5th Organic Seed Growers Conference

Proceedings

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Hosted by:

Organic Seed Alliance
Washington State University
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Center for Sustaining Agriculture & Natural Resources

http://www.seedalliance.org

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Organic Seed Growers Conference

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Planning Committee:

Micaela Colley, OSA
Alex Stone, OSU
Matthew Dillon, OSA
Carol Miles, WSU
Zea Sonnabend, CCOF
Sarah Collyer, OSA
Joel Reiten, Seeds of Change

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Organic Seed Alliance

MISSION:

Organic Seed Alliance supports the ethical development and stewardship of the genetic resources of agricultural seed. We accomplish our goals through collaborative education, advisory services, and research programs with organic farmers and other seed professionals.

VISION:

Seed is both our common cultural heritage and a living natural resource fundamental to the future sustainability of food production. Proper stewardship of our genetic resources necessitates not only its conservation, but careful management in a manner which allows seed to continually evolve with challenges of the environment, cultural practices of sustainable agriculture and the need to feed people. Through advocacy, collaborative education, advisory services, and research we work to restore and develop seed varieties for current needs while safeguarding invaluable genetic resources for future generations.

PROGRAMS:

- **Education, Information, and Advocacy:** Educational opportunities, workshops, and publications aimed at increasing genetic conservation, and improving organic seed production, plant breeding for organic agriculture, and developing healthy seed systems.

- **Collaborative Research:** Research that develops healthy seed systems, improves organic seed production practices and develops new, appropriate germplasm for organic agriculture. Participatory Plant Breeding activities are a core component of our research program, bringing together breeding experts with organic farmers to result in new organic seed varieties adapted to local ecosystems/ecological bioregions and communities.

- **Advisory Services:** Direct technical assistance and consultations to organic farmers, seed producers, and other seedspeople resulting in an over-all increase in the quality, quantity, and diversity of organic seed.

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Agenda – Thursday, February 14

8:00 – 9:00 Registration and breakfast

9:00 – 9:15 *Welcome* – **Micaela Colley**, Organic Seed Alliance

9:15 – 9:35 *Moving Organic Seeds Forward* – **Matthew Dillon**, Organic Seed Alliance

9:35 – 10:15 *New Seeds for Farmers of the Future* – **Fred Kirschenmann**, Leopold Institute, Iowa State University

10:15 – 11:10 *Concepts and Values in Organic Breeding* –**Edith Lammerts van Bueren**, Louis Bolk Institute, Driebergen, The Netherlands

11:10 – 11:30 *National Plant Germplasm System: How it Works* – **Ann Marie Thro**, USDA – CSREES

11:30 – 11:45 Coffee Break and Room Change

11:45 – 12:30 Breakout Sessions

Track 1: Selecting, Growing, and Marketing Value-added Wheat Varieties in Organic Cropping Rotations – **Kevin Murphy**, Washington State University

Track 2: Introduction to Organic Seed – **Zea Sonnabend**, California Certified Organic Farmers

Track 3: Evaluation of Organic Seed Treatments for Control of Damping Off / Seed Blight Pathogens – **Jaime Cummings**, Washington State University

12:30 – 1:30 Lunch

1:30 – 2:30 Breakout Sessions

Track 1: Organic Grains and Cover Crops – **Jim Bronec**, Praying Mantis Farm, and **Nash Huber,** Nash's Organic Produce

Track 2: Organic Hybrid Variety Production – **Tom Stearns** and **Jodi Lew-Smith**, High Mowing Seeds

Track 3: Infection of Seed and Transmission of Seedborne Pathogens: Organic Seed Treatments – **Lindsey du Toit**, Washington State University

2:30 – 2:45 Break

2:45 – 3:45 Breakout Sessions

Track 1: Seed Harvesting for Sustainable Agriculture – **Carol Miles**, Washington State University, and **Lourdes Gaitan** and **Roger del Cid**, GORACE from Panama

Track 2: Organic Seed Market and Economics – **Steve Peters**, Seeds of Change, and **Dr. Brian Baker**, Organic Materials Review Institute

Track 3: Overview of Organic Management of Diseases in Seed Crops – **Ken Johnson** and **Alex Stone**, Oregon State University, and **Frank Morton**, Wild Garden Seed

3:45 – 4:00 Break

4:00 – 4:30 *Experiences in Organic and Vegetable Seed Production* – **Brian Andersen**, Brian Andersen Farm

4:30 – 5:00 *Integrating seed into a diversified organic farm* - **Nash Huber,** Nash's Organic Produce

5:00 – 7:00 Seed Suppliers Social

7:00 – 10:00 Dinner and Talent Show

Agenda – Friday, February 15

8:00 – 8:30 Registration and breakfast

8:30 – 9:45 *University-based Public Plant Breeding* – **Jim Myers**, Oregon State University, and **William F. Tracy**, University of Wisconsin, and **Stephen Jones**, Washington State University

9:45 – 11:15 *Isolation and Genetic Contamination Issues in Organic Seed Production* –**Jim Myers**, Oregon State University, and **Frank Morton**, Wild Garden Seeds, and **Will Rostov**, Center for Food Safety

11:15 – 11:30 Break

11:30 – 12:30 Breakout Sessions

Track 1: Examples of Current Breeding Research for Organic Farming Systems in the Netherlands – **Edith Lammerts van Bueren**, Louis Bolk Institute

Track 2: Organic Potato Seed Production – **Jim Gerritsen**, Wood Prairie Farm

12:30 - 1:30 Lunch

1:30 – 2:30 Breakout Sessions

Track 1: Nitrogen Management for Organic Vegetable Seed Production – **Joel Reiten**, Seeds of Change, and **Dan Sullivan** and **Nick Andrews**, Oregon State University

Track 2: Organic Potato Seed Quality and Seed Certification – **Jim Gerritsen**, Wood Prairie Farm, and **Jeff McMorran** and **Al Mosley**, Oregon State University

2:30 – 2:45 Break

2:45 – 3:45 Breakout Sessions

Track 1: Participatory Approaches to Breeding Crop Varieties for Genetic Resiliency – **John Navazio**, Organic Seed Alliance

Track 2: Vegetable Seed: Ask the Experts – **Frank Morton**, Wild Garden Seeds, and **Joel Reiten**, Seeds of Change, and **Don Tipping**, Seven Seeds Farm

3:45 – 4:00 Break

4:00 – 4:30 *Organic Seed Alliance: Past and Future* – **Dan Hobbs** and **Micaela Colley**, Organic Seed Alliance

4:30 – 5:00 *Seed People: A Journey into the Organic Seed Movement* – **Scott Vlaun**, Moose Pond Arts+Ecology

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Welcome to the 2008 Organic Seed Grower's Conference

Micaela Colley, Conference Coordinator, Organic Seed Alliance, P.O Box 772, Port Townsend, WA 98368 (503) 871-9730, micaela@seedalliance.org

Welcome to the 5th Biennial Organic Seed Growers Conference. Some of you were present at the first conference in Port Townsend, WA, 8 years ago. Some of you are new and just considering organic seed. On behalf of the conference committee I'd like to thank you, the participants, who make this event more than a series of talks, information dissemination, and business negotiations. The Organic Seed Growers Conference is an event where insights and inspirations are shared and new relationships formed. I'd also like to thank the Organic Seed Growers Conference Committee including Alex Stone, OSU, Carol Miles, WSU, Joel Reiten, Seeds of Change, Zea Sonnabend, Ecological Farming Association, Sarah Collyer, OSA, and Matthew Dillon, OSA. Each has invested valuable time and insights in planning, networking, developing conference sessions, and promoting this event.

The 2008 conference program reflects the current state of affairs in the world of organic seed. Today organic and conventional seed growers are working together to protect their vegetable seed crops from contamination by genetically modified crops. While the organic seed market is developing NOP regulations still include exemptions for unavailability. At the same time breeding for organic and low-input systems is gaining momentum and we will hear of recent developments by both US and European researchers. University-based plant breeders will share challenges and directions of public breeding programs focused on organics. While retaining a core focus on organic specialty seed crops, the scope of this year's agenda includes sessions on organic grains, cover crops, and potato seed production. This year's farmer's talks include two inspirational, but distinct farms, Abbondanza Farm, a 40 acre highly diversified seed and produce operation, and Brian Anderson Farm, a 400 acre farm that has successfully produced 100 acres of organic hybrid carrot seed. The committee has listened to grower's requests for practical, usable seed production advice and included several sessions on managing seed born disease, soil nutrition, and opportunities to "ask the experts" your seed production questions.

Organic Seed Alliance continues to co-evolve with the organic seed community. In 2008, Dan Hobbs, joined the staff as Executive Director. He will present the organizations new developments and future plans. Director of Advocacy, Matthew Dillon, will share the big picture perspective of the state of organic seed. The fruits of OSA's research program are also beginning to ripen and OSA, Director of Genetic Research, Dr. John Navazio, will share inspiring examples of participatory plant breeding projects designed to increase genetic resiliency in our crop varieties.

We strive to keep the Organic Seed Growers Conference affordable and inclusive. We also like to cultivate an enjoyable experience filled with good humor and good organic food. We are thankful for the generous contributions we received this year of food from farmers and organic food businesses and financial support from numerous seed companies, the organic foods industry, non-profits, and WSARE. We welcome you to the5th Biennial Organic Seed Growers Conference.

Moving Organic Seed Forward

Matthew Dillon, Director of Advocacy, Organic Seed Alliance,
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The organic seed community (and my reasons for the use of community rather than industry I hope will become clear to you) is faced with two primary concerns; concerns that seem to be in conflict, but that I believe have more potential as compliments than combatants. The two concerns fit loosely under the titles “Farmers Seed Needs” and “Commercial Organic Seed Conundrum”. The Farmers Needs piece is best exemplified by a recent white paper from the international nonprofit GRAIN, entitled “Whose Harvest?: The politics of organic seed certification.” Whereas the Conundrum might be best exemplified by a series of emails amongst American Seed Trade Association organic committee members asking, “Why should we offer organic seed when it's not clear that the farmers want it, or are willing to buy it, or will ever be forced to buy it?” And at the center of the perceived conflict there is a shared issue, that of trust.

Let me first explore the concerns of the GRAIN authors. First, it is obvious that they are looking at this problem from an international perspective, and that they have very specific fears in regards to the European administration of the organic rule as in pertains to seed. Europe has a more regimented approach to all seeds than the US, requiring all commercial varieties to be “registered varieties” - with registration costs, minimum quantities produced, and so on – so that the organic market is already shadowed by the overall EU seed regulations. These are regulations that are not supportive of farmer seed systems or to smaller grassroots “heirloom” or conservation-based seed companies.

GRAIN sees a trend in organic seed certification towards a similarly restrictive, industry controlled model of seed breeding and distribution. They point to the use of organic seed databases in several European countries as a regulatory tool that will restrict seed, and set the standards for nations outside the EU. They believe that “legislation is forcing the marriage between seed corporations and organic farmers worldwide,” and fear that such a union will hinder farmer seed systems for organics. GRAIN calls on organic agriculture instead to promote the use of locally developed, and “biodiverse seeds that are in the hands of the farmers.” GRAIN looks at the last hundred years of seed development and sees a history of farmers being marginalized in seed systems as consolidation and restrictive ownership models have become dominant.

These are all incredibly valid concerns, and GRAIN's vision of the importance of farmer involvement in seed systems is closely akin to that of Organic Seed Alliance. I have written about many of the same concerns, and so I want to address their concerns, but first I want to examine the organic seed picture from the industry's side of the table, and in so doing perhaps the concerns might gain perspective. Maybe we can even get people off the different sides of the table if we make it round enough.

The industry's perspective, like that of farmer advocate's, is complex in that it is a patchwork of seed companies of varying sizes and histories, with variable scales of investments in organic

R&D and marketing, and with diverse corporate values. Not to say that the industry doesn't have some shared alignment – they want to sell organic seed – but that the approaches to meeting this goal are as diverse as their seed lists; some overlap in them, but plenty of distinction. There are "grassroots" organic seed companies that have from their entry into the market been all organic; there are companies that are transitioning a percentage of their line to organic; and there are companies with interest in organic production and sales but are watching and waiting to see how the market, and the NOP rule, develop. Obviously some are solely breeding and production firms, others distributors, and a few are distributors/retail but do a percentage of their own production and even breeding. It's a diverse group.

Again, collectively, these companies share an interest in selling more organic seed. And their concern is connected to this interest. They fear that the market for organic seed, which has grown since the implementation of the rule, will fizzle out if the NOP exemption is not addressed. But in my experience in working with many of these companies, with many of you in the room today, I have not had the perception that you feel that this should be done at the cost of farmer seed systems, or at the cost of the loss of biodiversity. Yes, I have heard grumbles. And yes, there were early rumblings in the ASTA organic working group that called for a drop dead deadline for the use of organic seed, and some who may feel that the deadline should have been yesterday. And yes, yes, yes, - there is an urgency that the seed exemption be addressed, so that it does not continue ad infinitum, so that investments are not wasted. But I don't think we can judge that desire a conspiracy; as much as I am fond of seed industry conspiracies, and as much as I believe that the industry on the level of biotechnology has colluded with government for lack regulation. In organic, I just don't see evidence that there is any serious push towards restricting farmers' rights.

There is worry about how to deal with the meaning of "equivalency" and "commercial availability", how to suss out acceptable organic breeding methodologies for cytoplasmic male sterility, and how to improve organic seed quality, explore additional technologies such as pelleting and seed treatments, and how to increase organic seed yields. And there is the concern that farmers will try to get around the rule, that even when the identical variety is offered organically an unethical farmer will buy the cheaper conventional seed of that variety. Now, we in organics don't think that allowing conventionally produced compost is good for organic integrity, so why would we want to allow it in seed? That is not protecting farmers' rights to use seed, it's slack regulation, and the farmer who does it is not working in the spirit of the organic movement, much less the letter of the law. Now, I also don't think there is a conspiracy amongst farmers to do this, as much as I have heard seed industry tell an anecdotal story of a farmer they know who does this as evidence of such a grand collusion amongst farmers.

I have been contacted by seed companies concerned that OSA is training farmers in seed production for their own on farm use, taking on the role of seed companies, and therefore taking away their market. I think they might be exaggerating our work, as much as I'd like to claim that OSA has had such a revolutionary and transformative impact. I have never met a fresh market vegetable farmer who produced all their own seed. Again, a bit of distrust, of paranoia. I know one or two who perhaps grow and save 5-10% of their seed. That's a rare case. Most perhaps save seed for one variety within a couple of crop types, but purchase seed of dozens of varieties of differing crop types. I don't think anyone in the industry is going to lose their house over this percentage. Even if the percentage quadruples. The rate at which organic farming is growing will certainly make up for the seed savers.

Obviously there are some trust issues here amongst farmers and seed companies, and towards the goals of Organic Seed Alliance; distrust within our community. These trust issues existed long before the organic rule. But that's old history. We in the organic seed community have an opportunity to create something new. Just as organic farming, in spirit and in the clear language of the National Organic Rule, is not simply substitution based – a scheme of replacing a conventional fertilizer for an acceptable organic one – but instead is an integrated approach to farming to increase ecological health and diversity, so the organic seed community can alter, for the better, the development of agricultural seed systems.

Four years ago in Corvallis, Joel Reiten gave a talk from the industry perspective, an employee of Bejo Seed at the time. He said some things that I was very happy to hear from a representative of one of the larger vegetable seed production firms in the world. Joel said "There is plenty of room at the organic seed table. Plenty of farmers who need organic seed, and no reason there can't be many different ways they get the seed they need." I believe he meant it. And I believe it is true. There is no need to abolish seed companies in order to increase the health of farmers' seed systems, or protect biodiversity. Nor should a healthy seed industry need to impose damaging restrictions upon farmers' rights to save seed, breed new cultivars, develop alternative seed distribution systems, or decrease their varietal options through highly limiting seed registries such as those in Europe. There is room for everyone, and there is much to be gained from collaboration.

