms and impacts of natural enemies will be discussed in an attempt to explain the observed results.
Effect of Serial Dairy Manure Amendments on Soil Biological Properties and Severity of Sweet Corn Root Rot

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Organic amendment of agricultural soils typically improves soil quality and in some cases suppresses soil-borne diseases (Stone et al, 2004). This study examined the effect of single year and serial organic amendment on soil microbial activity and severity of root rot of sweet corn (causal agents Pythium arrhenomanes, Phoma terrestris, and Drechslera sp.; Hoinacki et al, 2004) in the Willamette Valley, Oregon. In earlier work in this field site, root rot was suppressed for several months after amendment, and root rot severity was negatively related to microbial activity (Darby, 2003; Hoffman, unpub.). In addition to altering soil biological activity, residual organic matter increases soil water holding capacity, and severity of corn root rot is positively related to soil moisture (Peachey, pers. comm.). Therefore, it is likely that multiple factors affect corn root rot severity in serially amended field soils, including 1) microbial activity, which has been shown to be strongly associated with fungistasis, 2) other disease suppressive mechanisms not directly associated with microbial activity, and 3) soil physical factors such as water holding capacity and structure.

The objective of this study was to compare the effects of single, serial, and serial-residual organic amendment on 1) root rot severity, 2) soil properties, and 3) the relationship between root rot severity and soil properties.

In the spring of 2004, field plots that had received either the highest rate of raw manure or no manure amendment in 2003 were split in half. A randomly assigned half was re-amended with 33.6 dry Mg ha\(^{-1}\) of manure, while the other half was not re-amended. The following treatments resulted: 4-yrs, 3-yrs, 1-yr and 0-yrs of manure amendment, with the 4-yr and 1-yr treatments freshly applied in 2004. Soils were sampled 3 wks after amending, and soil microbial activity was measured as hydrolysis of fluorescein diacetate (FDA) according to Bandick and Dick (1999). Root rot severity was evaluated on field-grown corn plants at the six-leaf stage by evaluating percent necrosis of the radicle.

One-yr and 4-yr treatments suppressed root rot, demonstrating that root rot suppression can be generated in both single year and serially amended treatments. The 3-yr (residual) treatment also suppressed root rot, indicating that serial amendment can generate a more durable suppression than is typical in container systems or single year amendments. However, 3-yr/residual suppression was not as strong as 1-yr or 4-yr suppression. FDA activity was higher in the 3-yr treatment than in the control treatment and higher in the 4-yr than in the 1-yr treatment. Serial amendment therefore can increase microbial activity over time, and microbial activity can be maintained at elevated levels for at least one year after amendment. Although root rot severity was not different in the 1-yr and 4-yr manure treatments, FDA activity was significantly higher in the 4-yr treatment. This suggests that factors other than microbial activity affect root rot severity.

Onion thrips (Thrips tabaci) is the major insect pest of onions grown in the Treasure Valley production area of Idaho and eastern Oregon. The ability of currently registered insecticides to control onion thrips has gradually decreased. Thrips control with lambda-cyhalothrin, the most commonly used insecticide, has gone from 95% control to less than 70%. Straw mulch has been used commercially to enhance irrigation water infiltration. Growers report less thrips pressure when using straw. Using naturally occurring predators to control onion thrips would eliminate the problem of insecticide resistance currently encountered with the commonly used insecticides.

The bio-insecticides azadirachtin and spinosad have shown only slight control of onion thrips in conventional insecticide efficacy trials however, they are safe against many thrips predators. These bio-insecticides were used in conjunction with straw mulch, which was placed over the onion bed to enhance predator habitat. Predator activity was higher in the straw mulch plus azadirachtin plus spinosad treatment. Common predators were minute pirate bug, spiders, big-eyed bugs and damsel bugs plus an array of other common predators. Onion yield and quality were equal to onions treated with a conventional insecticide program used by growers and significantly higher than the untreated check.
Separated dairy solids are a locally available source of nutrients and organic matter for small-scale farming systems. This study was conducted to estimate the effect of dairy solids application on the timing and amount of plant-available nitrogen (ammonium + nitrate-nitrogen) produced by microbially-mediated mineralization processes in soils.

**Methods** We used two methods, field microplots and laboratory incubation, to measure N mineralization. For the microplot method, soil samples were collected in May or early June, to a 6-inch depth, mixed thoroughly, then packed into microplots (2 inch diameter x 6 inch long, open-ended PVC pipes with an anion exchange resin “trap” in the bottom of each pipe). After preparation, the microplots were inserted back into the field. For the laboratory incubation method, soil was moistened, then placed in zippered plastic bags at 22°C in the laboratory. Microplots were removed from the field every two to four weeks during the growing season to measure accumulated plant-available nitrogen. The soils from laboratory incubations were collected and analyzed on the same schedule as the microplots. We conducted these measurements at three locations: OSU Vegetable Farm (Corvallis, OR), OSU North Willamette Experiment Station (Aurora, OR) and at the WSU-Puyallup Experiment Station (Puyallup, WA). At each location, we compared N mineralized from a no-solids application control plot to N mineralized on soils that had received dairy solids application.

**Results** from the 2004 OSU Vegetable Farm site (below) highlight our findings. Day 0 on the graph is June 20. We consistently found that the decomposition of dairy solids immobilized plant-available N (in microbial biomass) for most of the summer following a May solids application. When dairy solids were applied in previous years, but solids were not applied during the current season, we observed greater plant-available N, compared to the “no-application” control soil. When dairy solids were applied year after year, the first year effect (N immobilization) and the second year effect (N mineralization) balanced each other, and no net effect of dairy solids application on N mineralized was observed.
Codling moth (CM), *Cydia pomonella*, continues to be the most devastating insect pest of apple in the Pacific Northwest. The development and adoption of alternative insecticides that are effective, safe to apply and leave no harmful residues on fruit is highly desirable. Recent work at the Yakima Agricultural Research Laboratory has focused on evaluating commercial formulations of the *C. pomonella* granulovirus (CpGV). CpGV targets neonate larvae before or during initial entry into fruit and provides growers with an option for CM control that is safe to humans and natural enemies of CM.

In 2003 field tests on apple we compared the persistence and efficacy of single applications of three CpGV products approved for organic orchards in North America. The success of repeated applications of one product (Cyd-X) as a principal control measure for CM in organic apple orchards was also monitored following operational use by cooperating growers at four separate locations. Early season application of all products at label rates remained highly effective for the first 24 h (averaging 94% larval mortality relative to controls) and moderately effective after 72 h (averaging 71% mortality) during dry sunny conditions. Significant activity remained for up to 14 days, suggesting prolonged survival of the virus in UV-protected locations, such as the calyx of fruit. A second application later in the season was slightly less effective.

Data obtained from the commercial orchards provide circumstantial evidence for the effectiveness of well-timed CpGV applications against CM outbreaks. In all cases where first generation larvae were targeted beginning at egg hatch (250 degree days) and treated areas monitored (0.3–1.6 ha plots), fruit damage during the second larval generation was reduced or eliminated. Based on the number of live larvae recovered throughout the season, mortality rates remained high (80.3–100% across sites). The cumulative number of moths caught in pheromone-baited traps was reduced (66–94%) in the second flight. Data from tree bands placed to catch diapause-destined larvae indicated overwintering generations remained low in treated sites (60.18 larvae/band).

In 2004 tests, different application strategies for the virus were tested. Virus was applied at 1, 3 and 6 oz per acre every 7, 10 or 14 days. Fruit injury, proportion of deep entries and larval mortality among each of the virus treatments were monitored. While the virus applications did not reduce fruit damaged by CM, there were significantly fewer deep entries and fewer surviving larvae among virus-treated fruit. The majority of damage was in the form of shallow stings (<¼”) and larval mortality was consistently high (>80% in all treatments). Moreover there were differences according to the treatment applied; higher doses and shorter application intervals resulted in consistently fewer deep entries and higher mortality rates. Rates of larval mortality were supported by the number of larvae captured in tree bands. The best dosage and application frequency of virus that provides acceptable control will depend largely on the localized pressure of codling moth.
Organic Wheat Breeding in the Pacific Northwest
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Challenge addressed
The best wheat varieties grown under conventional farming systems are not the best wheat varieties when grown under organic farming systems. Organic farmers require wheat varieties to possess traits that are not often found in conventional varieties. These traits include nutrient-use efficiency, competitiveness against weeds and certain disease resistances. These traits can be selected for both on organic farms and in breeding nurseries, and combined to develop wheat varieties well adapted to the unique challenges of organic wheat production.

Where are these traits to be found?
After 50+ years of wheat breeding under conditions of high inputs of fertilizers and crop protection chemicals, many traits beneficial to organic production are no longer present in our modern varieties. We are evaluating over 160 historical wheat cultivars and landraces grown in the Pacific Northwest from the 1840’s to the 1950’s (the era before heavy chemical use) for traits relating to disease resistance, nutrient-use efficiency and competitiveness against weeds.

Progress, exciting discoveries and preliminary results
Evaluations of the historical cultivars have unearthed interesting results (see poster for details). These results include historical cultivars that: 1) yield as well as or better than most modern varieties under low Nitrogen inputs, 2) contain excellent quality characteristics, 3) exhibit durable resistance to stripe rust, 4) exhibit the capacity to consistently suppress wild oats and prickly lettuce under field conditions and, 5) contain genes that confer superior emergence characteristics under adverse field conditions. While no single historical cultivar could out perform a modern variety in all desired characteristics, they provide invaluable sources of genetic diversity for organic growers. We have made hundreds of crosses of historical wheat varieties with modern varieties, generated thousands of unique lines, and evaluated these lines in the greenhouse, lab and field. While most of these lines are discarded due to inferior traits, the most promising are propagated and rigorously evaluated year after year on certified organic nurseries and the fields of our farmer cooperators, Joe and Sara DeLong in St. John, WA and Owen and Keith Jorgensen in St. Andrews, WA.

Where do we go from here?
We have initiated five new studies to aid in enhancing weed competitiveness and a new graduate student, Julie Dawson, has joined our program to focus on nutrient-use efficiency and farmer participation. We will continue the long-term process of developing wheat varieties for organic farmers and we welcome and encourage any farmers interested in our program to contact us for more information.
Weed pressure is one of the major obstacles to the expansion of organic farming (OF). The most effective way to control weeds in OF is tillage, a practice that depletes organic matter, exposes the soil to wind and water erosion, and is labor intensive. To increase organic crop production, natural weed control methods should be developed. The objective of this experiment was to find natural herbicides for the control of downy brome (Bromus tectorum), a major weed in winter wheat based cropping systems in the Pacific Northwest.

Forty seven plant species, meadowfoam seed meal, and pine oil were screened for allelopathy, the ability of plants to inhibit or enhance the germination or growth of other plants. Plants were grown in pots in a greenhouse, harvested at flowering, separated into leaves and roots, and dried and ground. Deionized water (100 ml) was added to 5 g of each sample and filtered after 2 hrs to obtain 5% extracts. Petri dishes were filled with 45 g of sand, and 10 downy brome seeds were placed on filter paper on top of the sand. The sand was wetted with 10 ml of extract and 3 filter papers, wetted with the same extract, were placed over the seeds. Petri dishes were incubated at 25ºC for 72 hrs. The experiment was replicated 4 times with a deionized water control. Shoot and root length were measured to determine allelopathic effects of the plants on downy brome. Extracts from selected plants were also evaluated on Stephens wheat seed.

Meadowfoam seed meal, yard-long bean leaves, Blue Spruce, Austrian pine needles, Austrian pine bark, and pine oil completely inhibited the germination of downy brome. Leaf extracts of radishes, grain amaranth, mustard, marigolds, brown flax, sugar pea, and pigeon pea, inhibited the germination of downy brome roots and shoots by 92 to 99%. Root extracts of Lab Rongai, radishes, sugar pea, tepary bean, grain sorghum, grain amaranth, and hairy vetch inhibited the germination of roots and shoots of downy brome by 82 to 99%. In contrast, root extracts of annual rye grass, safflower, robust barley, and white Dutch clover enhanced the germination of downy brome roots by 0.01, 4.5, 6.6, and 21.8% above the control. Of the selected extracts evaluated on wheat seed, meadowfoam inhibited wheat germination by 96%. The effect of radishes was variable and inhibited wheat germination by 45 to 81%.

These results clearly demonstrate that some plants are allelopathic to downy brome and wheat. Allelochemicals in these plants can be enhanced through breeding, stabilized and used as herbicides. Some plants may be used as companion crops to selectively interfere with the growth of certain weeds, while others may be used to induce germination of weeds at a time when they won’t survive. Allelopathic plants can be used as cover crops and their residues can be incorporated or applied as mulch to control weeds. More work, however, is necessary to determine the allelochemicals involved and to determine the efficacy of these extracts under field conditions. Allelopathy in meadowfoam, radishes, and mustard is attributed to a group of biomolecules called glucosinolates. Allelochemicals may be used to formulate natural herbicides, which may lead to the expansion of organic farming and, furthermore, pave the way for the development of direct seed organic farming.
Orchard Floor Management and Soil Quality
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The objectives of this study were to determine the effect of orchard floor management practices on soil physical, chemical, and biological characteristics and to determine the effect changes in soil quality has on fertilizer uptake. We placed an emphasis on understanding the changes in the soil biological community resulting from the use of soil amendments.