I believe that most seed companies' representatives know that if you try to shrink varietal options down to a short list, especially in the vegetable sector, organic farmers would stop getting certified, and without certified farmers there'd be no need to sell certified seed. This may not be true in Europe where they have grown accustomed to limited choice, but in the US it would not fly. It is clear that organic farmers rely on a much greater diversity of varietals than their more industrialized counterparts in conventional agriculture. Their customers demand it of them. Without that diversity, organic farming at a regional scale would cease to exist.

Variety – how much is enough? There are 76 listings for lettuce on the OMRI seed database, with several duplicates from different companies, such as the 3 listings for Green Deer Tongue. 70-some varieties of lettuce might seem like a lot, but it's not enough to meet the diversity of the market. Nor are the 70-some tomatoes. And three companies listed in these two crops, as good as they all are, are not enough to serve the diverse demand. What is the magic number in those crops, and in seed companies developing and producing organic seed? I don't know, and I don't think that's the primary question. The success we accomplish in moving organic seed forward is not going to come from restrictions and bean counters (excuse the pun), but from growth. The question is, how can the organic seed community find success, without restricting farmers' needs? It's a question made of many questions. And we need to ask those questions in an thoughtful way if we are to find a sustainable answer.

Organic Seed Alliance, as a public entity, is trying to provide the table for all of us to sit at. A round table, and all you valiant ladies and gentlemen are invited to sit with us. We work hard to represent the organic seed community – farmers and trade. We train farmers in seed production – some of whom only save seed, and others who go on to supply it to the trade. We support farmers in breeding projects, encourage farmers to consider their varietal needs via on-farm trialing. Again, this benefit is also shared with seed companies in that trialing leads to purchases if the varieties do well.

Over the last several months, Organic Seed Alliance has incubated two new entities that we feel will strengthen our service to you. One is the Organic Seed Growers and Trade Association. The mission of the Association is to develop, promote and protect the organic seed trade and its growers, and assure that the organic community has access to excellent quality organic seed, free of contaminants, and adapted to the diverse needs of regional and local organic agriculture. The Association is open to voting members of seed farmers, seed companies, breeders, and agricultural organizations that the association invites into the fold. It is also open to non-voting membership from farmers, gardeners, chefs, and other food/farming supporters; the end users of seed.

The Association, as it becomes populated and develops a board from its future members – hopefully many or most of you in this room – will have plenty of work to do. We will need to address the threat of contamination from GMO crops, and some of us have already felt the economic loss from such contamination, loss that will continue if RoundUp Ready beets, BT cabbage, and other new products hit the fields. And the Association will need to approach the NOP rule, make recommendations to the National Organic Standards Board, and work to overcome the gaps that prevent farmers from having access to 100% organic seed. We will be called on to help close those gaps by collecting information about which crops are receiving the greatest exemptions, and by increasing production, improving quality, training more commercial seed producers in organic methods and organic producers in commercial seed production. And we will need to listen to concerns that regulation damages organic markets, farmers' livelihoods, and diversity – as well as speak our concerns that the organic seed trade needs support and assurance. We will need to trust, and to work in collaboration if we are to move forward in a sustaining manner.

Just as agricultural plant genetics must continually change with their environment, improving with maintenance and selection or declining in quality with neglect, so the organic seed community must move forward with the spirit of organics – with diversity, complexity, and a systems approach that values the health and well being of all members of the community. If we don't select for improvements we will certainly face pressures that we do not have the resilience to overcome.

New Seeds for Farmers of the Future

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As we enter the 21st century it is becoming increasingly clear that preserving and invigorating whatever is left of our seed bank will be critical to our ability to transition into our post-petroleum future. Modern hybrid varieties, developed to perform narrow, specialized functions will not serve us well in a world that, like all of nature, will require the resilience of substantial bio-diversity. Genetically engineered varieties that have not been developed with ecological fitness in mind may serve us even worse. It is the seeds that have evolved in many ecosystems, under many different circumstances that stand the best chance of providing us with the resources we will need for people to feed themselves in our new world.

Concepts and Values in Organic Agriculture Relevant to Plant Breeding Techniques

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Introduction

Being a protest movement against developments in industrialised conventional agriculture, the organic movement has been value-based from the very beginning. However, the objectives of values are not only to resist unwanted developments, but also to support development and extension of organic agriculture into new areas; and to plan pro-active research. This paper will focus on how the concepts and values relevant to plant breeding techniques have been made explicit and discussed in the European context of organic agriculture. This will be elaborated by first describing the development of the discussion on ethical aspects in animal husbandry and biotechnology in Europe which lead to the concept of integrity of animals. Then the step towards the concept of naturalness, including the concept of integrity of plants will be described. And finally the consequences of the concept of naturalness for the assessment of breeding techniques will be discussed.

Discussion on values in Europe

There are several important developments in Europe that triggered the discussion on ethical issues in the organic sector. First of all, the development of GMOs and the decision of IFOAM to ban the GMOs for organic production in 1993 certainly pushed the desire of the organic sector to strive harder to close the organic production chain with respect to inputs such as seeds. This ethical sensitivity was already triggered earlier because of the rapid development in intensified animal husbandry in the Netherlands and other European countries. Dutch animal protectionists forced a governmental statement on the intrinsic value of animals to counterbalance the so called ‘instrumentalization’ of animals in agriculture and medical research. This led in 1992 to a first paper on describing the concept of integrity of animals (Verhoog, 1992).

In the context of the ongoing developments in biotechnology the Dutch parliament asked why one should not question genetic modification techniques with plants from an ethical point of view? A commission studied whether ethical aspects of plant biotechnology would lead to necessary changes in regulations (Kockelkoren, 1995). They came to the conclusion that there was no need to restrict biotechnology with plants from an ethical point of view, provided that environmental and health risks are taken into account. Kockelkoren concluded that it will depend on the man-nature attitude whether one will accept genetically modified food, and that free choice is important.

In the 1990s, the ongoing intensification of animal husbandry, including measures such as cutting tails of pigs, debeaking chickens and dehorning cows to avoid damage by high densities of animals, made the public more aware of their disapproval of harming animal integrity and of regarding animals as merely production factors. It led to a shift in attitude towards nature from a merely anthropocentric attitude towards a more biocentric oriented bio-ethical framework of action. Within the scientific community, Eursafe, the European Society for Agricultural and Food Ethics, was founded in 1999, and aims to encourage: a) academic education and research on the ethical issues involved in agriculture and food supply and b) international debate on the ethical issues involved in agriculture and food supply through the peer-reviewed Journal of Agriculture and Environmental Ethics and its frequent conferences (see www.eursafe.org).

The Dutch ministry of agriculture became anxious to know whether the organic sector has drawn the borderline with respect to banning GMOs, or if we might have second thoughts about the other techniques being developed in the past, such as embryo-rescue and other *in-vitro* techniques, and required a consistent evaluation. We published a report for the Dutch ministry of Agriculture in 1999 to define ecological criteria (e.g. biodiversity, closed cycles) and discussed it among European partners (Lammerts van Bueren et al., 2001). This was the base for IFOAM to publish the first draft standards for organic plant breeding in 2002, published unchanged in the latest version (IFOAM, 2005).

However, after having defined the concept of naturalness including the non-chemical, agro-ecological and integrity of life approach (Verhoog et al., 2003), we had a sounder base to further deepen the ethical aspects in plant breeding techniques (Lammerts van Bueren et al., 2003). The ecological and ethical aspects are to be taken into account when managing production because organic agriculture has its reasons for existence in focussing on environmentally and ethically sound production systems, and thus has process-oriented standards in the first place, not product-oriented ones. Transferred into the area of plant breeding, this means that not only the variety characteristics but also the way of achieving such traits in the breeding process are important.

The concept of naturalness

Within the concept of naturalness, the non-chemical approach is the best known aspect of organic agriculture that is communicated to the public: no artificial fertilizers, no chemical pesticides. This has consequences; for example, the search for more natural types of seed treatments or physical treatments, such as hot water treatments.

During the conversion period from conventional to organic farming, farmers' experience is that a sustainable farming system can only be created by co-operating with nature and stimulating its self-regulatory capacity and robustness, e.g. through biodiversity at all levels, and not by merely eliminating inorganic fertilizers and pesticides. A new attitude is needed based on respect for nature and ecological measures. With respect to variety traits, one will select those varieties for organic seed production that have traits that make them ecologically fit for organic farming conditions. Examples of required traits are: broad field tolerance against diseases, ability to perform under low input of organic fertilizers, deeply rooting characteristics, the ability to associate with beneficial soil micro-organisms and – a factor often forgotten – the ability to produce healthy seed!

The third approach in organic agriculture refers to the respect for the integrity of life, including that of plants. It is the ethical element of naturalness, determined by a biocentric framework of action. In the biocentric theory all living entities are considered ethically relevant, which means that the intrinsic value is taken into account in decisions on the exploitation of nature. Organic agriculture will take these elements of integrity into account and will refrain from violation of integrity. Organic agriculture therefore accepts and cherishes the characteristic nature or way of being of living entities, their wholeness, completeness, their species-specific characteristics and their being in balance with the species-specific environment.

The integrity of plants

From a biocentric perspective the intrinsic value of plants is a reflection of their integrity on different levels: at the level of integrity of life, at plant-typic level, genotypic and phenotypic level. To use this concept of integrity to evaluate breeding techniques one needs to derive criteria from these levels:

Integrity of life level

Plants have integrity as living beings; in organic agriculture the notion is that a plant is more than the sum of its genes and biochemical pathways. Organisms maintain themselves through self-regulating and self-ordering activities, and respecting this integrity leads to the criterion not to violate this self-regulative ability, for example by applying biochemical inputs that interfere with the self regulating ability.

Plant-specific level

Plants belong to a specific realm of nature. Usually they only require elements from the mineral realm to satisfy all their metabolic needs, possess a nutritive system based on photosynthesis and have rigid cell walls. Plants also differ from animals as plants have no central nervous system and a different way of interacting with their environment or coping with (biotic or abiotic) stress in order to survive, to grow and develop, and to reproduce independently. Plants do have the ability to interact with their rhizosphere and to live in symbiosis with beneficial soil microorganisms. Similarly, plants need to live in an optimal association with bacteria on their leaves, with endophytes as well as with their abiotic environment. At this level plant-specific integrity is operational, and breeding should improve and not affect the ability to adapt and interact and be able to reproduce under soil-bound conditions.

Species-specific level

Plant species differ in life form, life cycle, ontogeny, morphology, metabolism and reproductive strategies. Each species can be distinguished from other plant species on the basis of these aspects. Its unique characteristics are defined by its genome (with a certain genotypic variation depending on the species). At this species-specific level genotypic integrity is operational. Genetic integrity can be defined as the state of wholeness or completeness of the species-specific genome. This integrity can be violated by bringing in genes from non-related species through genetic engineering or by breaking reproductive barriers.

Phenotypic integrity level

Plants are less individualized than animals. Depending on the agricultural sector, the focus of individuality lies either on the crop (arable farming and vegetable growing) or on the individual plant (fruit trees, ornamentals). A plant’s appearance is, within the boundaries of its species, plastic. The boundaries of plant production can be challenged by altering the plant’s environment or the genome of its progeny. At this level phenotypic integrity is operational. Phenotypic integrity is the state of wholeness or completeness of an individual plant or crop, including its health. It can be violated from an organic agricultural point of view by, for example, cultivating and developing plants/crops in such a way that they cannot maintain themselves and perhaps cannot complete their life cycle without chemical crop protection.

Assessment of plant breeding techniques

To assess consequences of acknowledging integrity of plants for the compatibility of different kinds of techniques with organic plant breeding and seed production we should not only distinguish the three approaches of naturalness in organic farming, but also the three levels of organization in a plant. The techniques for variation induction, selection, maintenance and propagation can be applied at plant or crop level; cell or tissue (*in vitro*) level, and at DNA level. The latter includes techniques that go beyond the level of the organized cell.

Table 1 shows the extent to which plant breeding and seed production techniques at plant, cell or DNA level are compatible with the three approaches of the concept of naturalness.

Conventional techniques at plant level (e.g. manual crossing, mass or pedigree selection, or maintenance) are considered plant-worthy as they do not interfere with the plant's natural interaction with the soil or with the natural reproductive barriers and do not affect the wholeness when pollination, fertilization, and seed formation can occur on the whole plant itself. Techniques at DNA level operate beyond the organised cell level and are therefore not compatible with the integrity of plants. However, DNA-marker technology may be of value in the selection process of organic breeding programmes and can be used if non-chemical methods are applied: without radioactivity and carcinogenic substances.

As to the techniques at cell level, the so-called *in vitro* techniques used in breeding programmes, such as embryo culture, the artificial growing-conditions of Petri dishes do not comply with the organic production methods using organic substances. One can also argue whether tissue culture remains within the (lowest) level of organized life or that an organism as a whole is the basic unit to work with in organic agriculture. This is indicated in Table 1 with +/–. To make it really compatible with the non-chemical approach, one can suggest designing growing media by using natural substances for a substrate and natural plant growth regulators. Note that arguments from the non-chemical, via agro-ecological to integrity approaches can be cumulative.

Table1. The extent to which plant breeding and propagation techniques at plant, cell or DNA level are compatible with the three approaches of the concept of naturalness. Note that arguments from non-chemical, via agro-ecological to integrity approaches can be cumulative. (Lammerts van Bueren & Struik, 2004)

Organization level/approach of naturalness	Non-chemical	Agro-ecological	Integrity of life
Plant	+	++	+++
(Organized) cell	+/-	+/--	+/---
DNA	-	--	---

+ = compatible; + + = very compatible; + + + = most compatible; – = incompatible; – – = very incompatible; – – – = most incompatible with the principles of organic farming; +/– = compatible, but there are arguments for rejection; +/– – = there are arguments for compatibility, but even more arguments for rejection.

The debate over where to draw a line for the standards, is not yet over! Based on agro-ecological criteria, one may consider in-vitro techniques not compatible because of the use of artificial growing media. The application of these techniques is an ecological detour, yet one that still operates within the level of life, albeit the lowest integration level (i.e., of organized cells). From the principles of integrity of plants there are much clearer arguments against in-vitro techniques, as they affect the plant-specific and phenotypic integrity of plants.

IFOAM's draft standards indicate that only techniques at whole plant level are compatible for the principles of organic agriculture (IFOAM, 2005). IFOAM has intentions to guide the discussion in the next few years to come to final standards.

The main consequences of possible future standards could look like this:

- Breeding, maintenance and propagation under organic conditions;
- Only those techniques that allow crossing, pollination, fertilization and seed formation on the whole plant itself;
- Respect for natural crossing barriers;
- No in-vitro techniques, no GMOs, no protoplast fusion;
- No male sterility without restorer genes;
- No patents on life, but acknowledgement for farmers' and breeders' rights.

Novel breeding techniques

Recently, several novel breeding techniques are being developed, e.g. cis- or intragenesis and reverse breeding, including genetic engineering in such a way that the end product in future might not be classified as genetic modified organism (GMO) by the GMO regulations (a.o. De Cock Buning et al., 2006; Schouten et al., 2006).

Whether the products of these breeding processes will be classified as GMOs depends on the interpretation of the relevant regulations. In the EU the regulations are both process and product based, where in US they are product based.