Physical soil quality attributes that we measured included: infiltration rate, bulk density, chemical, nutrients, organic matter content, pH, buffering ability and cation exchange capacity. Biological soil quality attributes that we measured included: microbial activity, that is mineralization and turnover, population size, community structure (soil food web).

Methods for this study included 2 orchard sites – MCAREC, Hood River, OR (3-yr ‘Red Delicious’) & Corvallis (7-yr ‘Fuji’). Main plot treatments were herbicide (Round Up) or cultivation, and sub plot treatments were vetch/barley cover crop mow and blow (18:1 C:N), compost (22:1), bark mulch (275:1); and none. Fertilizer use efficiency was also measured through ¹⁵N. ¹⁵N labeled fertilizer was applied to 1 tree in each plot, once a year from 2001 – 2003. Trees were destructively harvested in 2003 for analysis of fertilizer uptake and distribution within trees.

The dependent variables that we measured in this study were soil physical variables including bulk density, measured 2003; and infiltration rate, measured 2003. Soil chemical variables that were measured included nutrients – N, P, K, B, Ca, Na, Mg – measured 2001-2003; percent organic matter, measured 2001-2003; pH, measured 2001-2003; and cation exchange capacity, measured 2001-2003. Soil biological variables that we measured included fungal & bacterial biomass, measured 2001; soil respiration (activity), measured 2003; and nematodes (community structure), measured 2002, 2003. Horticultural variables that we measured included yield, measured 2001-2003; fruit quality, measured 2001-2003; TCSA, measured 2001-2003; and in 2003 me measured ¹⁵N analysis, dry weight, %N, %¹⁵N of tree components, N derived from fertilizer, and fertilizer uptake efficiency.

Based on our results, the conclusions that we can draw from this experiment are:
- Compost amended soils generally had the best physical and chemical characteristics. The microbial activity, as indicated by soil respiration, was highest in compost amended soils early in the season. Later in the season bark and compost amended soils generally had higher respiration rates.
- All of the soil communities fall in the same quadrat of the faunal profile plot, but compost has the least structured community while the mow and blow was the most enriched.
- Trees grown in compost and bark amended soils are less dependent on N from fertilizer applications.
Alternatives to Plastic Mulch for Weed Control in Organic Vegetable Production
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Weed control is a primary concern in organic farming and mulching with black plastic has become a standard practice. However, plastic mulch has become an environmental management concern due to disposal issues. The purpose of this study was to identify degradable mulch products that can be used as effective and affordable alternatives to plastic mulch.

We tested five alternative mulches in an organic vegetable production system and evaluated their durability and effect soil temperature and crop yield. Mulch treatments in this study were: 1) 81-lb Kraft brown paper; 2) 42-lb Kraft brown paper with polyethylene coating; 3) Garden bio-film, a biodegradable black film produced from cornstarch, degradation begins at 50-60 days; 4) Envirotec 1, XP-4611W, a thermal/photo degradable black film composed of low-density polyethylene, degradation begins at 75 days, degrades to CO₂ and H₂O; 5) Envirotec 2, XP-4611J, the same as Envirotec 1, but degradation begins at 140 days; 6) black plastic, 1.0 mil embossed poly film (control). Our field site was certified organic and managed accordingly. The experimental design was a randomized complete block with four replications. Main plots were 3 feet wide by 50 long, and included four subplots: lettuce (short season cool), broccoli (long season cool), bell peppers (short season warm), and icebox watermelon (long season warm). Plots were irrigated with drip tape laid beneath the mulch.

Crop yields were not significantly effected by mulch type, however, Envirotec 1 tended to produce the highest lettuce yield and head size, followed by black plastic. Broccoli yields tended to be much larger in plots treated with black plastic than any of the others. Peppers grown with Garden Bio-film produced the largest yields and average pepper size, and Envirotec 1 tended to produce the largest average number of peppers per plot. Watermelon yields tended to be the largest in plots treated with Envirotec 1, followed by Black Plastic. The mulch products showed significant differences in quality over time (durability). Black plastic was the most durable, and the Envirotec mulches were similar but declined slightly at the end of the season. Both Kraft paper mulches exhibited fair quality, but were significantly less durable than black plastic and Envirotec mulches. Garden Bio-Film exhibited the poorest durability. Temperature highs and lows under the black plastic mulch were less extreme than above the mulch. This insulating effect occurred similarly under all of the mulches except for the Kraft 81-lb paper, which showed greater extremes of high and low temperatures. Approximate costs per acre were calculated for 80% mulch cover. Black plastic costs $252 - $281 per acre, and may differ depending on the source. Envirotec films are similar in price to black plastic, ranging $215 to $243 per acre, and the coated Kraft 42-lb paper is also similar in cost, approximately $235 per acre. The cost of Garden Bio-Film is higher, ranging from $695 to $1087, and the Kraft 81-lb paper costs vary depending on the supplier.

This study will continue in 2005. Preliminary results indicate that the Envirotec films are effective and affordable degradable alternatives to plastic mulch. They were comparable to black plastic in durability, crop yield, soil temperature, and affordability.
Icebox Watermelon Variety Trial
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Icebox watermelons were recently introduced to the U.S. marketplace and several new varieties have very recently been developed and released. Icebox watermelons generally weigh between 8 and 12 pounds, and come in a variety of shapes and colors. They are rapidly gaining in popularity, as their smaller size is ideal for small families and for storage in home refrigerators. With a rise in interest in local production and direct marketing, farmers in Washington are looking to diversify crop varieties to meet these demands. Icebox watermelons offer a means of producing high quality watermelons locally. The purpose of this study was to determine which varieties of icebox watermelon are most suitable for organic production in our region.

Forty-four varieties of icebox watermelon were grown at Washington State University Vancouver Research and Extension Unit. The greenhouse and field were managed organically, but some chemically treated seeds were used when seeds of those varieties were not otherwise available. The plants grown from treated seeds were separated from the plants grown from untreated seed by a 30 foot buffer in the field. The study design was a randomized complete block with three replications. Plots were single rows, 20 feet long, with 7 plants per plot. Spacing was three feet between plants in the rows, and 10 feet between rows. Varieties were seeded in the greenhouse on April 12, 2004, and transplanted into the field on May 26. Plants were irrigated by drip tape, for 4-hour intervals twice weekly. Watermelons were harvested twice weekly from August to September, and were measured for weight, length and width, and number per plot. After each harvest, the sugar content of one melon per plot was measured using a Brix meter. Brix is a measure of the percentage of soluble solids, and is an estimate of sugar content in watermelon. General eating quality was evaluated five times throughout the course of the study.

Preliminary results of this study show significant differences in total yield, number of melons per plot, average melon weight, Brix readings, and number of days to harvest among the varieties grown from untreated seed. Navajo Sweet, Winter King & Queen, Early Crimson Treat, Tiger Baby, and Orchid Sweet produced high yields and Brix readings, and they matured early. Petite Perfection, Smile, and Ultra Cool also produced high Brix readings. In this study, Cathay Belle and Genesis were the least productive. Most varieties were ready for harvest by mid-august, but Gold Baby, New Queen, Southern Light, and Ultra Cool were not ready until September. Among the varieties grown from treated seed, Baby Doll, Bobbie, and Imagination produced the highest yield, however, these differences were not significant. Extazy, Fenway, Gypsy, and Mini Seedless produced the highest Brix readings. Gypsy and Imagination were the earliest to mature, and Desert King, Baby Doll, Extazy, and Valdoria were the latest. Lycosweet, Thai Black, and Desert King were the least productive. In this study, most varieties had 8 to 10 percent soluble sugars when ripe. Brix is commonly used to evaluate fruit ripeness and flavor, but determining ripeness of multiple varieties proved difficult because each variety had a different range of percent soluble sugars when ripe.

Preliminary results of this study indicate that over 40 varieties of icebox watermelon are productive in our region.
The Northwest Biocontrol Insectary/Quarantine (NWBIQ) screened several introduced species of aphid parasitoids in quarantine in the 1990’s for use against Russian Wheat Aphid (RWA). During the quarantine screening it was discovered that several species and strains of species had a strong affinity to attacking *Myzus persicae*, the green peach aphid (GPA).

Objectives of the study were to determine the aphid host range of these parasitoids and to determine the spectrum of suitable host plants that could be grown for their propagation near potato fields. The host aphids being used in the field had to be non-pestiferous to potatoes, allow host switching to GPA and be cultured easily. The other objective was to determine movement of parasitoids from natural enemy banks and their area of impact within the field.

Host ranges of parasitoids were determined with no-choice tests of candidate aphids. The parasitoids *Aphidius colemani*, *Aphidius matricarae* and *Aphelinus asychis* were the parasitoids used in the study. Over 25 aphid species were screened as suitable hosts. Mated 5 day old females of each parasitoid species were reared from *Diuraphis noxia* (RWA) for the no-choice test on other aphid species. They were exposed for a 24 hour time interval with subject aphids in 50mm petri dishes. Aphids were dissected 5 days later to determine parasitism. Host switching to GPA was done in a similar manner but using different species of test host aphid.

Area of impact and within field movement was determined by using within field releases of parasitoids from natural enemy banks. Banks were meter³ cages covered in 100-mesh fabric. A mixture of wheat, oats, and barley were planted into the cages at time of potato emergence in the field. Ten cages were established at two fields of organic potato in Washington. The aphids *D. noxia*, *R. padi*, and *S. avenae* were reared and weighed into 2 gram portions for inoculation into cages along with 100 mated females of the three test parasitoids. Three sentinel potato plants with 0.5 grams unparasitized GPA were placed at 5, 15 and 30 meters from the cages along the four perpendicular axes. Sentinels were placed bi-weekly from mid June to mid August for a 48 hour exposure in the field. Sentinels were brought back to the lab for rearing to determine parasitism.

The complex of grain aphids and grains such as wheat, barley and oats proved to be the best hosts for switching to GPA in potato fields. All grain aphids tested are specific to grains and do not attack potato. The grain aphids all proved to be suitable hosts that allowed switching to GPA. All parasitoids were recovered from sentinels up to 30 meters from the release point. Percent parasitism peaked at the end of July at all distances. Peak parasitism was 22% at 30 meters, 37% at 15 meters and 54% at 5 meters. The two *Aphidius* species were better at dispersal and their population levels peaked earlier.

Effective use of natural enemy banks can provide a source of GPA parasitoids all through the growing season in potato. A spacing of 60 meters between banks is a reasonable starting point for field implementation. Further studies are needed in this area.
Integrated Management Strategies for the Control of Carrot Rust Fly (*Psila rosae* Fabricius)

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Washington State is the number one producer of processing carrots in the U.S. and 4\(^{th}\) in the U.S. for fresh market carrots. As of 2000, ca. 2\% of the carrots grown in Washington were grown organically. The Carrot Rust Fly (CRF) is a major pest of carrots in Washington State, causing significant economic losses. The adult emerges in early spring, eggs are laid at the base of the carrot and the newly hatched larvae burrows into the soil and feeds on side roots of the host plant during the first two instars. During the third instar, larvae feed on the taproot causing economic damage. This cycle is repeated three times during each season. To avoid CRF damage, organic producer’s options are crop rotation at least every other year, covering the crop with row covers or delayed planting and early harvesting to avoid CRF populations. All the above options are effective, but have major drawbacks for the producer. The statewide Washington State University (WSU) Small Farms Program is developing an integrated approach that will help all farmers (organic and conventional) employ alternative practices to manage CRF populations that are economically competitive and environmentally superior to present recommended practices. Conventional carrot growers generally rely on the highly toxic organophosphate Diazinon as the only insecticide currently registered for use against the CRF and so they will especially benefit from new alternative control strategies.

We will report on our on going efforts to monitor CRF throughout the western Washington carrot growing region, and the use of cultural and mechanical control practices of cover crops, row covers and crop rotation. We will also report on our efforts to integrate those practices with the introduction of low toxicity suppression practices using strategic application of the insect pathogens *Beauveria bassiana* (Mycotrol-O\(^{TM}\)) and two species of entomopathogenic nematodes individually and in combination.

Throughout the carrot growing season, few CRF were captured by the yellow sticky traps, and this corresponded with minimal damage to harvested carrots. Our data suggests that neither underseeding of cover crops or row covers had a negative impact on marketable carrot yields. We will also present data on the effectiveness of *Beauveria* and two *Steinernema* species alone and in combination against the larval stage of the carrot rust fly.