In cisgenic plants, the genes being introduced through genetic modification are from a crossable donor plant and thus the source of the genes is considered to be of the same nature. In reverse breeding, the recombinant genes, essential to the breeding process, are no longer present in the product resulting from the entire breeding process, and thus the end product as such is not transgenic. Should varieties obtained through cisgenesis or reverse breeding be allowed in organic agriculture? The answer to this question depends on whether merely the product or the process of breeding is taken into account. Assessment based on the product implies a choice for an ethical approach that only considers the extrinsic consequences of human action by making a risk-benefit analysis. It neglects so-called intrinsic ethical arguments related to the applied technology (the process) itself. The organic movement uses the intrinsic argument of 'unnaturalness' against genetic engineering. Therefore, a logic conclusion would be that products of cisgenesis and reverse breeding should be subject to the current GMO regulations in organic agriculture and should thus be banned from organic agriculture (Lammerts van Bueren et al., 2007).

Conclusions

To understand the above discussed approach of assessing plant breeding techniques, it is essential to realize that norms and standards are derived from values. However, values are a result of culture which can changes over time. So it is good to discuss organic values from time to time to adjust rules to current value perceptions as IFOAM recently did by reformulating the four principles (Luttikholt, 2007).

We must also keep in mind that only from a holistic perspective integrity of plants makes sense. From a purely reductionistic, anthropocentric perspective there is no reason for acknowledging integrity. From that point of view plants merely have extrinsic values for the utility of mankind and can be regarded as production units.

The consequences of respecting the integrity of plants and the urgent need for improved varieties require identification and prioritization of short-term and long-term steps for the practical development of organic seed production and plant breeding. Some breeding companies start with the non-chemical approach, others include the agro-ecological approach by putting more emphasis on traits that improve the adaptation to organic growing conditions (e.g. improved root systems, nutrient-efficiency and early soil coverage), and some even accept the more challenging integrity approach in breeding by excluding certain breeding techniques. Some countries in Europe, e.g. Switzerland and Hungary, are already drafting a certification system for plant breeding programs only including techniques that comply with the organic values and conducting the whole breeding process under organic growing conditions. With such a certification system they aim at distinguishing such programs as being 'organic breeding programs (OPB)' compared to conventional breeding programs for organic agriculture (BFOA) but not necessary excluding certain *in-vitro* techniques and not necessary conducting the whole breeding process under organic growing conditions.

The last conclusion in this context is that organic agriculture is in development and requires improved varieties better adapted to both ecological and ethical principles of OA. The consequence is that for a certain period the organic sector will have to deal with three categories of varieties: a) a gradually increasing amount of varieties bred from (certified) organic breeding programs, including maintenance under organic conditions; b) unavoidable for a long time varieties derived from conventional breeding programs, with reasonable to good performances in organic farming and of which the seed is produced organically and c) the banned (GMO) varieties.

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The National Plant Germplasm System:
Background for a Discussion with the Organic Seed Alliance

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This presentation is part of an effort by the funding and managing agencies of the National Plant Germplasm System (NPGS) to communicate with stakeholders. The goals of this stakeholder communication effort are two: to serve stakeholders better, and to reach new stakeholder groups, thereby enlarging the base of user support for the NPGS.

Introduction: Organic farmers as germplasm stakeholders

Plant genetic resources are essential for any agricultural system. They tend to be deployed differently in different systems, however. Some systems deploy genetic diversity primarily over time. Diversity is used in the form of parental materials, to develop successive genotypes that cope with environments found over relatively large areas, such as regions.

Organic agricultural systems tend to use plant genetic diversity differently because they focus on maximizing beneficial crop-environment interaction with few external inputs. With many environmental factors fixed by the site, plant genetics is among the key factors that ingenuity can vary to maximize the system. Organic agriculture is likely to deploy genetic diversity simultaneously, within and among sites, as well as sequentially. Clearly, then, organic seed producers and farmers are among the stakeholders of national efforts to conserve plant genetic resources.

This presentation will briefly introduce the main features of the NPGS and who is involved. It will also describe how you can be involved -- to obtain seed, provide direction, or express support. My intent is to allow a good proportion of my time for discussion of how the NPGS does or does do not serve your needs, and whether there are feasible measures that could increase its value to you.

The National Plant Germplasm System (*www.ars-grin.gov/npgs)*

The U.S. National Plant Germplasm System (NPGS), one of the world's largest collections of plant genetic resources, includes major and specialty crops, both new and established, of temperate, tropical, and sub-arctic regions. Among them are grains and oilseeds; vegetables and fruits; fiber, forage, and feed crops; sugar crops, herbs, spices, ornamentals, beverage crops, and medicinals. In addition to wild relatives and land races, the collection includes heirloom varieties. It is also the official repository for samples of new varieties that obtain plant variety protection and will become part of the collection after the PVP expires. Materials in the collection are available free, without restrictions, to any bona fide user including researchers; also any bona fide farmer-breeder or seed company or association of any scale.

An example of how the NPGS can be used is the Organic Seed Partnership (OSP) (www.plbr.cornell.edu/psi/OSP%20home.htm) a collaborative project involving the NPGS, land-grant university plant breeders, and small-scale seed growers and farmer/breeders. This group and its predecessor, the Public Seed Initiative (PSI) use materials from the NPGS and university breeding programs to meet the needs of small-scale seed production for local and organic farmers in the Northeast, a unique niche market too small to be served by large seed companies. By getting locally-robust varieties with the right consumer quality out to regional farmers, they are helping to remove a significant barrier to sustainability of local food systems. The OSP also conducts field days to share expertise on seed production and storage, and brings portable equipment to community seed cleaning days.

The NPGS is funded and managed through a collaborative effort of USDA and the state land-grant universities. The system consists of some 20 “active” sites, a single back-up site for long-term secure storage, and a service lab. All are ARS facilities, though frequently co-located and collaborative with land-grant universities. There is also a set of committees of germplasm experts, for each crop or crop group, convened by ARS,USDA: and, four multi-state research projects by region and one national research support project, convened by the land grant universities and CSREES, USDA. These components, which may appear complex at first meeting, in fact developed over time as an effective and interactive system for day to day operations, access to expert guidance; and ensuring participation.

The active sites hold the “active collections”; that is, it is they who actively acquire, maintain, regenerate, distribute, document, characterize, and evaluate germplasm. Acquisition, characterization and evaluation, in particular, are often done in collaboration with germplasm users such as land grant university researchers. The active sites are advised by the relevant crop germplasm committees (CGCs) for the crops at that site . CGC members include representative experts on the crop, from any sector, whether federal, state, private, or non-profit. OSA members may already serve on some CGCs. If there are relevant crops for which there is no OSA representation on the committee, contact the chair of the relevant CGC (www.ars-grin.gov/npgs/cglist.html).

Finally, users of the active sites are organized in multi-state research projects by region. These projects are now the longest-running in the multi-state research project system, and are best known by their low numbers dating from the years after WW II: North Central, “NC7”; North Eastern, “NE9”; Southern, “S9”; and Western ,“W6”. The national research support project, “NRSP6”, is dedicated to potatoes because of their national importance plus propagation challenges. These five projects are the primary mechanism for state and CSREEES participation in NPGS funding and management. They are not limited to land-grant participation , however.

They welcome participation by other entities that can make a contribution to the research goals. Organic seed producers would often be relevant participants.

ARS contributes about 90% of NPGS funding, from its annual appropriation for federal ag research. Through the multi-state research projects, the NPGS also receives state-directed federal Hatch funding, through CSREES, amounting to about 10% of the NPGS budget (varying by region). This Hatch funds contribution through CSREES and the states is effectively magnified because the state connection allows the NPGS to use in-kind university resources. Allocation of Hatch funds for the NPGS must be approved by each region's association of state agricultural experiment station directors. In deciding whether to allocate scarce Hatch funds for the NPGS, state directors look for value to their citizens. That includes usefulness to their state's organic farming community, local food chain enterprises, and their customers.

NPGS would like to know how it serves or can serve your needs, and/or if there are things that could be done by the NPGS that would better serve your needs. It also invites you to become an NPGS user if you are not one already, and to communicate about your needs via the ARS and CSREES national program staff, the NPGS CGC for your crop(s) of interest, or via your state's rep to your region's NPGS multistate project.

Selecting, Growing and Marketing Value-added Wheat Varieties In Organic Cropping Rotations

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Target audience

1. Organic producers who grow wheat as part of their cropping rotation
2. Seed growers who want to sell wheat cultivars with value-added traits
3. Plant breeders selecting for higher nutritional value and/or weed competitive ability in cereal cultivars

Abstract

Wheat has traditionally been grown in many environments as a rotational crop with other higher-value crops. Although usually grown as a commodity to be sold on the open market, wheat has the potential to realize both enhanced monetary and agronomic value for farmers. Historical varieties, landraces, semi-domesticated wheat and wild wheat relatives have been shown to contain characteristics of interest to both organic growers and consumers. Abundant genetic diversity among adapted wheat landraces and traditional varieties provide farmers, seed companies and plant breeders a source of value-added traits. Two of these value-added traits, high nutritional content and enhanced weed competitiveness, will be discussed in this paper.

Improving human health is a primary motivating factor for many organic consumers. Our results show that wheat grown in organic systems has higher mineral concentration of copper (Cu), magnesium (Mg), manganese (Mn), phosphorus (P) and zinc (Zn) than wheat grown in conventional systems. We have evaluated historical and modern wheat varieties in organic systems and found varieties that both yield well and contain high levels of specific mineral nutrients. Diverse blends of nutritionally dense wheat varieties will not only create a value-added marketable product, but has the potential to reduce disease pressure as well.

Weed management has consistently ranked as a high priority for organic farmers. Our results describe specific varieties that are capable of suppressing weeds up to 500% better than other varieties. These varieties can suppress weeds through allelopathic root exudates and growth habit traits. Identification of varieties capable of suppressing weeds will provide seed companies with an extra marketing niche and growers with an additional weed control tool.

The objective of this talk and paper will be to give organic growers, seed companies and plant breeders: 1) specific varietal information on weed suppression and micronutrient content; and 2) marketing options and management tools to consider when using wheat as a rotational crop in organic farming systems.

Nutritional Value

Our preliminary results suggest that grain grown in organic systems in the Palouse bioregion of Washington State have significantly higher levels of Cu, Mg, Mn, P and Zn than grain grown in conventional systems. Grain calcium (Ca) concentration was significantly higher in the conventional system than in the organic systems; and no significant difference between systems was found for grain iron (Fe) concentration (Table 1).

Table 1. Mean mineral concentration (mg/kg) between organic and conventional systems

System	Ca	Cu	Fe	Mg	Mn	P	Zn
Organic	339	2.78*	28.6	971*	45.1*	2845*	17.1*
Conventional	349*	2.40	29.2	929	43.6	2650	15.8
Lsd	8.9	0.11	1.8	15	1.2	57	0.5

* significantly higher value (P<0.05); lsd=least significant difference

These differences are likely due to differences in soil characteristics. We found that soil organic matter, pH, and available soil P and nitrogen (N) (nitrate + nitrite) were greater in the organic systems. Available N (ammonia) Cu, Fe, Mn and Zn were greater in the conventionally farmed soils than in organically farmed soils (Table 2). Cation exchange capacity was similar in both systems.

Table 2. Soil characteristics between organic and conventional systems

System	Organic Matter	Cation Exchange Capacity	pH	N (Ammonia)	N (Nitrate + Nitrite)	Cu	Fe	Mn	P	Zn
	(%)	cmol(+)/kg					(ug/g)			
Organic	3.4	24	6.1	14	12	2	54	61	11	0.8
Conventional	2.4	23	5.2	32	9	2.4	81	81	6	1.7

The question arises as to why the organic grain had higher levels of Cu, Mn and Zn than the conventional grain, despite there being lower concentration of these minerals in the organic soil. Concentrations of available Cu, Mn, Zn, and Fe in soil were greater in the conventional system, likely as a result of lower pH (Fageria et al. 2002). These micronutrients become available at a lower pH. The lower soil pH may be due to the higher applications of inorganic N fertilizer and higher levels of available soil N in the form of ammonia.

Root colonization by mycorrhizal fungi can improve acquisition of P, Cu, Zn, Mn, and Fe (Marshner and Dell 1994), and has been found to be greater in organic as compared to conventional wheat cropping systems (Ryan et al. 2004). The higher soil organic matter content may have allowed greater root colonization by mycorrhizal fungi which resulted in the higher nutrient concentrations in grain from the organic system.

Our research shows that wheat grain nutritional content is significantly less today than it was between 50 to 125 years ago, particularly for soft white winter cultivars. Because evidence exists that there is no genetic trade-off between nutritional value and grain yield in wheat, positive selection for both yield and nutritional content has a high probability of success. Tremendous variation for mineral nutrient concentration exists within wheat varieties adapted to the Pacific Northwest (Table 3). For more information, please see the article entitled 'Nutritional

Value of Winter and Spring Wheat: A Comparison of Historic and Modern Varieties' in the Summer 2007 edition of Sustaining the Pacific Northwest (http://csanr.wsu.edu/whatsnew/SPNW-v5-n2.pdf#page=7).

Table 3. Market class, year introduced, grain yield (bushels per acre) and mineral nutrient content of 26 hard red (HR), soft red (SR) and hard white (HW) spring wheat varieties. **Note:** These varieties were grown with very low levels of Nitrogen in organic conditions and this is reflected in the low yields; increasing Nitrogen will likely greatly increase the yields.

Variety	M.C.	Year	Grain Yield	Ca	Cu	Fe	Mg	Mn	P	Se	Zn
Cadet	HR	1946	25	341	5.1	34.1	1531	55	4026	15	37
Canadian Red	HW	1919	24	371	4.2	36.4	1280	50	3421	13	33
Canus	HR	1934	29	471	4.3	36.5	1358	51	3804	15	34
Ceres	HR	1926	15	453	5.1	28.8	1430	60	3989	20	33
Comet	HR	1940	19	413	4.3	36.1	1366	54	3738	13	35
Flomar	HW	1933	20	414	3.9	34.6	1355	49	3613	14	32
Hard Federation	HW	1915	18	358	4.9	35.8	1462	56	3725	12	36
Henry	HR	1944	16	366	4.7	31.9	1353	44	3840	12	36
Hope	HR	1927	23	349	4.3	32.7	1351	51	3588	11	34
Hybrid 123	SR	1907	6	515	4.5	34.9	1279	47	3780	19	31
Komar	HR	1930	16	471	4.4	30.3	1386	48	3806	14	35
Ladoga	HR	1888	21	385	4.4	38.4	1368	49	3935	15	35
Marquis	HR	1911	18	380	3.9	28.7	1271	44	3748	10	33
Red Bobs	HR	1918	21	298	3.5	31.4	1145	43	3206	13	30
Red Fife	SR	1842	5	398	4.5	35.5	1435	50	4041	11	34
Reliance	HR	1926	22	387	3.6	31.4	1177	39	3315	14	26
Reward	HR	1917	18	371	4.7	35.8	1271	52	3895	13	36
Rival	HR	1939	15	401	5.3	32.4	1426	51	3868	19	38
Ruby	HR	1917	24	338	3.8	33.5	1161	39	3243	14	29
Scarlet	HR	1999	24	387	4	34	1295	46	3527	12	28
Sea Island	HR	1890	16	490	4.2	29.7	1237	47	3532	16	28
Spinkota	HR	1944	30	288	3.4	40.5	1277	45	3437	21	29
Supreme	HR	1922	18	346	3.8	33.8	1275	49	3593	9	34
Thatcher	HR	1934	21	396	4.4	27.1	1301	47	3789	12	28
Westbred Express	HR	1991	26	414	4.9	33.8	1336	51	3545	13	27
White Marquis	HW	1923	25	441	4.3	30.9	1314	49	4052	19	33

Several varieties have high levels of certain nutrients in organic systems and lower levels of the same nutrients in conventional systems. The reverse is also true. This suggests that certain cultivars may be optimally adapted to organic farming systems in a way that allows for higher grain mineral concentration. These cultivars are likely capable of exploiting the higher organic matter in the organic systems to achieve increased nutritional value.