Previous studies have demonstrated that cover crops can reduce CRF damage. Due to the very low population pressure of CRF this year we were unable to verify this, but we were able to demonstrate that both row covers and underseeding of cover crops does not negatively impact carrot yield, making cover crops a potentially effective tool for integration into any overall pest management strategy. When timed properly, entomopathogenic nematodes appear to be somewhat effective against CRF. *Beauveria* appears less effective but at higher concentration shows some effectiveness. Further research is needed to verify these conclusions.
Effect of Cover Crop on Apple Leafroller Populations, Leafroller Parasitism and Selected Arthropods in an Orchard Managed Without Insecticides.
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In Washington State the Pandemis leafroller, \textit{Pandemis pyrusana} (Kerefoll), and obliquebanded leafroller, \textit{Choristoneura rosaceana} (Harris), are serious pests in organic and conventional apple orchards in which mating disruption is used to control codling moth, \textit{Cydia pomonella}. Leafroller management with \textit{Bacillus thuringiensis} (Bt) is often uncertain or more marginal than desired for a variety of reasons. There is a need for effective, ecologically-based biological control of leafroller using tactics such as parasitoid and predator conservation and augmentation via habitat manipulation, and insecticide reduction.

The objectives of these studies were to: 1) evaluate and compare development of leafroller populations and their biological control by parasitoids in an apple orchard with either a grass or alfalfa cover in which no insecticides were used; 2) evaluate the influence of cover crops on the general orchard arthropod population in an orchard managed without insecticides; and 3) evaluate the use of alfalfa as an orchard cover crop on fruit tree growth and development. Experiments were conducted in a mature, bearing Fuji apple orchard in East Wenatchee, over four years. Plots were approximately 0.5 ha in size and were sown to either grass cover or alfalfa. Insecticide applications were eliminated. Various species-appropriate monitoring techniques were used.

Leafroller populations initially rose to high levels and then dramatically declined. A granulovirus may have been primarily responsible for this decline. Leafroller parasitoids also contributed to leafroller biological control though not extensively. There were no differences in leafroller populations between ground cover treatments. In some instances parasitism was significantly greater in alfalfa cover plots but this did not seem of practical significance. Six species were identified in the parasitoid complex. No secondary arthropod pest ever achieved pest status in either ground cover during the study. Codling moth however became a serious problem in year four. Though not a formal part of this study, subsequent codling moth management with a combination of mating disruption and codling moth granulovirus treatment has provided adequate control. Alfalfa as a cover crop imposed no adverse effects on tree growth and development during the duration of these studies.
Evolutionary Participatory Plant Breeding
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Modern landraces – Farmers can develop their own unique varieties
Genetically uniform varieties developed by standard breeding methods dominate commercial production in many self-pollinated crops due in large part to their high yields and wide geographic adaptability. These varieties perform optimally when they are grown in favorable environments and under high-input agronomic systems. However, they typically do not perform well in marginal environments or without the external inputs with which they were selected. Organic farmers rely on varieties bred and selected under conventional methods that often include the use of synthetic pesticides and fertilizers, options not available under organic certification standards. In addition, these crops are often selected in environments that may or may not represent the local environment of the farmer. Our goal is to apply an efficient, economical, wide-reaching breeding program that incorporates farmer knowledge and agroecosystem variability, and provides organic farmers with the means to develop their own unique varieties.

What breeding method is most appropriate for organic grain farmers?
In organic and low-input agriculture, where synthetic pesticides and fertilizers are not applied due to regulatory or socio-economic reasons, genetic variation is the primary mechanism for buffering environmental fluctuations and maintaining important traits such as yield stability, resistance to pathogens and weeds, and adaptation to low soil fertility. An Evolutionary-Participatory Breeding (EPB) method emphasizes the utilization of natural selection in combination with site-specific farmer selection in early generations of a crop population.

EPB is a combination of two specific breeding methods, Evolutionary Breeding and Participatory Plant Breeding. Evolutionary Breeding has been shown to increase yield, disease resistance, genetic diversity and adaptability of a crop population over time. It is based on a mass selection technique used by farmers for over 10,000 years of crop improvement. Participatory plant breeding (PPB) was developed over the past 20 years to meet the needs of low-input, small-scale farmers in marginal environments often overlooked by conventional crop breeders. PPB emphasizes collaboration between breeders and farmers to share knowledge and skills to identify and improve suitable cultivars previously unavailable to low-input farmers.

Our vision for organic plant breeding
We believe that farmers are uniquely suited in developing high-yielding, well-adapted varieties on their own farm for their own particular system. The end-use of the grain varieties could range from high protein chicken feed to premium straw mulch to artisan quality bread wheat. There is no minimum farm size for growing and developing cereal grains. We encourage farmers to begin to reincorporate basic yet powerful plant breeding techniques back into their farming system.
Sustainable Organic Agroecosystems: Exploring Low Disturbance Dryland Cropping Systems on the Palouse
Stacey M. Nievweija¹, Dave R. Huggins¹, and John P. Reganold². ¹USDA-ARS Pullman, WA, (509)-335-6818, onegaia@hotmail.com; ²Department of Crop and Soil Sciences, Washington State University, Pullman, WA

In the dryland cropping region of the Pacific Northwest (PNW), tillage-intensive, agrichemically-based agricultural systems have led to severe soil erosion, depleted soil organic matter, and agroecosystems with limited diversity along with questionable sustainability. Organic production systems offer an alternative farming approach; however, few strategies have been explored and no known dryland organic agroecosystems have been designed to meet sustainability criteria. Low soil disturbance management strategies integrated with diverse cover crop and rotation options, and soil quality enhancement practices are considered vital to ecologically-sound organic production in this region.

Our overall objective is to design and test sustainable organic farming systems suitable for the dryland cropping region of the PNW. In 2001, a low soil disturbance organic cropping system was established under the Agroecosystem Research Trials at the USDA-ARS Palouse Conservation Field Station near Pullman, WA. Replicated, field-scale, organic trials consist of cover crops, forage legumes, and spring cash crops established using direct-seed techniques.

Key practices are: no-tillage and broadcast methods for crop establishment; mechanical mowing and undercutting sweeps for weed and cover crop management; avoidance of summer fallow and winter cash crops; establishment of winter cover crops for erosion protection, mulching, and soil benefits; and strategic use of crop rotation to meet agronomic objectives. We present the strengths and weaknesses of our experiences to date, lessons learned, and future research directions.
Farmers’ Market Enhancement

Farmers’ markets are gaining recognition for their significant contribution to farm profitability and community development. Researchers developed strikingly innovative research and training methods that have documented the economic benefits of markets to farmers and business districts, trained managers to conduct their own market research, and strengthened statewide market organizations and sales. More than 160 farmers’ markets in the Pacific Northwest: 1) have gross sales exceeding $50 million, 2) have sustained annual sales increases of 15% in Oregon and 20% in Washington, 3) attract more than 250,000 customers each summer week, and 4) provide primary or supplemental incomes to more than 4,000 producers.

The Rapid Market Assessment technique pioneered by the IFAFS project has enhanced vendor sales and community economic benefits through improvements in market management. Through 20 participatory assessments and 13 manager and board training sessions, this project has trained 200+ people with the following results:

- Quantified consumer willingness to pay for local agricultural products.
- Demonstrated financial impact of customers’ purchases at downtown retailers.
- Learned customer preferences, leading to diversified vendors and higher sales.
- Caused markets to shift from traditional advertising to word-of-mouth and email.
- Markets are now researching their customer base, site, operations and budgets.
- One association has conducted 31 similar studies on its own in three years.

Profitability of Direct Marketing Strategies

The project team has conducted 12 in-depth case studies of farms that use direct marketing strategies. Through interviews and analysis of farm management records, the team is evaluating the profitability and sustainability of marketing strategies such as farmers’ markets, on-farm sales, direct-to-retail and Community Supported Agriculture.

- Direct market farms retain a higher share of gross sales than their conventional counterparts. One small-acreage farmer direct markets 100 percent of his produce to urban markets three hours away, netting 30 percent or $54,000.
- In one urban county, direct sales of products such as broccoli, lettuce, and apples were resulting in prices two to four times higher than wholesale rates.
- One Idaho blueberry grower’s wholesale berry profit is $0.66 per pound but his profit averages $1.16/lb. at farmers’ markets and $1.21/lb. at his farm stand.
- Around 20 percent of Washington farms direct market some of their products.

Removing Barriers to Direct-Marketing Meat

Market research indicates tremendous consumer demand for locally raised meat products; however, most producers have been unable to access these markets. Forums have brought together producers and government regulators to address:

- County health codes prohibiting meat products at farmers’ markets and on-farm.
- State regulations governing on-farm poultry processing.
- Federal regulations restricting co-packing by state certified poultry processors.

Such discussions have resulted in changes to county health codes to permit meat sales at the major urban markets in Washington and new state legislation facilitating on-farm poultry processing on farms with 1,000 birds or less.
The Soil Science Society of America (SSSA) is working with the Smithsonian Institution to plan an interactive soils exhibit as part of their Global Links Gallery at the National Museum of Natural History. The museum, located in Washington, DC, charges no admission fee to view their exhibits.

The exhibit will include a display of state soil monoliths and an educational, interactive section to help the museum's 6–9 million visitors understand how soil is intricately linked to the health of humanity, the environment and the planet. Related publications and web activities will reach millions of additional people.

In Washington State, the effort toward developing this exhibit is headed by the WA Smithsonian Soils Development Committee, which is collecting educational materials for the exhibit as well as organizing fund-raising to support sponsorship of the WA State Soil Monolith in the exhibit. Committee members come from the Washington Society of Professional Soil Scientists (WSPSS), NRCS, WSU and other organizations. For more information or to become involved in the WA State effort, see the web site at: http://css.wsu.edu/smithsonian.htm

Never before have we had such an opportunity to advance the understanding of soil. This work will move forward our journey to sustain Earth and its people by educating visitors to the Smithsonian on the importance of soil and earth sciences.

For more information, check out the national Smithsonian Soils Exhibit website at: http://www.soils.org/smithsonian/
We have developed a university-level course to teach academic students and community members about food and farming systems from a systems perspective, and under the banner of understanding and learning about sustainability. The approach we use brings students and faculty together as co-learners in a week long immersion experience where students and faculty travel, work, observe, discuss, interview, live, and learn together. We visit several different aspects of, and approaches to, sustainable food systems (SFS) – including organic, conventional, and others – in order to give us all exposure to a large number of different components of our food systems.

This course is geared for the upper-level undergraduate or graduate student, and is also open to community members for continuing education units (CEUs). It is offered at both Washington State University (WSU) and University of Idaho (UI), through the departments of Crop and Soil Sciences, and Agricultural & Extension Education, respectively. The course includes both experiential and community learning activities, which are both recognized as being important for student learning. Using these together, we have developed an educational experience where students (and their instructors!) study sustainability and food systems in all their complexity!

During this intense week of data collection, analysis and interpretation, students have extensive opportunities to learn with and from each other, and from the sites and people visited. Students approach SFS analysis through a cooperative small group process, with faculty participating as co-learners. Students are responsible for designing their modes of inquiry and observation for the various sites, plus preparing oral and written analyses. The students are charged with developing a protocol or framework for understanding sustainability with respect to the various sites. This can be stressful at times, since there is no ‘right answer.’ Part of the exhilaration within this course is that students create and refine criteria during the course, sometimes finding that their own ideas are being challenged, and always finding the systems connections.

The course was originally developed and taught collaboratively by faculty at Iowa State University and Dordt College (IA), the University of Minnesota, and the University of Nebraska using a week-long immersion experience visiting a variety of farms and natural settings (Agroecosystems Analysis). It has been offered now 5 times in the region surrounding the intersection of these three states.

At WSU and UI, we have teamed up to extend this same teaching approach to our university students, as well as community members in WA and ID. We have also extended our scope to beyond the “farm gate” - such that we now include marketing, processing and transportation facilities and teach it under the title of Field Analysis of Sustainable Food Systems. The next offering of the course will be in Summer 2005.

If you would like to learn more about the course, check out the course web site at: http://classes.css.wsu.edu/soils445/, or contact Cathy Perillo (cperillo@wsu.edu), Cinda Williams (cindaw@uidaho.edu), or Theresa Beaver (tbeaver@uidaho.edu).
Both the University of Idaho and Washington State University have strong histories of research in sustainable and organic agriculture, with current activities recently compiled (Miles et al., 2002). However, there has not been a systematic review of the classroom teaching activities at these two universities. In this presentation we attempt to highlight the current course offerings at the two universities – partly to better let people know of their existence, and partly to provide a discussion point for faculty teaching in this area that will lead to continued and additional future collaborations. A number of the courses are fairly new. A number also fulfill General Education Requirements (GERs), which means they bring in students who otherwise might never take courses in agriculture of any kind.

Classes dedicated specifically to sustainable and organic agriculture. All of the following classes are taught at the main campuses in Moscow/Pullman, with additional offerings at other locations and/or through distance education.

- Organic Gardening and Farming (Soils 101, WSU only)
- Science, Society and Sustainable Food Systems (Soils 150, Ag 150)
  - fulfills [Q] GER (“science for non-science majors”)
- Agriculture, Environment, and Community (CRS 336)
  - fulfills [S] GER (social sciences)
- Sustainable Agriculture (Soils 345 at both schools)
- World Agricultural Systems (Crops/Soils 360, Ag 360) *
  - fulfills [I] GER (intercultural studies)
- Sustainable Small Acreage Farming and Ranching (Soils 404 / Ag 416) **
- Agricultural Entrepreneurship – Tilling the Soil of Opportunity (Soils/CRS 403 / Ag 417) **
- Field Analysis of Sustainable Food Systems (Soils 445/545, Ag 445)*
  - Week-long immersion experience, with follow-up work online
- Practicum in Organic Agriculture (Soils 480)
  - Intensive hands-on course offered in Summer
- Special Topics classes (e.g., Issues in Organic Agriculture, Spring 2004).