To maximize the nutritional value of wheat in organic farming systems, we need to determine the relationship between agroecological factors (including climatic conditions, soil characteristics and wheat variety) and value-added traits (including nutritional content, yield in organic systems and quality) for wheat and other crops. Using this information, we will develop agronomic strategies, economic analyses and value-added marketing options that focus on optimizing the nutritional value of, and financial compensation from, wheat grown in different regions of the Pacific Northwest.

Weed Suppression and Allelopathy

Economic costs and the potential for unintended environmental effects of herbicides have led to an increasing emphasis by crop breeders to select for weed suppression ability (WSA). Crop varieties that are capable of suppressing weeds will benefit organic farmers and provide a value-added trait for seed producers and seed companies. Genetic variation for traits conducive to crop competitiveness against weeds may be concentrated in historical cultivars and landraces that were selected before the widespread use of crop protection chemicals.

We evaluated 63 spring wheat landraces and modern cultivars for six potential competition traits, including plant height, allelopathy, leaf area index, juvenile growth habit, coleoptile length and 1000 kernel weight, and for the ability of these cultivars to achieve high yields while simultaneously suppressing weeds in field conditions. Major differences were found among the 63 spring wheat cultivars for grain yield, weed weight and all six growth habit traits. The top five cultivars for WSA reduced dry weed weight at harvest per plot by 573% over the bottom five cultivars. Plant height, allelopathy and coleoptile length were responsible for a significant percent of the variation in WSA.

The potential effect of allelopathic root exudates on WSA was tested in the laboratory using varieties with the highest WSA and varieties with the lowest WSA grown together with the target weed species 'lambsquarters' (*Chenopodium album*). Root length of lambsquarters was measured when grown with each cultivar. The high-WSA wheat cultivar group treatment had significantly shorter lambsquarter root length than the low-WSA cultivar group. This suggests that allelopathic root exudates may play an important role in WSA among wheat varieties. 'Big Club', 'Comet', 'Ladoga' and 'Hard Federation' were the varieties with the most allelopathic potential and 'Alpowa', 'Penewawa' and 'Hyper' had the lowest allelopathic potential. The varieties with high WSA would be beneficial to include with other high yielding varieties in 'cultivar mixtures' for use in cropping rotations and on farms where weed competition is a serious consideration.

Concluding Thoughts

In many cases, improvements in yield have maintained priority over improvements in other traits such as end-use quality, nutritional value, competition against weeds in the absence of herbicides and nutrient uptake efficiency in low input conditions. Often, only those characteristics that directly affect crop yield have benefited from significant plant breeding efforts. Breeding for organic agriculture necessitates a change in the way breeding objectives are approached, methods are laid out and selection strategies are implemented. It is no longer sufficient to justify all agricultural activities, including plant breeding, on the basis of increased production alone. Selection of wheat varieties for value-added traits, including increased nutritional value and weed suppression ability, provides both agronomic and economic benefits to farmers and seed growers.

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Evaluation of Organic Seed Treatments for Control of Damping Off/Seed Blight Pathogens of Spinach for Use in Organic Production

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Summary: A range of 14 seed and/or drench treatments, as well as conventional treatments and non-treated seed were evaluated under greenhouse conditions against each of three soilborne pathogens, *Pythium ultimum*, *Fusarium oxysporum* f. sp. *spinaciae*, and *Rhizoctonia solani*, using spinach as a model small-seeded vegetable. Inoculation rate trials were carried out using non-treated seed for each pathogen prior to the treatment trials. The purpose of the inoculation rate trials was to determine an appropriate rate of inoculation for each pathogen that would result in approximately 50% disease for evaluating each of the seed and/or drench treatments. Treatments included products that were EPA-registered and approved for use in organic agriculture, and products that were being developed for compliance with organic standards. Seed health and germination assays were conducted for each seed treatment to determine potential effects on seedborne fungi, or germination. Selected treatments were then evaluated under field conditions at three locations in western Washington based on performance of the treatments in the greenhouse trials. Results will be presented.

Introduction: There are many concerns regarding losses to seedborne and soilborne pathogens in organic production systems because of limited effective options available for disease management that satisfy organic standards. Seed treatments can be inexpensive and effective, including those with biological control agents (BCAs). However, the reliability of BCAs for disease control is affected by crop species, whether a pathogen is seedborne or soilborne, and numerous abiotic factors.

Objectives: The specific objectives of this study were to:

1. Determine effective rates of inoculation for each of the three pathogens to achieve approximately 50% damping-off or seedling mortality under greenhouse conditions;
2. Evaluate selected seed and drench treatments in a greenhouse against each of the three pathogens separately;
3. Determine if any of the selected seed treatments reduce the incidence of necrotrophic fungi present on spinach seed;
4. Determine if any of the selected seed treatments affect germination of spinach seed;
5. Evaluate selected seed and drench treatments under field conditions at two different certified organic sites in western Washington, using plots inoculated with *P. ultimum*, *R. solani*, and *F. oxysporum* f. sp. *spinaciae*; and
6. Evaluate selected USDA NOP-approved seed and drench treatments under field conditions at a certified organic farm in western Washington that had known problems with damping-off of spinach.

Methods: The research was conducted by an M.S. student, Jaime Cummings, in the WSU Dept. of Plant Pathology. These studies were conducted at the Washington State University Northwestern Washington Research and Extension Center in 2006-2007 (WSU Mount Vernon NWREC), and in Vancouver and Sequim, WA in 2007.

Greenhouse Seed and/or Drench Treatment Trials. The efficacy of 14 seed and/or drench treatments, as well as conventional fungicide seed or drench treatments, and non-treated seed planted into inoculated and non-inoculated potting medium (control treatments) was evaluated separately against each of the three soilborne pathogens: *Pythium ultimum*, *Fusarium oxysporum* f. sp. *spinaciae*, and *Rhizoctonia solani*. The seed and drench treatments included products that were EPA-registered and approved for use in organic agriculture, as defined by the National Organic Standards, and products that were being developed for registration and compliance with organic standards (Table 1). Each trial was set up as a randomized complete block design with five replications of the 17 treatments, and maintained according to organic standards. Emergence/stand counts and disease ratings were conducted weekly for four to nine weeks, depending on the pathogen. Each trial for each pathogen was conducted twice. Seedlings were harvested at the end of each repeat trial to measure above-ground dry biomass.

Seed Health Assays. A modified freeze-blotter seed health assay was conducted on four replications of 100 seed for each seed treatment on each of two ‘Lazio’ spinach seed lots used in greenhouse and field trials to determine the incidences of seed that were infected with various necrotrophic fungi. All seed treatment products were included in the seed health assays, including the two conventional seed treatments (Apron XL LS and Mertect 340F) and non-treated seed. The seeds were examined microscopically 5, 9, and 14 days after plating, and necrotrophic fungi developing on the seed were identified and recorded.

Germination Assays. For each of the two spinach seed lots used in the greenhouse and field trials, 100 seed treated with each of the seed treatment products, including the two conventional seed treatments (Apron XL LX and Mertect 340F) and non-treated seed, were subjected to a germination seed assay based on the Association of Official Seed Analysts (AOSA) protocol. The incidence of seed that had germinated, had abnormal germination, or was rotten was counted after 7, 14, and 21 days of incubation for both assays. In addition, a 5 day reading for the second assay was included because two of the treatments appeared to cause earlier germination.

Field Seed and/or Drench Treatment Trials. Field trials were conducted to evaluate selected seed and drench treatments under field conditions at each of three locations. One trial was planted at the WSU Mount Vernon NWREC in Mount Vernon, WA on 18 May 2007. A second trial was planted at the WSU Vancouver Research and Extension Unit (WSU Vancouver REU) in Vancouver, WA on 5 June 2007. The third trial was planted on a grower-cooperator’s certified organic farm in Sequim, WA on 7 August 2007. Each field site was certified for organic production. The Mount Vernon and Vancouver trials were each set up as a split plot, randomized complete block design with five replications of a 4 x 12 factorial treatment design. The main plots received four inoculation treatments: inoculation of the soil with *P. ultimum*, *F. oxysporum* f. sp. *spinaciae*, or *R. solani*, and a non-inoculated control treatment. The split plot treatments included 12 seed and/or drench treatments. The Sequim trial was set up as a randomized complete block design with five replications of nine EPA-registered and OMRI-listed seed and/or drench treatments approved for use in organic production. This trial was not inoculated with the three pathogens because it was on a grower-cooperator’s farm. Seedling emergence and wilt ratings were conducted at 7 day intervals for 5 or 6 weeks after planting at each field trial. Additionally, total above-ground, dry weight of the plants was determined for a section of each split plot at the Mount Vernon and Vancouver sites, and each plot at the Sequim site.

Results and Discussion: For *P. ultimum*, two experimental seed treatments, Experimental #1 and #2, provided equivalent control to that provided by a conventional fungicide seed treatment, Apron XL LS; while Natural II, Natural X, and Subtilex seed treatments each suppressed damping-off significantly in only one of two trials (Table 2). For *F. oxysporum* f. sp. *spinaciae*, drenches with a compost tea or Prestop, and seed treatment with Yield Shield suppressed post-emergence wilt significantly in one of two trials; but no treatment was highly effective (Table 4). For *R. solani*, Experimental #1 and Natural II seed treatments reduced damping-off as effectively as a drench with the conventional fungicide Terraclor (Table 3). Seed health assays revealed that treatments with Experimental #1, Experimental #2, or Mycostop Mix significantly reduced the incidence of seedborne *Verticillium* and *Alternaria*. Natural II and Natural X seed treatments significantly reduced early germination in seed germination assays. There was little consistency in results among field trials (Tables 5 and 6). However, Experimental #1 and #2 seed treatments consistently caused significantly earlier emergence than the other treatments (Table 5). In contrast, the compost tea drench resulted in low total emergence and low spinach biomass, but also low post-emergence wilt in two of three trials.

Conclusions: This research provided an independent and objective evaluation of seed and drench treatment products for management of soilborne damping-off and seedling blight pathogens for use in organic production. The results provide valuable information to growers on the efficacy of selected treatments for use in organic vegetable production, as well as for organic seed production. Additional research is needed to continue these evaluations under irrigated and dryland organic production of a diversity of vegetables.

Table 1. Seed and drench treatments evaluated in greenhouse trials for efficacy against damping-off and vascular wilt of spinach caused by *Pythium ultimum*, *Rhizoctonia solani*, and *Fusarium oxysporum* f. sp. *spinaciae*[a].

Treatment[b]	Active ingredient (rate in product)	Registrant or manufacturer	Rate of application of product[c]	Method of application	OMRI-listed[d]	Registered for spinach in WA State in 2007[e]
Compost tea	High bacterial diversity compost tea[f]	Washington State University, Pullman, WA	646 liters/100 m^3 potting mix	Drench immediately after planting	Yes	No
Experimental #1	Proprietary organic disinfectant	Proprietary	Proprietary	Seed treatment	Not yet applied	No
Experimental #2	Proprietary organic disinfectant + *Trichoderma harzianum* T-22	Proprietary	Proprietary	Seed treatment	Not yet applied	No
Kodiak Concentrate Biological Fungicide	*Bacillus subtilis* (1.37%)	Bayer CropScience, Research Park Triangle, NC	31.2 g/100 kg seed	Slurry seed treatment	Yes	No
Micro 108 Seed Inoculant + Actinovate AG	*Streptomyces lydicus* (10^8 cfu/g) + *S. lydicus* (10^7 cfu/g)	Natural Industries, Houston, TX	1.76 kg/100 kg seed + 1.29 kg/100 liters water	Dry seed coating + drench immediately after planting	Yes	Yes
Mycostop Mix	*Streptomyces griseoviridis* (4%)	Verdera Oy, Luoteisrinne, Finland	625.7 g/100 kg seed	Dry seed coating	Yes	Yes
Natural II	Actinomycete (0.6%)	Agricoat LLC, Soledad, CA	750.7 g/100 kg seed	Seed treatment	No	No
Natural X	Actinomycete (0.6%)	Agricoat LLC	750.7 g/100 kg seed	Seed treatment	No	No
PGPR Galaxy	Bacterial mixture[g]	Holmes ENVIRO, LLC, Philomath, OR	223 ml /100 kg seed	Slurry seed treatment	Yes	No
Prestop Biofungicide Powder	*Gliocladium catenulatum* (32%)	Verdera Oy	180 g/100 liters water	Drench immediately after planting	Not yet applied in US, but approved in EU	No
SoilGard 12G Microbial Fungicide	*Gliocladium virens* (12%)	Certis USA, Columbia, MD	239.7 g/100 liters water	Drench >24 h before planting	Yes	No
Subtilex Biological Fungicide	*Bacillus subtilis* (2.75%)	Becker Underwood, Ames, IA	15.6 g/100 kg seed	Slurry seed treatment	No	No

Table 1. Continued.

Treatment[b]	Active ingredient (rate in product)	Registrant or manufacturer	Rate of application of product[c]	Method of application	OMRI-listed[d]	Registered for spinach in WA State in 2007[e]
T-22 Planter Box Biological Fungicide	*Trichoderma harzianum* T-22 (1.15%)	BioWorks, Inc., Victor, NY	250 g/100 kg seed	Dry seed coating + drench 4 days after planting	Yes	Yes
Yield Shield Concentrate Biological Fungicide	*Bacillus pumilus* (0.28%)	Bayer CropScience	6.26 g/100 kg seed	Slurry seed treatment	Yes	No
Apron XL LS	Mefenoxam (33%)	Syngenta Crop Protection, Greensboro, NC	20.8 ml/100 kg seed	Slurry seed treatment	No	Yes
Mertect 340F	Thiaben-dazole (42.3%)	Syngenta Crop Protection	122.4 ml/100 kg seed	Slurry seed treatment	No	No
Terraclor 75% WP	Pentachloro-nitrobenzene (75%)	Crompton Uniroyal Chemical, Middlebury, CT	59.9 g/100 liters water	Drench immediately after planting	No	No
Non-treated seed	-	-	-	-	-	-

[a] Each trial was set up as a randomized complete block design with 4 or 5 replications. Each experimental unit consisted of one 30.5 cm x 30.5 cm x 6.4 cm tall flat containing 1,200 g wetted potting mix (Sunshine Organic Growers Mix, Sun Gro Horticulture, Bellevue, WA) inoculated with the selected pathogen at a rate determined by inoculation rate trials, and planted with 6 rows of 6 seed of the spinach hybrid 'Lazio'.

[b] Products were selected for evaluation against each of the three pathogens. Not all products were approved by the USDA National Organic Program (NOP) or the Organic Materials Review Institute (OMRI) for use in organic systems in 2007. Apron XL LS, Mertect 340F, and Terraclor 75% WP were included as conventional fungicide seed or drench treatments for control of *Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp., respectively. Non-treated seed was included as a control treatment.

[c] Each product was evaluated at the highest recommended label rate for spinach and/or a crop with similar size seed to spinach, or according to registrant recommendations. Drench treatments were applied according to the labels based on surface area or volume of potting medium treated.

[d] The OMRI provides organic certifiers, growers, manufacturers, and suppliers an independent review of products intended for use in certified organic production, handling, and processing in the U.S. (http://www.omri.org/). "Not yet applied" means registrant had not yet applied for OMRI approval.

[e] Approved by the Washington State Department of Agriculture for use on certified organic spinach crops in Washington State in 2007.

[f] Ingredients of the compost tea included vermicompost (50 ml), seaweed powder (1 ml), liquid humic acids (2 ml), and Azomite rock dust (3 g) per 1 liter water brewed aerobically for 18-24 h, applied as 0.6 liters tea/experimental unit (Scheuerell and Mahaffee, 2004). The compost tea was brewed by C. Crosby at Washington State University, Pullman, WA.

[g] PGPR Galaxy contains *Bacillus azotofixans*, *Azotobacter chroococcum*, *Pseudomonas putida*, and *Pseudomonas fluorescens* (each at 304 x 10^9 cells/liter).

Table 2. Greenhouse evaluation of seed and drench treatments for control of *Pythium ultimum* as a damping-off pathogen of spinach[z].

	Trial 1					Trial 2				
		% Damping-off[x]					% Damping-off			
Treatment[y]	% Emergence	Pre-emergence	Post-emergence	Total	Total dry weight (g)[w]	% Emergence	Pre-emergence	Post-emergence	Total	Total dry weight (g)
Compost tea	80.0 b	11.1 e	16.6 e	27.7 d	4.09 c	62.8 de	28.9 ab	47.2 abcde	71.7 abc	1.24 g
Experimental #1	95.6 a	0.0 f	3.5 fg	3.5 f	5.39 ab	92.2 a	0.6 e	15.8 gh	16.3 d	4.37 ab
Experimental #2	95.6 a	0.6 f	6.4 f	7.0 e	6.06 a	95.6 a	0.0 e	29.5 fgh	29.5 d	3.70 bc
Kodiak	79.5 b	11.1 e	43.5 cd	54.6 c	2.61 d	7222 bc	19.4 cd	31.1 defg	50.6 bc	3.09 cd
Micro 108	67.2 de	23.3 bc	41.3 d	64.6 bc	2.30 def	73.9 b	17.8 d	34.4 bcdefg	52.2 bc	2.65 cde
Mycostop Mix	67.8 de	22.8 bc	59.4 ab	81.9 ab	1.87 f	73.3 b	18.3 d	36.7 bcdef	52.2 c	2.80 cd
Natural II	93.9 a	1.7 f	0.6 g	2.3 f	4.49 bc	54.5 e	37.2 a	64.1 a	91.0 a	1.24 g
Natural X	90.6 a	2.8 f	7.4 f	10.2 e	4.03 c	68.3 bc	23.3 cd	32.2 efg	55.5 bc	2.70 cde
PGPR Galaxy	71.1 bcde	19.5 bcd	51.8 abcd	71.2 abc	2.30 def	71.1 bc	20.6 cd	30.1 efg	50.6 bc	2.78 cd
Prestop	47.8 f	42.8 a	57.3 ab	95.4 a	0.85 g	55.6 de	36.1 ab	54.1 ab	85.6 a	1.34 fg
Soilgard 12-G	64.4 e	26.1 ab	41.4 d	67.5 bc	2.41 def	48.3 e	43.3 a	51.6 abcd	89.4 a	1.40 fg
Subtilex	75.0 bcd	15.6 cde	50.6 abcd	66. 1 abc	2.56 de	85.6 a	6.7 e	11.2 hi	17.8 d	3.06 cd
T-22 Planter Box	69.4 cde	21.1 bcd	54.7 abc	75.8 abc	1.99 def	72.8 b	18.9 d	57.8 a	76.7 abc	1.76 efg
Yield Shield	78.3 bc	12.2 e	61.3 a	73.5 abc	1.95 ef	66.1 cd	25.6 bc	53.2 abc	78.7 ab	2.16 def
Apron XL LS	94.4 a	0.0 f	2.4 fg	2.4 f	5.07 b	91.1 a	1.7 e	3.7 ij	5.4 e	4.61 ab
Non-treated seed in inoculated medium	77.8 bc	12.8 de	48.5 bcd	61.3 bc	2.28 def	72.2 bc	19.4 cd	33.0 cdefg	52.5 bc	2.82 cd
Non-treated seed in non-inoculated medium	90.6 a	0.0 f	3.7 fg	3.7 f	4.55 bc	91.7 a	0.0 e	1.8 j	1.8 e	5.20 a
LSD (Pr < 0.05)[v]	9.09	Rank	Square root	Log	Log	Rank	Rank	Arcsin	Log	Arcsin

[z] This table presents results of two *P. ultimum* greenhouse trials evaluating seed and drench treatments on spinach for use in organic production. A randomized complete block design with five replications was used for each trial. Each experimental unit consisted of one 30.5 cm x 30.5 cm x 6.4 cm tall flat containing 1,200 g moistened organic potting mix (Sunshine Organic Growers Mix, Sun Gro Horticulture, Bellevue, WA) inoculated with the pathogen at a rate determined by inoculation rate trials. Six rows of six seed of the spinach hybrid 'Lazio' were planted in each flat. The number of emerged seedlings and the number of wilted seedlings was recorded at weekly intervals for 4 or 5 weeks. Results are shown for the final rating (35 and 28 days for trials 1 and 2, respectively).

[y] Not all products were EPA-registered or reviewed for compliance with the USDA National Organic Program (NOP) or the Organic Materials Review Institute (OMRI) in 2007. Refer to Table 1 for details of the treatments. Apron XL LS (mefenoxam) was included as a conventional fungicide seed treatment for control of *P. ultimum*. For both control treatments, the seed was not treated. For all treatments except the non-treated seed planted into non-inoculated medium, seed was planted into potting mix that was inoculated with *P. ultimum* at a rate of 1,000 cfu/g (w/w).

[x] Pre-emergence damping-off was determined as a percentage of non-emerged seedlings in each flat compared to the non-inoculated control flats in each replication. Post-emergence damping-off was determined as the percentage of emerged seedlings in each flat that died or exhibited damping-off symptoms. Total damping-off was determined as pre- plus post- emergence damping-off.

[w] Biomass was determined as above-ground dry weight (g) of all the emerged seedlings present in each flat at the final rating. The seedlings were cut at the soil line, and the tissue was dried and weighed.

[v] LSD = Fisher's protected least significant difference. Means followed by the same letter within a column are not significantly different. 'Log', 'square root', 'arcsin', or 'rank' indicate the original mean values are presented, but means separation by LSD was based on transformation (logarithmic, square root, or arcsin square root transformation) or Friedman's non-parametric rank test of the data because of heterogeneous variances and/or non-normal distribution of residuals.

Table 3. Greenhouse evaluation of seed and drench treatments for control of *Rhizoctonia solani* as a damping-off pathogen of spinach[z].

	Trial 1					Trial 2				
		% Damping-off[x]					% Damping-off			
Treatment[y]	**% Emergence**	**Pre-emergence**	**Post-emergence**	**Total**	**Total dry weight (g)[w]**	**% Emergence**	**Pre-emergence**	**Post-emergence**	**Total**	**Total dry weight (g)**
Compost tea	44.4 cd	46.5 fg	15.7 abcde	62.3 cd	1.78 bcdef	65.0 f	15.0 a	4.7 a	19.7 a	1.92 i
Experimental #1	63.9 ab	27.1 hi	11.7 bcdef	38.8 de	3.89 a	79.4 abc	5.0 bcde	3.4 a	8.4 a	4.74 ab
Experimental #2	41.0 cd	50.0 fg	16.5 abcd	66.5 cd	1.75 bcd	78.3 abcd	3.9 cde	7.6 a	11.5 a	4.78 ab
Kodiak	22.9 fgh	68.1 bcd	17.1 abcd	84.3 ab	0.97 fghij	80.0 abc	5.0 cde	4.9 a	9.9 a	4.08 bcde
Micro 108	27.1 fgh	63.9 bcd	11.8 bcdef	75.6 bc	0.81 ghij	78.9 abc	5.6 abcde	7.4 a	12.9 a	3.92 cde
Mycostop Mix	20.1 ghi	70.8 abc	22.9 abc	90.3 ab	0.60 ijk	85.6 a	0.6 e	4.0 a	4.5 a	4.18 abcd
Natural II	65.6 abc	27.2 ghi	8.5 cdef	35.7 de	2.17 bcde	81.1 abc	3.3 cde	3.4 a	6.7 a	4.42 abc
Natural X	41.7 bcd	48.2 fgh	13.4 bcdef	61.6 cd	2.03 abc	73.9 bcdef	5.0 abcde	6.5 a	11.5 a	3.52 def
PGPR Galaxy	16.0 hi	75.0 ab	11.3 cdef	86.1 ab	0.53 jk	75.6 abcde	9.5 abc	7.0 a	16.5 a	4.24 abcd
Prestop	34.7 de	56.3 ef	7.1 def	63.4 cd	1.31 efgh	66.1 ef	12.8 ab	6.2 a	19.0 a	2.47 hi
Soilgard 12-G	32.6 def	58.3 def	22.2 abc	80.4 ab	1.04 fghi	68.3 def	10.0 abc	7.4 a	17.4 a	3.10 fgh
Subtilex	38.9 de	52.1 ef	26.2 ab	77.3 abc	1.19 defgh	75.0 bcdef	6.1 bcde	8.4 a	14.5 a	3.77 cdef
T-22 Planter Box	27.8 efg	63.2 cde	28.9 a	87.9 ab	1.47 cdefg	72.2 cdef	8.9 abcd	3.4 a	12.3 a	4.27 abcd
Yield Shield	0.0 i	91.0 a	0.0 f	91.0 a	0.00 k	80.6 abc	2.8 bcde	11.5 a	14.3 a	3.85 cdef
Terraclor	81.3 a	10.4 i	1.7 ef	12.1 e	3.54 a	81.1 abc	2.3 bcde	0.7 a	3.5 a	2.70 ghi
Non-treated seed in inoculated medium	23.6 fgh	67.4 bcd	7.2 def	74.6 bc	0.76 hijk	82.8 ab	1.7 de	4.7 a	6.4 a	4.93 a
Non-treated seed in non-inoculated medium	91.0 a	0.0 i	1.5 ef	1.5 e	2.57 ab	78.3 abcd	0.0 e	1.6 a	1.6 a	3.28 efg
LSD ($Pr < 0.05$)[v]	Rank	Rank	14.54	Rank	Rank	10.36	Rank	NS	NS	0.806

[z] This table presents results of two *R. solani* greenhouse trials evaluating seed and drench treatments on spinach for use in organic production. A randomized complete block design with four or five replications was used (trials 1 and 2, respectively). Each experimental unit consisted of one 30.5 cm x 30.5 cm x 6.4 cm tall flat containing 1,200 g moistened organic potting mix (Sunshine Organic Growers Mix, Sun Gro Horticulture, Bellevue, WA) inoculated with the pathogen at a rate determined by inoculation rate trials. Six rows of six seed of the spinach hybrid 'Lazio' were planted in each flat. The number of emerged seedlings and the number of wilted seedlings was recorded at weekly intervals for four weeks. Results are shown for the final rating (28 days).

[y] Not all products were EPA-registered or reviewed for compliance with the USDA National Organic Program (NOP) or the Organic Materials Review Institute (OMRI) in 2007. Refer to Table 1 for details of the treatments. Terraclor 75% WP (PCNB) was included as a conventional fungicide drench treatment for control of *R. solani*. For both control treatments, the seed was not treated. For all treatments except the non-treated seed planted into non-inoculated medium, seed was planted into potting mix that was inoculated with *R. solani* at a rate of 50,000 or 25,000 cfu/g (w/w) for trials 1 and 2, respectively.

[x] Pre-emergence damping-off was determined as a percentage of non-emerged seedlings in each flat compared to the non-inoculated control flats in each replication. Post-emergence damping-off was determined as the percentage of emerged seedlings in each flat that died or exhibited damping-off symptoms. Total damping-off was determined as pre- plus post- emergence damping-off.

[w] Biomass was determined as above-ground dry weight (g) of all the emerged seedlings present in each flat at the final rating. The seedlings were cut at the soil line, and the tissue was dried and weighed.

[v] LSD = Fisher's protected least significant difference. Means followed by the same letter within a column are not significantly different. 'Rank' indicates the original mean values are presented, but means separation by LSD was based on Friedman's non-parametric rank test of the data because of heterogeneous variances and/or non-normal distribution of residuals. 'NS' indicates that the means were not significantly different for that dependent variable.

Table 4. Greenhouse evaluation of seed and drench treatments for control of *Fusarium oxysporum* f. sp. *spinaciae* as a wilt pathogen of spinach[z].

	Trial 1					Trial 2				
		% Wilt[x]					% Wilt			
Treatment[y]	% Emergence	Pre-emergence	Post-emergence	Total	Total dry weight (g)[w]	% Emergence	Pre-emergence	Post-emergence	Total	Total dry weight (g)
Compost tea	90.6 abcde	5.0 bcdefg	28.4 gh	33.4 g	6.64 a	74.4 abc	7.8 cde	11.7 de	19.5 d	12.95 bcd
Experimental #1	93.3 abcd	2.2 defg	56.5 abc	58.7 bcd	4.03 efg	73.9 abc	8.3 abc	19.1 cd	27.5 abcd	13.71 ab
Experimental #2	93.8 abc	1.1 fg	54.0 abcd	55.4 cde	3.50 fgh	67.8 cde	13.3 bc	20.3 bcd	33.7 abc	12.37 cde
Kodiak	90.6 abcde	3.3 cdefg	60.7 ab	64.0 abc	3.21 ghi	76.1 abc	8.9 abc	26.5 abc	35.4 abc	11.60 ef
Micro 108	83.3 ef	10.6 abcd	44.5 cdef	55.1 cde	3.00 hij	57.8 e	20.6 ab	26.6 abc	47.2 a	10.51 f
Mycostop Mix	92.8 abcd	2.8 cdefg	53.9 abcd	56.7 cd	3.32 gh	73.3 bcd	6.7 cd	24.3 abc	31.0 abc	12.63 de
Natural II	88.3 bcde	5.6 abcdef	33.7 efgh	39.3 efg	4.23 def	83.9 ab	4.4 cde	25.6 abc	30.1 abc	12.40 de
Natural X	96.7 a	1.7 fg	43.3 cdefg	44.9 defg	4.03 efg	87.2 a	1.7 de	21.3 bcd	23.0 cd	12.85 cde
PGPR Galaxy	90.6 abcde	6.7 bcdef	55.8 abc	62.5 abc	3.23 ghi	80.6 abc	5.6 cde	34.4 a	39.9 abc	12.44 de
Prestop	85.6 def	8.3 abcde	25.5 h	33.8 g	4.65 cde	60.0 de	20.0 a	11.6 de	31.6 abc	11.74 ef
Soilgard 12-G	84.4 ef	12.2 ab	66.5 a	75.0 ab	2.40 ij	73.9 abc	9.4 cd	31.8 ab	41.3 abc	11.82 de
Subtilex	91.1 abcde	3.9 cdefg	33.2 fgh	37.1 fg	5.06 bcd	72.2 bcd	11.1 cde	29.5 abc	40.6 ab	12.71 cde
T-22 Planter Box	80.0 f	13.9 a	66.1 a	77.7 a	2.14 j	83.9 ab	1.7 cde	26.0 abc	27.7 abc	13.27 bcd
Yield Shield	86.7 cdef	8.9 abc	22.3 hi	31.2 g	5.81 ab	77.2 abc	6.7 cde	23.0 abcd	29.7 abcd	11.78 ef
Mertect 340F	92.8 abcd	3.3 cdefg	48.3 bcde	51.6 cdef	3.54 fgh	85.0 ab	3.3 cde	21.9 bcd	25.3 bcd	13.44 abc
Non-treated seed in inoculated medium	95.6 ab	2.2 efg	40.7 defg	42.9 defg	3.48 fgh	79.4 abc	3.9 cde	26.1 abc	29.9 abc	12.85 cde
Non-treated seed in non-inoculated medium	93.9 abc	0.0 g	10.2 i	10.2 h	5.17 bc	77.8 abc	0.0 e	0.7 e	0.7 e	14.90 a
LSD ($Pr < 0.05$)[v]	7.95	Log	14.97	16.36	0.908	13.44	Rank	12.19	Log	Rank

[z] This table presents results of two *F. oxysporum* f. sp. *spinaciae* greenhouse trials evaluating seed and drench treatments on spinach for use in organic production. A randomized complete block design with five replications was used for each trial. Each experimental unit consisted of one 30.5 cm x 30.5 cm x 6.4 cm tall flat containing 1,200 g moistened organic potting mix (Sunshine Organic Growers Mix, Sun Gro Horticulture, Bellevue, WA) inoculated with the pathogen at a rate determined by inoculation rate trials. Six rows of six seed of the spinach hybrid 'Lazio' were planted in each flat. The number of emerged seedlings and the number of wilted seedlings was recorded at weekly intervals for six or seven weeks. Results are shown for the final rating (42 or 49 days for trials 1 and 2, respectively).