* Also offered through WSU’s Distance Degree Programs (DDP)
** Also offered at several additional sites in WA and ID, typically through Extension offices. For more information and locations see: [http://www.cultivatingsuccess.org/](http://www.cultivatingsuccess.org/)

An important strength of sustainable and organic agriculture educational opportunities at these two land grant institutions is the depth and breadth of supporting coursework that allow students to develop an understanding of the scientific principles involved in sustainable and organic operations. For example there are numerous classes that are relevant to the subject and/or include specific sections on organic or sustainable agriculture, including classes in Crop and Soil Sciences, Horticulture, Entomology, IPM, Agricultural and Resource Economics, Community and Rural Sociology, etc.

Both universities have recently established Certified Organic Teaching Farms on the main campuses (Pullman, WA and Moscow, ID), with additional certified organic land available to support teaching activities at other university facilities, including the Puyallup and Mt. Vernon Research and Education Centers. Graduate programs in numerous departments have long been important in WSU and UI’s sustainable/organic agriculture teaching and research mission – and increasingly continue to be so. For more information: [http://csanr.wsu.edu/EducationOpps/index.htm](http://csanr.wsu.edu/EducationOpps/index.htm)
Beneficial insects and spiders can play an important role in pest suppression. For organic producers, natural enemies may be the only control option for some pests. It is important to understand how we can conserve these natural enemies in order to maximize their efficacy as biocontrol agents. Field margins are a source of beneficial arthropods to re-colonize fields in the spring, and so margins play an important role in predator conservation.

For two years we have surveyed ground-dwelling insects and spiders in both organic and conventional fields. In 2001 our objective was to compare predator densities in fields that had grassy versus bare margins. In 2002 our additional objective was to determine if higher predator densities in the field margins led to higher densities of beneficials in the fields they surrounded. Also, we examined whether organic and conventionally managed fields both benefited equally from having grassy margins.

We used pitfall traps to collect ground-dwelling predators. Traps consisted of a cup buried in the ground such that the opening was level with the ground – the cups were filled with soapy water, and so insects and spiders that fell in were trapped and killed. In 2001, traps were run weekly from late May until late August, and were placed along field margins in a 30 m transect with 3 traps per transect. In 2002, traps were run every three weeks from early April until late July. In each field, three traps were placed in two transects, 10 m apart, each running 20 m from the margin into the field. In both years all arthropods were collected, sorted, preserved and identified.

Overall, the most common ground-dwelling predators were spiders and predatory beetles. In our first year, when we measured predator activity in the margins themselves, we found that arthropod activity was initially higher in field margins that had grassy cover. In the second year we measured predator densities in fields surrounded by margins of varying quality. We found that spiders and predatory beetles re-colonized organic fields with grassy margins more quickly and reached higher densities than in organic fields with bare margins. However, grassy margins did not increase predator densities in conventional fields. These results support the findings of other researchers who have shown that field margins can be an important refuge for natural enemies in agricultural fields, provided that in-field activities, such as the application of pesticides, do not disrupt re-colonization.

We have found that organic fields with higher quality margins have higher densities of beneficial arthropods. However, grassy margins do not lead to higher predator densities in conventional fields, where broad-spectrum pesticides are applied. We are currently conducting experiments to address our next question: is pest control better in fields with grassy margins? That is, do good margins conserve enough predators to significantly improvement bicontrol?
Investing in Natural Enemy Diversity: Beetle Banks
Renée Priya Prasad and Bill Snyder. Dept of Entomology, Washington State University, Pullman WA, 99164

An important component of agricultural sustainability is conservation of endemic natural enemies. Beetle banks provide ground dwelling beetles and spiders with overwintering refuges. Natural enemies are thought to rotate from the field to the beetle bank at the end of the growing season and back into the field in the spring. In order to be effective for the control of insect pests, natural enemies must move out of the beetle bank and into the field as pests move into the field.

There are three criteria by which all conservation biological control tactics, including beetle banks, need to be evaluated:

- **Enhancement** of natural enemy populations;
- **Efficacy** of conserved enemies in controlling pest populations;
- Determining the underlying **mechanisms** that result in success or failure. In this study we examined enhancement. We specifically asked two questions: 1) Are natural enemy densities higher in beetle banks during the winter? And 2) Are populations of enemies higher adjacent to beetle banks during the growing season?

We focused on ground and rove beetles for this study. We monitored densities of beetles in winter using soil samples and in the spring using pitfall traps. We compared beetle densities in organic fields with beetle banks and organic fields without beetle banks. Pitfall trap data were collected in May, June and July, 2003. Traps were located within 10 m of beetle banks or 20 m from field margins (in fields with no beetle banks). Insects were collected from pitfall traps, stored in alcohol and sorted to nearest taxa – family, genus or species.

Are natural enemy densities higher in beetle banks during the winter? There were significantly more beetles collected in soil samples taken from beetle banks than from adjacent areas of the same field or from randomly located areas of fields without beetle banks.

Are populations of enemies higher adjacent to beetle banks during the growing season? We divided our predator beetle community into two groups: small beetles (less than 1.5 cm in length) and the largest beetle *Pterostichus melanarius*. We found that activity-densities of small beetles were significantly higher in fields with beetle banks at the beginning of the season, but then declined to levels similar in non-beetle bank fields. In contrast there was no statistical difference in *Pterostichus melanarius* activity-densities in fields with and without beetle banks. Another interesting result was that the ratio of small beetles to *P. melanarius* went from 100:0 in May to 50:50 by July. This result was not observed in fields without beetle banks and is intriguing because in previous studies we have shown that *P. melanarius* can eat the smaller predator beetles and negatively impact the biological control of some pests, e.g. root maggots.

We found that predatory beetles used beetle banks in the winter and that spring populations of the smaller predators was higher adjacent to beetle banks than in fields without beetle banks. We also found that the largest beetle in our community of predator beetles responded to beetle banks in a different way than the smaller beetles. We are currently investigating the implications of this difference for biological control.
Controlling the Oriental Fruit Moth, *Grapholita molesta*, Using Entomopathogenic Nematodes

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The oriental fruit moth (OFM) is a serious pest of stone fruits. Although it is the most important insect pest of peaches, it also attacks apple, quince and pear. In Washington State, OFM has three generations per year and it overwinters as a diapausing larva in small cocoons beneath tree bark, on twigs, or on the soil. Early in the season, the larvae bore into the tips of tender twigs causing them to wilt and die back due to feeding damage. Later on in the season, the larvae bore into the fruit causing serious damage. Entomopathogenic nematodes (EPN) vector pathogenic bacteria which kill the insect host within 24-48 h, showing considerable potential in biological control of insect pests, particularly in soil environments and cryptic habitats i.e. trees. Steinernematid and Heterorhabditid nematode families have a broad host range, are safe to the environment, are easy to apply, and are compatible with most agricultural chemicals.