[y] Not all products were EPA-registered or reviewed for compliance with the USDA National Organic Program (NOP) or the Organic Materials Review Institute (OMRI) in 2007. Refer to Table 1 for details of the treatments. Mertect 340F (thiabendazole) was included as a conventional fungicide seed treatment for control of *F. oxysporum* f. sp. *spinaciae*. For both control treatments, the seed was not treated. For all treatments except the non-treated seed planted into non-inoculated medium, seed was planted into potting mix that was inoculated with *F. oxysporum* f. sp. *spinaciae* at a rate of 10,000 cfu/g (w/w).

[x] Pre-emergence damping-off was determined as a percentage of non-emerged seedlings in each flat compared to the non-inoculated control flats in each replication. Post-emergence damping-off was determined as the percentage of emerged seedlings in each flat that died or exhibited damping-off symptoms. Total damping-off was determined as pre- plus post- emergence damping-off.

[w] Biomass was determined as above-ground dry weight (g) of all the emerged seedlings present in each flat at the final rating. The seedlings were cut at the soil line, and the tissue was dried and weighed.

[v] LSD = Fisher's protected least significant difference. Means followed by the same letter within a column are not significantly different. 'Log', or 'rank' indicate the original mean values are presented, but means separation by LSD was based on transformation (logarithmic transformation) or Friedman's non-parametric rank test of the data, respectively, because of heterogeneous variances and/or non-normal distribution of residuals

Table 5. Evaluation of seed and drench treatments for organic management of soilborne diseases of spinach in Mount Vernon and Vancouver, WA, 2007.

Field site, pathogen inoculation, and seed and/or drench treatment (rate/100 kg seed or rate/100 liters water)[z]	Emergence (dap)[y]		AUPC[x]		Dry biomass (g)[w]
	7	35 or 42	Emergence	Disease	
Mount Vernon, WA					
Pathogen inoculation					
Non-inoculated	10.2 a[v]	92.3 a	3018 a	163 a	79.5 a
P. ultimum	8.4 a	87.6 a	2778 b	162 a	71.5 b
F. oxysporum f. sp. *spinaciae*	6.0 b	70.9 b	2375 c	212 a	55.5 c
LSD	Log	5.01	168.8	NS	6.48
Seed and/or drench treatment					
Non-treated seed	6.1 b	97.7 ab	3179 ab	239 a	71.3 b
Combination conventional fungicides[u]	4.5 b	103.7 a	3301 a	127 a	88.9 a
Compost tea 50 liter	1.3 c	63.0 d	2059 d	105 a	60.2 bc
Experimental #1	29.0 a	65.5 d	2248 d	130 a	62.0 bc
Experimental #2	28.4 a	59.4 d	2150 d	144 a	53.2 c
Kodiak Concentrate Biological Fungicide 31.2 g	3.7 b	86.4 c	2786 c	157 a	68.0 b
Micro 108 Seed Inoculant 1.76 kg + Actinovate AG 2.58 g	3.3 bc	84.9 c	2780 c	219 a	71.7 b
Natural II 750.7 g	4.4 b	90.0 bc	2936 bc	218 a	70.7 b
Natural X 750.7 g	3.9 b	90.9 bc	2884 bc	221 a	72.7 b
SoilGard 12G Microbial Fungicide 239.7 g	5.2 b	86.9 c	2771 c	175 a	70.8 b
Subtilex Biological Fungicide 15.6 g	4.2 b	88.8 bc	2833 c	211 a	68.3 b
Yield Shield Concentrate Biological Fungicide 6.26 g	4.3 b	85.7 c	2755 c	204 a	68.3 b
LSD	Log	10.03	337.6	NS	12.96
Vancouver, WA					
Pathogen inoculation					
Non-inoculated	1.2 a	57.5 a	1426 a	35 c	79.5 a
P. ultimum	1.6 a	56.5 a	1401 a	44 b	80.6 a
F. oxysporum f. sp. *spinaciae*	1.8 a	57.5 a	1464 a	62 a	74.4 a
LSD	Rank	4.11	96.7	9.0	6.90
Seed and/or drench treatment					
Non-treated seed	0.9 cd	62.2 a	1543 ab	46 bc	80.4 ab
Combination conventional fungicides[u]	0.5 d	61.1 a	1502 ab	54 ab	73.8 bc
Compost tea 50 liter	2.2 bcd	44.5 c	1081 c	39 bc	61.5 c
Experimental #1	5.5 a	51.2 bc	1403 b	40 bc	92.0 a
Experimental #2	2.9 ab	60.3 a	1535 ab	69 a	80.1 ab
Kodiak Concentrate Biological Fungicide 31.2 g	0.4 d	64.8 a	1606 a	47 bc	92.1 a
Micro 108 Seed Inoculant 1.76 kg + Actinovate AG 2.58 g	1.3 bcd	45.7 c	1159 c	42 bc	69.4 bc
Natural II 750.7 g	1.1 cd	61.1 a	1516 ab	43 bc	80.9 ab
Natural X 750.7 g	0.5 d	61.5 a	1479 ab	35 c	74.4 bc
SoilGard 12G Microbial Fungicide 239.7 g	2.9 abc	48.7 c	1198 c	47 bc	71.1 bc
Subtilex Biological Fungicide 15.6 g	0.3 d	65.5 a	1661 a	53 ab	81.7 ab
Yield Shield Concentrate Biological Fungicide 6.26 g	0.3 d	58.9 ab	1473 ab	52 abc	79.9 ab
LSD	Rank	8.22	193.4	17.9	13.80

[z] Each treatment applied as a seed treatment at the rate shown/100 kg seed, except for the compost tea, Actinovate AG, and SoilGard 12G Microbial Fungicide treatments which were each applied as a soil drench at the rate shown/100 liters water. Ingredients of the compost tea included vermicompost (5 liters), seaweed powder (100 ml), liquid humic acids (200 ml), and Azomite rock dust (300 g), which were aerated in 95 liters water for 24 h prior to application (Scheuerell and Mahaffee, 2004). The compost tea was applied as 3.79 liters tea in 7.57 liters water per split-plot. Actinovate AG was applied as 0.2 g product dissolved in 7.57 liters water per split plot. SoilGard 12G Microbial Fungicide was applied as 70.94 g product suspended in 23.65 liters water per split plot.

[y] The Mount Vernon and Vancouver field trials were carried out for 42 and 35 d, respectively.

[x] Area under progress curves (AUPCs) for emergence and post-emergence disease (damping-off or wilt). AUPC is a cumulative measure of emergence or disease ratings over time: $[(\Sigma(y_i + y_{i+1}/2)(t_i - t_{i+1})]$, where y_i = the number of emerged or diseased seedlings at the i^{th} rating, y_{i+1} = the number of emerged or diseased seedlings at the (i+1) rating, t_i = the number of days at the i^{th} rating, and t_{i+1} = the number of days at the (i+1) rating.

[w] Above-ground dry weight of plants sampled at the final rating (35 or 42 dap).

[v] For main plot pathogen inoculations, and for split plot seed and/or drench treatments, each mean is averaged over five replications and all levels of the other factor. At each location, main plot means followed by the same letter within a column are not significantly different based on Fisher's protected least significant difference (LSD) at $P < 0.05$; similarly for split plot means. Means are not presented for the interaction of pathogens with seed or drench treatments because the interaction term in the analysis of variance was not significant for any dependent variable. Log = original means presented but means separation is based on logarithmic transformation to meet requirements for parametric statistical analyses. Rank = original means presented, but means separation is based on Friedman's non-parametric rank test because assumptions for parametric analyses could not be met using transformations.

[u] A combination conventional fungicide treatment consisting of seed treatment with Apron XL LS (20.8 ml/100 kg seed) and Mertect 340F (122.4 ml/100 kg seed), and a drench with Terraclor 75% WP (59.9 or 30.0 g/100 liters water at Mount Vernon and Vancouver, respectively) for control of *Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp., respectively.

Table 6. Evaluation of seed and drench treatments for organic management of soilborne diseases of spinach in Sequim, WA, 2007.

Seed and/or drench treatment (rate/100 kg seed or rate/100 liters water)[z]	Emergence (35 d)	Damping-off (7 d)	AUEPC[y]	Dry biomass (g)
Non-treated seed	129.2 bcd[x]	1.4 a	3996 bcd	146.6 abc
Compost tea 50 liter	163.6 ab	0.8 ab	4558 ab	170.6 ab
Kodiak Concentrate Biological Fungicide 31.2 g	92.0 e	0.4 b	3200 e	119.2 c
Micro 108 Seed Inoculant 7.16 kg + Actinovate AG 2.58 g	194.4 a	0.2 b	5179 a	176.4 a
Mycostop Mix 625.7 g	125.2 cde	0.8 ab	4334 ab	137.4 bc
PGPR Galaxy 223 ml	117.2 cde	0.0 b	3546 cde	113.4 c
SoilGard 12G Microbial Fungicide 239.7 g	143.2 bc	0.0 b	4261 bc	132.0 c
T-22 Planter Box 250 g	118.0 cde	0.6 ab	3797 bcde	115.8 c
Yield Shield 6.26 g	106.0 de	1.2 a	3352 de	131.2 c
LSD	35.65	Rank	Log	37.24

[z] Each treatment was applied as a seed treatment at the rate shown/100 kg seed, except for compost tea, Actinovate AG, and SoilGard 12G Microbial Fungicide which were each applied as a soil drench at the rate shown/100 liters water. Ingredients of the compost tea included vermicompost (5 liters), seaweed powder (100 ml), liquid humic acids (200 ml), and Azomite rock dust (300 g), which were aerated in 95 liters water for 24 h prior to application (Scheuerell and Mahaffee, 2004). The compost tea was applied as 7.58 liters tea in 15.16 liters water/plot. Actinovate AG was applied as 0.39 g product in 15.14 liters water/plot. SoilGard 12G Microbial Fungicide was applied as 141 g product suspended in 47.31 liters water/plot.

[y] AUEPC is a cumulative measure of emergence over time: $[(\Sigma(y_i + y_{i+1}/2)(t_i - t_{i+1})]$, where y_i = the number of emerged seedlings at the i^{th} rating, y_{i+1} = the number of emerged seedlings at the (i+1) rating, t_i = the number of days at the i^{th} rating, and t_{i+1} = the number of days at the (i+1) rating.

[x] Each mean is averaged over five replications. Means followed by the same letter within a column are not significantly different based on Fisher's protected LSD at $P < 0.05$. Log = original means presented but means separation is based on logarithmic transformation to meet requirements for parametric statistical analyses. Rank = original means presented, but means separation is based on Friedman's non-parametric rank test because assumptions for parametric analyses could not be met using transformations

Cover Crop Seed Production

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On my certified organic farm in Canby, Oregon, I grow organic crimson clover, red clover, and faba bean seed. I also grow organic pumpkins, squash, sweet corn and peppers. I am a third generation farmer and I grew up raising conventional grass seed. Approximately eight years ago I transitioned 50 acres of ground to organic, and the farm has been 100% organic ever since.

Rotation and Crop Establishment

The cover crop seeds I grow fall in between my row crops within my rotation system. This is important because the mechanical and hand weed control in the row crops will help with weed control in following years of seed crops. My four-year rotation is squash or pumpkins, red clover, sweet corn or peppers, and crimson clover.

When the field is in squash, care is taken to do a good job of cultivation for weed control. The field is direct seeded and a tine weeder is used for early weed control. Every 5 days the ground is gone over with the tine weeder to kill newly germinated weeds. The squash grow well even with the rough treatment of the tine weeder. When the plants get too big to withstand the tine weeder, then we run the cultivator between the rows and hand hoe within the rows. By keeping the squash clean of weeds through cultivation, I can kill several generations of weed seeds and get a cleaner seed bed for the red clover seed crop the following year. When the canopy of the squash plants are just about to close over, I broadcast red clover seed into the squash and do my last row cultivation. The red clover seed crop gets a competitive advantage because it establishes well in the shade of the squash, summer weeds are choked out by the lack of sunlight, and the top few inches of soil has had much of the weed seed killed so there are fewer germinating new weeds. This technique works well in almost any irrigated above ground summer crop that does not require soil disturbance for harvest.

Crimson clover is planted in the same fashion into corn or peppers. The only difference is that the crimson clover must be planted closer to October, to avoid the crimson clover going to seed in the late fall. This technique works well for the establishment of a green manure cover crop as well. Establishment costs are reduced when you broadcast the winter cover crop into the summer cash crop and use a cultivation pass to incorporate the seed. This practice can also lead to better ground cover over the rainy winter months by getting a head start on establishment of the winter cover crop.

Harvesting

Growing organic clover seed has provided my farm with a good rotation system. Growing a cover crop seed was an easy transition for me because of my background in grass seed production. I already had most of the equipment needed. My seed cleaning has had mixed results and I am considering investing in my own seed cleaner.

Marketing and Benefits

The large poundage of cover crop seed required by farmers makes delivery expensive. Because of this expense, I tend to focus on the local market. I sell most of my organic cover crop seed directly to farmers. The financial return per acre is not as great for my cover crop seed as for my vegetable crops. I accept this because I like having legume cover crops in my rotation system for long periods of time. In the case of red clover, the red clover crop will cover the soil for at least 1 ½ years of my 4 year rotation. This leads to better nitrogen levels and better soil quality overall. Due to these benefits, cover crop seed production has been successful for my farm.

Cover Crop and Grain Seed Production

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Introduction

My presentation will discuss growing grain and cover crop seeds. I will discuss a whole spectrum of growing conditions and problems for amounts of grain ranging from a few hundred pounds to several tons. I will also discuss production techniques, equipment needs, and adjustments that can be made for farms not usually set up for grain production. The advantages of producing your own organic grain for cover crop seed, feed for animals, and as another product for off-farm sales will also be illustrated.

Farm Background

Our farming operation has for the last 25 years or so been a diversified vegetable row crop operation. We produce, pack and ship wholesale, and sell retail at farmers markets and at a farm store about 30 different vegetable crops produced on about 180 acres. Our whole farming venture manages about 400 acres within the Dungeness River Delta of the North Olympic Peninsula of Washington State. About 10% of our land is devoted to wildlife habitat, such as a barley grain plantings which is left standing in the field for bird feed and habitat.