The objective of this study was to evaluate the susceptibility of OFM larvae to four species of entomopathogenic nematodes under laboratory conditions. The methods included:

1. All experiments were conducted in 9 cm Petri dishes lined with moist filter paper and containing 20 larvae of OFM inside cardboard strips.
2. EPN species tested: *Steinernema carpocapsae*, *S. feltiae*, *S. riobrave*, and *Heterorhabditis marelatus*.
3. Concentrations of EPN: 5, 10 and 20 infective juveniles (IJs) /cm\(^2\) of cardboard strips applied in 1 ml of water.
4. Five replications per EPN species and 10 untreated controls were used. Two trials were performed.
5. Incubation time of EPN + OFM: 5 days at 25\(^\circ\)C.
6. OFM mortality was recorded by dissecting all larvae.

**Results and Discussion.** OFM larvae are susceptible to all four EPN species tested at all concentrations. Significantly more OFM died, 84%, due to *S. feltiae*; 65% due to *S. carpocapsae*; 73% due to *S. riobrave*; and 71% due to *H. marelatus* in comparison to 4% mortality of the untreated controls. These results suggest that *S. riobrave* and *S. feltiae* show good potential as biocontrol agents of OFM. Further work is in process to determinate LC\(_{50}\) and LC\(_{90}\). In addition, greenhouse studies will be performed with *S. riobrave* and *S. feltiae* against OFM.

These results suggest that *S. riobrave* and *S. feltiae* show good potential as biocontrol agents of OFM.
Farm-to-School Project
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Introduction. Lopez Island is a small island community of 3,000 people, located in the Puget Sound, a 50-minute ferry ride from the mainland. Essentially all the food and fiber that is consumed on the island is imported via the Washington State ferry system. The primary goal of our project is to train island residents to become more self-sufficient in regards to food production and consumption patterns. We aim to accomplish this by designing and teaching a 4-month elective high school agricultural science class, Principles of Ecological Food Production. We are also collaborating with the school chef to select and prepare vegetables with the class and to serve these vegetables in the school cafeteria. The class will be taught at S&S Center for Sustaining Agriculture and Homestead Farm, which is located approximately 1/2 mile from the school.

Objectives. (1) Teach students how to produce nutritious vegetables year round using low-cost production techniques that are environmentally friendly. (2) Develop school menus with the school chef to utilize island-produced food year-round, teach the students how to prepare such foods, and to generally improve the nutritional quality of the school lunch program. (3) Give high school students an opportunity to learn in a hands-on fashion agricultural science for credit.

Curriculum. Students will have the option of taking the class pass-fail or for A-level credit. Students who opt for pass-fail will earn credits through hands-on work such as hoop-house construction, vegetable planting, maintenance and harvesting, and kitchen vegetable preparation. Students who take the class for A-level credit will work on a research project on the farm or in the kitchen using the vegetables they produce. We have designed a curriculum that includes a field and a cafeteria component:

Agricultural Field Science Class in Ecological Food Production
- Students learn the importance of local, seasonal and sustainable food production and consumption.
- Students learn about the impact of their food choices on their own health, their community, and their environment.
- Students learn about agricultural science in higher education and as a career opportunity.

School Cafeteria Component
- Students prepare and serve vegetables in the school cafeteria.
- Students carry out surveys to evaluate consumers’ response to eating local and seasonal foods.

Community Outreach and Publication
- Students publish their work through school bulletin boards, posters, and articles in local press, WSU newsletters, websites and journals.
- Students incorporate experimental data in senior theses.
- Students may present their projects at the Washington Junior Science Symposium.

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Assessing Heirloom Dry Bean Varieties as a Niche-Market Crop
For Small-Scale Farmers

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Heirloom varieties are often selected for their taste as well as the glimpse into history that
they provide. A story connected with an heirloom variety may be passed down from generation
to generation, or a variety may have cultural significance from centuries past. Farmers can save
their own seed of heirloom varieties and the maintenance of genetic diversity may be one of the
most significant reasons to grow heirlooms. Gene pools will continue to decrease if old varieties
are not maintained. Though the reasons for growing heirlooms apply to numerous crops, this
project will focus on heirloom dry beans.

One objective of this research is to look at dry beans as a niche market crop. Dry beans
can be an excellent crop because they require relatively low inputs, need little in the way of
specialized equipment, and can be grown in a variety of cropping systems. With easy storing
abilities, dry beans can be a good addition for direct market farmers who need additional
crops at the beginning and end of the growing season. A survey conducted by Washington State
University in 2002 reported that thirty-seven small-scale farmers grew dry beans in Washington
for niche markets. There has been an ample amount of research pertaining to dry bean
production on a large-scale, but little information is available regarding small-scale niche market
production, and even less regarding heirloom varieties.

A second objective of this study is to investigate the genotypes of selected heirloom dry
beans. For thousands of years, farmers selected plants with promising qualities. Through the
discovery of hereditary “factors” by Gregor Mendel, plant selection became more technical and
opened many doors for farmers and breeders to improve crop qualities. While the pace of crop
development was increasing, crop improvement was advancing through only a few varieties for
each crop. The Green Revolution began with great promise to help feed the growing world
population through crops modified to increase yield. Eventually, however, the lack of genetic
diversity left crops vulnerable to insects and diseases, while farmers became dependent on sellers
for the “package deal” of seed, fertilizer, and pesticides.

New technology has allowed genes to be cut and transferred as never before. These
techniques have created endless possibilities for new varieties including disease resistant beans,
rice with high levels of vitamin A, herbicide resistant varieties, freeze resistant tomatoes, and
modified fruit ripening, to name just a few. Although heirlooms may not be ideal for all
situations, they may be valuable since they have undergone natural selection for centuries.

The purpose of this research project is to gain a better understanding of heirloom dry
bean varieties. Information such as emergence, stand, yield, and additional uses (such as green
beans) could be useful for small-scale farmers. Additionally, understanding genetic similarities
and differences among heirloom varieties will help us to maintain genetic diversity, will enable
plant breeders to provide small-scale farmers with new niche-market varieties, and can provide
consumers with an historical connection when they purchase these “old” varieties.