We have been a certified organic farm since the late 1970's, and have experienced the growth that a good part of organic agriculture has seen. Farming within a river delta means we have a silty loam soil, some well drained and some not so well drained. Early on I was interested in grain and other seed crops as a source for my cover crop seed material for our soil fertility program. Having a readily available source of organic cover crop and grain seed allows us to use plant-based soil building techniques which would otherwise be too expensive if you had to purchase the cover crop or grain seed. We do not purchase fertilizers for our farm. I think for the total time I have been farming, maybe I have purchased 2 tons of fertilizer. Cover cropping is our primary means of soil fertility building, but we also make some compost applications.

Cover Crop and Grain Seed Production

We grow a cover crop each year in every field as part of our crop rotation plan. This means that each year we have in excess of 200 acres planted to cover crops. Annual rye grain interplanted with a vetch is our primary cover crop choice. At 100 lbs. annual rye grain seed per acre, this amounts to 10 tons of annual rye grain seed per year that we use on our farm. I have found it much easier and less expensive to grow this seed on our farm as opposed to sourcing the grain within our northwest region. I am not even sure that we could find organic seed within a reasonable shipping distance and at a reasonable price.

The last few years we have let about 5 plus acres of our September planted winter cover cropped land mature into a seed crop. We plant and grow our vetch with the rye, and the vetch will climb up into the rye crop. Vetch seems to do very well on our heavier wet soils and will become the dominant crop in the interplanting. The rye will often lodge because of the heavy vetch growth. Rye is a tall crop and usually reaches at least 6 feet in height at maturity. Lodging of the rye crop can be a problem due to the vetch or in areas of heavy wind and on poorly drained soils. In our area, rye grain for seed is usually ready for harvest in mid August.

A crop that produces 6 feet of straw leaves a considerable amount of biomass on the field after harvest. This is quickly turned into a soil fertility building advantage, with a couple of passes with our heavy Kello cover crop disc. Any mature seed that has passed through the grain harvest combine will sprout and grow into a very nice green cover just in time for fall rains. The next spring, we incorporate the green cover crop at the boot stage (seed head is formed in the stalk, but not yet emerged). This gives us a field ready for a May planting. The field will have abundant fertility and a big boost in stable soil organic matter.

Several years ago I started raising some laying hens for eggs for our farm store, and I finished some feeder pigs. We were buying barley from another farmer in the area for feed at that time. We are now raising our own barley, using our own seed saved from the last years harvest. Last year we harvested about 25 acres of barley grain and seed. Barley is probably one of the easiest and fastest ways to capture sunlight into grain. We try to plant our barley in April, the earlier the better, and harvest in early September. Barley grain yields are about 2 tons per acre. I have tried a September barley planting and I prefer it over Spring planting. Unfortunately a challenge for our farm is that many of our vegetable crops are harvested in the fall and winter, and the fields are not ready for replanting until late winter or early spring. Another major issue with a winter barley crop appears to be a leaf rust that attacks the crop during the winter season but does not seem to have an impact on a spring planted crop.

Barley is a good fit in our vegetable rotations as it provide us with a way to move out of vegetables for a year and to build up some durable organic matter with its straw. With the price of feed grains now on the rise this is one more good reason for us to produce our own grain and seed. The eggs and pork are also two more products our farm has to offer to our community and these would not be possible without producing our own feed grain. This year we will feed out maybe 60 feeder pigs.

Triticale is another grain we have experimented with for the last 5 or 6 years. Triticale is a cross between rye and wheat, it is a hull-less grain, and looks similar to wheat. Chickens seem to prefer triticale to barley. We have not yet raised more than a few tons of triticale in any one year. Triticale can be planted in early spring, as early as a good seed bed can be prepared and no later than early May as it takes a bit longer to mature than barley. Fall planting works best, but again we have had some rust problems with fall planted triticale.

Buckwheat is a good summer crop for cover cropping and for bee forage, and it is another grain feed source. We find buckwheat grain/seed is relatively easy to grow and is such a quick growing crop that it can be planted twice during the year. First, in May or early June, and second as a late season crop following an early spring vegetable crop, seeding no later than July 15. A July planting will still mature but it is a little risky given our fall rains and cool temperatures. For both plantings, we seed about 80 lbs to the acre.

Equipment considerations

Equipment needs can vary depending upon your budget and the number of acres being cropped for grain. Some of our first pieces of planting equipment were quite humble and of marginal utility. We first used an old steel wheel 12'MM grain drill that was mostly worn out when we got it and was difficult to move between fields – the steel wheels did not roll well and the disc openers did not raise enough to clear the curved camber of our country roads. For seed harvesting, we first used an old Massy Harris 90 combine from the early 50's.

As our acres planted to cover crop and grain seed increased we upgraded our equipment. We now use a John Deere 95 with a gas engine and a 6600 John Deere with a diesel engine, and we have recently purchased a used International Harvester 10-foot grain drill. If purchasing a grain drill seems beyond your means, you can broadcast the grain seed on top of the prepared seed bed and harrow it in. As with any job, when you are trying to do it without the proper tools there are trade-offs. Broadcasting grain seed requires more seed to get a good stand.

Finding good used older equipment depends upon the area you are farming in. In the Willamette Valley it should be relatively easy to find good used grain equipment. On the North Olympic peninsula we are a 3-hour drive and a ferry ride from the nearest farming community, and this presented some problems. I suggest you ask the field person at your local equipment dealership to find out if someone in your area may be selling their equipment. The field person is usually in contact with other farmers in the area or is in touch with other dealers who may have the equipment you are looking for. Of course the Capital Press classified pages are a good place to look.

Sometimes it is necessary to clean your grain seed, depending on weed contamination and any chaff contamination from harvesting. This becomes especially important if you plan to sell seed. The set-up of your combine harvester can sometimes help in cleaning. Wild mustard seed can be a problem in our fields, but the proper adjustments of the harvester can let that small seed pass on through the machine and not get into the finished seed.

We have installed an older seed cleaner to clean our grain crop. It's a two screen Crippen 243 and will process about a ton in four hours. It also works pretty well for the carrot seeds and other smaller seeds we grow for our own use, such as cauliflower, and cabbage.

Conclusions

We have been growing our own cover crop and grain seed on our farm for about 20 years now. While we are best known for our vegetable crops, our farm's soil fertility is dependent on the cover crop and grain crops that we grow. In addition, we feel it is likely that our vegetable rotation systems that include cover crop and grains likely result in reduced pest issues. More recently, with the addition of chickens and feeder pigs, we have been able to supply our own feed grain for these new farm enterprises. Through cover crops and grains, our farm has become more diversified and therefore more sustainable.

Hybrid Seed Production Techniques for *Cucurbita pepo* in Organic Agricultural Systems

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Summary

Expanding demand for organic produce is driving a need for larger quantities of commercially-available organic seed. Concomitantly, organic producers wish to have the superior qualities realizable in first-generation (F1) hybrids for many crops. Our project seeks to develop a cost-effective, commercial-scale process for producing organically-suitable F1 hybrid seed. High Mowing Seeds has begun by assessing the objective as applied to *Cucurbita pepo* (summer squashes, zucchini, pumpkins, certain winter squashes). Organically-appropriate methods for hybrid seed production in *Cucurbita pepo* typically require labor-intensive techniques such as hand-pollination or hand-emasculation of the female parent.

Using the natural plant hormone ethylene, we have attempted to achieve more consistent results and eliminate 40-50% of the labor of producing organic hybrid seed. While ethylene gas use for this purpose is not specifically allowed under USDA National Organic Program Rules, ethylene is allowed for floral induction, post-harvest ripening, and degreening of certain fruits. With completion of this project, we believe a petition to the National Organic Standards Board for use of ethylene in hybrid seed production is highly likely to succeed. The broader outcome will be substantial increase in organic production with its attendant environmental benefits, improved vegetable varieties, and a significant opportunity for organic seed producers

Introduction

Sales of organic agricultural products are growing at approximately 21% per year (Organic Trade Association, 2004), and increasing numbers of farmers are either starting up small organic farms or transitioning to organic as a means of adding value to agricultural products (Economic Research Service, USDA, 2001). The value-added nature of organic products allows farms to be profitable on a smaller scale and with fewer off-farm inputs, thereby making small family farms more viable and allowing for more diversity within the farm.

The preponderance of research to date pertaining to organic production systems has focused on nutrient management and insect control within organic systems (Organic Agriculture Consortium, www.organicaginfo.org) , with very little research focusing on selection or development of varieties specifically for organic cultivation. Research on developing hybrids for organic vegetable production has not yet been addressed in the literature.

Organic farmers emphasize diversity and soil health, and do not employ synthetic fertilizers, fungicidal seed treatments, herbicides, or synthetic pesticides. Thus selection of "organic" varieties must include traits such as cold-soil germination, disease resistance, weed suppression characteristics, and other traits of benefit for organic farmers. For example, vegetables bred for organic production systems might be selected for prolific root hair development. Vigorous root hairs facilitate better detection and absorption of the finely-distributed nutrients in the humus-rich soil of organic production systems, as compared to soil supplemented with inorganic fertilizer in conventional systems.

Breeding of varieties with heritable disease and pest resistance is especially critical for organic production systems, as organic producers largely rely on the vigor and health of their plants for resistance to attack by pathogens. For certain crops the use of hybrids is especially important for obtaining both vigor and disease resistance. Hybrid varieties for these crops typically outperform open-pollinated (non-hybrid) varieties in terms of vigor, earliness, yield, and uniformity, all of which contributes to disease resistance. Specific introduction of genes conferring disease resistance can also be accomplished by careful choice of parent lines, such that hybrid progeny carry the desired resistance traits together with other target traits.

For crops expressing substantial hybrid vigor, which include spinach, cabbage, broccoli, squash, pepper, tomatoes, and corn, hybrid varieties have become the mainstay of all varieties offered, representing upwards of 85% of all seed sales for these crops (Dr. Mark Hutton, Vegetable Specialist, Maine Cooperative Extension, personal communication, May 2005), Open-pollinated varieties of these species are often hard to find, and frequently offered only as heirloom or specialty varieties, not main crop varieties.

Objectives

For several crops, including cucurbits, hybrid seed is typically produced by means that are not suitable for organic production systems. Within *C. pepo* hybrid seed production, labor inputs required for hand-emasculation are reduced in conventional systems by means of a synthetic ethylene-releasing compound called ethephon (2-chloroethylphosphonic acid, trade names Ethrel™ and Florel™) (Bassett, 1986; Robinson, et al., 1970; Robinson and Decker-Walters, 1997). Synthetic compounds such as ethephon, however, are not allowable in organic production systems as defined by the USDA National Organic Program Rules. As a means to similarly reduce labor costs but in a manner more suitable for organic production systems, we have begun to examine the feasibility of applying the plant hormone ethylene itself as an emasculator, the reasons for which are explained in detail below.

Our choice of *Cucurbita pepo* as our research subject for our Phase I efforts reflects the importance of this species to organic agriculture. Summer squashes and zucchini are a cornerstone of every fresh market operation, and pumpkins and winter squash represent a key niche market for a large number of organic vegetable growers. Cucurbits represent roughly 20% of vegetable seed sales, and F1 hybrids (i.e. first generation progeny from a cross between two distinct parent lines) clearly dominate the market for these crops.

Conventional cucurbit breeding has a long history. *Cucurbita pepo,* as one of the two most economically-important species in the *Cucurbita* genus, has attracted a significant portion of research interest (Whitaker and Davis., 1962). It was determined in early studies that the summer squashes display significant heterosis for early yield, and thus F1 hybrids have become especially important for this group (Bassett, 1986). Breeding for disease resistance in the *Cucurbita* group, however, has lagged behind that for other genera, such as *Cucumis* (cucumber and melon), most likely due to the lack of genetic diversity available in early germplasm pools

(Bassett, 1986, Whitaker and Davis, 1962). However, one advantage of cucurbits is that a number of genes for disease resistance are dominant, such that resistant F1 progeny can be produced from a cross between one resistant and one susceptible parent line (Basra and Robinson, 1999).

Production of hybrids differs among the different cucurbit classes, with cross-pollination typically affected in cucumbers by use of male-sterile (gynoecious) female parent lines, in melons by labor-intensive hand-emasculation and/or hand-pollination due the bisexual nature of the flowers, and in squashes and pumpkins by use of ethylene-releasing compounds to suppress male flower production and promote female flower production among the female parent plants (Basra and Robinson, 1999; George, 1986; Murray, et al., 1997; Robinson, et al., 1970).

The use of the synthetic chemical ethephon (2-chloroethylphosphonic acid) to induce pistillate flower formation was first demonstrated by Robinson, et. al. in 1969. Since that time the use of ethephon in hybrid cucurbit seed production has become deeply entrenched. Ethephon, sprayed at doses of 250-400 ppm, is easy to use and practically eliminates all hand-labor from cucurbit cross-pollination fields (Robinson, et al., 1970; Shannon and Robinson, 1979). Fields are planted in alternating male and female rows, with two female rows for every male row. Female rows are sprayed with ethephon to promote pistillate flowering such that no pollen of the female genotype is available to afford self-pollination. Once hybrid fruit set has been accomplished, male rows are turned under and all newly-formed fruits are discarded, so that all fruit in the field is the product of cross-pollination.

Without having the option to use ethephon to induce pistillate flower formation in organic hybrid cucurbit seed production, we are attempting to determine whether low doses of ethylene gas itself might have comparable effects. Ethylene gas is a naturally-occurring phytohormone produced by all plants, and is in horticultural use as a ripening agent and floral inducer. It is used for ripening tomatoes, bananas, avacadoes, pineapples, and others, as well as for degreening citrus (Krupnick, et al., 1999; Raven, et al., 1992), both in organic and conventional systems. Once released from a chamber, ethylene quickly disperses into the air, leaving no residue. Ethylene has been shown to have gametocidal effects on pollen in rice (Naik and Mohapatra, 1999) and stimulation of ethylene by ethephon promotes pistillate flower formation in a number of plant species, including *Cucurbita* (Robinson, et al., 1970; Shannon and Robinson, 1979; Takahashi and Jaffe, 1984). In cucumbers (*Cucumis melo*), application of ethylene gas in a controlled environment caused plants forming hermaphroditic flowers to switch to formation of pistillate flowers (Byers, et. al., 1972). And then, a 1968 study by Russo, et al. demonstrated that there were no discernible differences in ripening response when bananas were subjected to 100 ppm ethylene gas as compared to 1000 ppm ethephon (then called Amchem 66-329).

It is the unfortunate case, however, that experiments asking whether ethylene gas will directly promote pistillate flower formation when applied to *C. pepo* have not been performed, largely because ethephon was already in use as an ethylene substitute when the role of ethylene in cucurbit sex expression was discovered (Robinson, et al., 1969), and thus all experiments on *C. pepo* were done with ethephon in place of ethylene.

Methods
Given the available data, we believe it should be quite possible to apply ethylene gas to *C. pepo* transplants so as to induce pistillate flower development, and we began by applying the gas for three different application durations and at two different stages of plant development so as best to assess the efficacy of the method (we are unable to modify concentrations of the gas due to technical considerations discussed above and below). To assess feasibility we compared use of ethylene as an emasculation agent to the labor-intensive practice of manual emasculation. For each treatment we compared seed yield and several variables pertaining to seed quality with the total labor inputs and total costs for each method.

2007 Field Plot Design
The controlled experiments began with developing a field plot design to assess the differences between the various ethylene treatment methods as compared to the standard of hand emasculation. We developed our overall experimental design in consultation with Dr. Hutton, and with a view to his extensive cucurbit breeding experience. Given the following eight treatments involving complete emasculation of the female parent, we planted 100 plants (a 200-ft row at 2-ft spacing) each of the female parent treated appropriately, with two replications conducted at two separate locations, for a total of 1600 female plants. Additionally we planted a row of 100 male parent plants for every two rows of females, with male rows on the outsides of the plots, for a total of 1000 male plants in 10 rows. Thus, each of the two ¾-acre plots consisted of eight female and five male six-ft-wide rows. All plants were transplanted into solar plastic mulch to provide season extension and weed suppression, and received fabric row cover to reduce cucumber beetle damage and provide adequate heat for rapid growth.

Treatments:
1. Ethylene gas at 10 ppm for **12 hrs** at the **four-leaf** stage of growth (prior to transplanting)
2. Ethylene gas at 10 ppm for **24 hrs** at the **four-leaf** stage of growth (prior to transplanting)
3. Ethylene gas at 10 ppm for **48 hrs** at the **four-leaf** stage of growth (prior to transplanting
4. Ethylene gas at 10 ppm for **12 hrs** at the **six-leaf** stage of growth (prior to transplanting
5. Ethylene gas at 10 ppm for **24 hrs** at the **six-leaf** stage of growth (prior to transplanting)
6. Ethylene gas at 10 ppm for **48 hrs** at the **six-leaf** stage of growth (prior to transplanting)
7. Mock-treatment of 24 hours in the sealed chamber without gas application, performed on plants at the four-leaf stage of growth
8. Untreated hand-emasculation control

In 2007, male and female parent plants were germinated in a heated research greenhouse at High Mowing Seeds (HMS) in early- to mid-May. Plants to be treated at the six-leaf stage were planted two weeks earlier and then transplanted from plugs to 5-inch pots in early May.

Ethylene gas treatments were conducted in a sealed hoophouse, with clear plastic covering over the ground. Shade cloth was attached over the top of the structure to reduce temperatures inside. Ethylene was generated by means of a commercial ethylene generator developed for fruit ripening, and was monitored by means of a commercial ethylene sensor. Given the requirement for low doses, we could not leave the generator on at even the lowest setting, and thus we employed a timer that turned the generator off and on at specified times. Thus concentrations were not able to be held fully steady, but were maintained within a discreet range.

After treatments, plants were transplanted out to the test plots in two replications, isolated from one another by two miles. Plants began flowering in early June, and early flowers were all removed to allow us to set a baseline after which male floral development could be monitored by means of counting male flowers and the amount of time required to remove them.

Results and Discussion

It was quickly apparent once we began collecting data that none of our treatments had completely suppressed male flower development, as all rows had significant numbers of males (Fig. 1) What we did find, however, was that in two treatments, numbers 4 (six-leaf for 12 hours) and 5 (six-leaf for 24 hours), there were significantly fewer males per plant relative to the controls (Fig. 1) This result, while not of immediate use since there are still enough males that the rows would require almost as much time emasculating as untreated rows, is yet an intriguing indicator that the gas has the potential to modify sex ratios in a way that will be useful for hybrid seed development. What was interesting, though possibly disappointing, was that we did not see an equivalent result in the plants at the four-leaf stage that underwent the same treatments at the same time.

Another observation was that the plants at the six-leaf stage that had been treated with gas for 48 hours – the longest treatment time – were sickly looking and had very few flowers at all in both replications of the experiment. Plants at the four-leaf stage that had been treated for the same length of time in the same chamber at the same time did not appear sickly looking and had copious numbers of flowers. Thus the older plants appear to be more sensitive to extended gas treatment, as might be expected for plants that have already entered a full reproductive program and are thus less able to respond to stress.

In retrospect we realized that it was necessary to better define the parameters of gas treatment before expecting to obtain useful data from a full field experiment. The insight that we gained from the full field experiment has its uses, but we have extended the project into another field season to better be able to narrow down treatment parameters by means of a series of smaller greenhouse experiments. We began these experiments in fall of 2007, and will continue them into summer of 2008.

Conclusions

The experiments are not complete enough to warrant any real conclusions, but we saw enough effects on the initial round of experiments to conclude that the technique has promise and we will pursue it further.

FIG. 1

TRT No.	TREATMENT	Replication	Males/Plant First Count	Males/Plant Second Count	NOTES
1	12 hr gas on 4-leaf plants	1	4.54	6.06	plants healthy
2	24 hr gas on 4-leaf plants	1	6.61	6.18	plants healthy
3	48 hr gas on 4-leaf plants	1	7.09	4.35	plants healthy
4	12 hr gas on 6-leaf plants	1	*3.25	6.07	plants healthy
5	24 hr gas on 6-leaf plants	1	*3.85	*4.34	plants healthy
6	48 hr gas on 6-leaf plants	1	2.18	4.77	most plants dead or nearly dead, with no flowers at all
7	mock-treated controls	1	6.05	8.01	plants healthy
8	untreated controls	1	7.5	5.76	plants healthy
1	12 hr gas on 4-leaf plants	2	8.58	9.63	plants healthy
2	24 hr gas on 4-leaf plants	2	9.13	9.18	plants healthy
3	48 hr gas on 4-leaf plants	2	7.17	7.19	plants healthy
4	12 hr gas on 6-leaf plants	2	*4.26	*4.97	plants healthy
5	24 hr gas on 6-leaf plants	2	*4.80	*5.16	plants healthy
6	48 hr gas on 6-leaf plants	2	2.32	3.39	most plants dead or nearly dead, with no flowers at all
7	mock-treated controls	2	5.74	6.43	plants healthy
8	untreated controls	2	5.67		plants healthy

* indicates results that we consider significant

Infection of Seed and Transmission of Seedborne Pathogens

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This presentation discusses attributes of seed borne and seed transmitted pathogens, including the importance of the "seed borne" vs. "seed transmitted" status of plant pathogens, as well as factors that affect the ability of pathogens to gain access to seed, survive commercial seed processes, and establish infection on emerging seedlings. A range of biological factors affect these attributes, including pathogen infection methods, timing of infection of seed crops, the nature of the pathogens, and survival structures or states of the pathogens.

There are several methods by which plant pathogens gain access to seed: 1) active methods of infection that usually result in the presence of the pathogen within seeds, and 2) passive methods of access that typically result in the presence of the pathogen on the seed surface and/or as contaminants in seed lots. Active routes of seed infection include penetration of the developing seed through the ovary walls, systemic infection via the vascular system of the mother plant, and penetration through floral parts. The method of seed infection can influence the ability to clean or treat seed lots in order to eradicate or reduce the incidence of seeds infected. Active methods of infection usually result in more recalcitrant infection of seed than passive methods (i.e., the seed may be difficult to clean or treat effectively), and may be associated with higher rates of seed transmission compared to passive methods of seed infection. Some pathogens have multiple methods of invading flowers and developing seed. Examples of diseases with different methods of seed infection will be discussed. The factors affecting seed borne and seed transmitted plant pathogens are complicated by the controversy surrounding the nature of seed borne and seed transmitted pathogens. For example, some seed borne microorganisms are not plant pathogens, and some seed borne plant pathogens are not readily seed transmitted. Furthermore, the potential for seed transmission is readily influenced by environmental factors, host genotype (cultivars), and inoculum potential of the pathogen.

To assess the risks for seed transmission from an infected seed lot, it is necessary to consider the epidemiology of the pathogen, the importance of seed borne inoculum relative to other sources of inoculum (, e.g., soilborne inoculum, infested crop residused, etc.) particularly if the pathogen is endemic in an area of production, the availability of effective measures for managing the disease in the crop if seed transmission does occur, and whether there are established thresholds for levels of seedborne inoculum under the diversity of production areas and conditions for a crop species. The latter is particularly challenging for growers and researchers because of the very complex nature of research methods to assess economic thresholds. As a result, there are very few established thresholds for seed borne and seed transmitted plant pathogens.

In summary, the main challenges presented by seed borne pathogens include determining definitively if a seed borne pathogen is seed transmitted, developing thresholds for seed borne inoculum that are applicable to a range of environments, and regulatory implications for a plant pathogen based on the status of being seed borne vs. seed transmitted.

Developing a Sustainable Seed System in Malawi

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Seed is a primary and fundamental input utilized by farmers world-wide to ensure a healthy and plentiful harvest. Most farmers in developing countries rely on farm-saved seed for non-hybrid crops. Furthermore, they rely on seed of old varieties that are often susceptible to disease, insect pests, drought and other problems. Through development programs, new improved varieties of most major food crops have been released throughout the developing world. A primary factor limiting adoption is an inadequate seed multiplication and dissemination system in most developing countries. There is a chronic lack of government support within developing countries to support a centralized seed system. In this paper we will briefly contrast the seed system in the U.S. and in Malawi, East Africa, (Figure 1) where the author has been working for the past seven years with colleagues on the Bean/Cowpea CRSP to develop a sustainable bean seed multiplication and dissemination system. The seed system situation in Malawi is common to much of Africa and other developing countries.

Bean/Cowpea Collaborative Research Support Program (CRSP)

The Bean/Cowpea CRSP was established in 1980 by United States Agency for International Development (USAID) and had projects in the U.S., West Africa, East and Southern Africa, and Central and Latin America. The objectives of the project included improving varieties through drought, disease, and insect resistance, and increasing access to improved, high quality bean seed.

There are limited government support systems in Malawi to serve the seed industry and farmers. There is no agency responsible for foundation or certified seed production, and seed inspection services have historically been difficult to obtain. As a result, production of certified seed in Malawi has been insufficient to meet demand (SADC, 2004). To address these issues, several projects including the Bean/Cowpea CRSP included breeders who developed improved varieties and other staff who multiplied and disseminated seed of these varieties at the village level in target bean production areas.

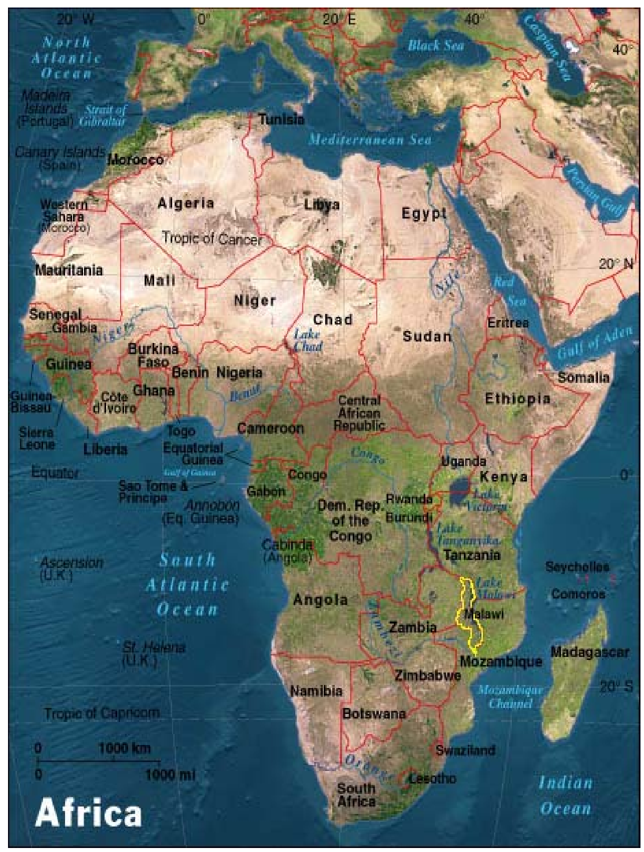

Figure 1. Malawi is located in East Africa (outlined in yellow) and has been an area where the Bean/Cowpea CRSP has focused its seed systems project.

Importance of Beans in Malawi
Beans were moved from Central and South America to various regions of the world, and in the 1500s, beans arrived in East Africa with the Portuguese. Today, beans are a primary source of protein in the human diet throughout Africa. Average bean yield in the U.S. is approximately 1,500 lbs/acre, whereas in Malawi, average bean yield is 400 lbs/acre. A primary constraint to bean yield is the lack of improved varieties.

Developing a Seed Multiplication Program
A successful seed multiplication program requires a plan that sets targets each year for foundation and certified seed production. Seed production capacity as well as storage facilities need to be in place. Some primary tasks for a seed multiplication program are to:

1) Develop a strategy for seed multiplication to meet seed demand projections and production goals.

2) Produce foundation and first generation certified seed to support a seed system.

3) Develop partnerships to multiply certified seed.

4) Provide training to new and continuing seed farmers and NGO staff to better ensure quality seed production.

5) Disseminate quality seed of improved varieties.

The following are some key strategies for creating a successful seed multiplication program:

- Identify actual end-use of seed by purchasers – determine if they are seed multipliers or grain producers
- Prioritize seed sales based on actual use – early generation seed sold to seed multipliers, later generation seed sold to grain producers
- Survey past seed purchasers to determine likely demand for upcoming year
- Contact new potential seed purchasers
- Target seed production to meet likely demand
- Retain appropriate amounts of seed to meet production goals

Foundation Seed Production. One of the primary constraints to establishing a seed system in Malawi is the lack of an institutional base to produce foundation seed. In the U.S., many universities (usually land grant institutions) have foundation seed multiplication units that charge for their services, and in some states university programs carry out seed multiplication at an agricultural experiment station – much of the cost is absorbed by the university department. In some cases, the foundation seed unit is a private association that operates in collaboration with the university and/or the state department of agriculture.

For example in Washington, Washington State University (WSU) produced breeder and foundation seed of new publicly released WSU varieties until the 1970s. Then in the 1970s this function was handed over to the Washington State Crop Improvement Association

(WSCIA), a non-profit organization founded in 1954. WSCIA currently operates under a memorandum of agreement with WSU, Oregon State University and the University of Idaho to produce and distribute breeder and foundation seed of their publicly released varieties, and it produces some private varieties for seed companies on a contract basis (WSCIA, 2000). WSCIA has authority from the Washington State Department of Agriculture (WSDA) to certify breeder and foundation seed of the seed crops they produce (chickpea, field pea, lentil, soybean, sorghum, small grains, and forest reproductive material). In addition to seed multiplication, WSCIA provides public education, instruction and promotion to aid in the development, production and distribution of certified seed in order to improve crop yields in Washington.

In the U.S., the foundation seed system is also generally supported by each state department of agriculture. For example, in Washington the WSDA supplies trained personnel to conduct field inspections and lab seed quality testing (WSCIA, 2001). These services are provided at a fee that covers the cost of materials but not the salaries of these personnel or infrastructure overheads. In essence, the Washington state government provides the infrastructure and the trained personnel for this segment of the seed system.

In Malawi, there is no university, government or non-profit support for foundation seed production. Thus, programs with a vested interest in a new variety must take responsibility for generating breeder and foundation seed. In other countries where the Bean/Cowpea CRSP is active, several breeders have established seed multiplication programs within their universities. These breeders have taken on the responsibility for multiplying breeder, foundation, and certified seed of their new varieties (Miles, 2005; Miles, 2006a).

Certified Seed. NGO seed multiplication projects are commonly viewed as a mechanism for producing certified seed. In our project, we supplied seed to NGO seed multiplication projects in Malawi (Concern Universal, Action Aid, OXFAM, Total Landcare) with the expectation that these projects would generate the seed they would need to meet their own demands. This approach has been unsuccessful with the exception of Total Land Care, and each year most NGOs have the same if not greater requests for seed.

Currently, the seed component has established two successful mechanisms for multiplying certified seed. First, it established a network of seed farmers around the Agricultural College and is working closely with these farmers to ensure quality seed production. Second, it established a partnership with Total Land Care, an NGO that has proven to be a successful seed multiplication project. We provided seed and training to new seed farmers and to NGO staff, and fields were inspected to ensure high quality production.

Ensuring High Quality Seed. In our project the Seed Services Unit, the official entity responsible for certifying seed in Malawi, was unable to provide inspectors at critical times for field inspections (Miles, 2006b). In 2006, the Seed Services Unit was decentralized and inspectors are now located in districts throughout the country, making travel to bean fields more accessible.

To further ensure high quality seed production, seed should be multiplied in the dry season when disease pressure is the lowest. If seed is multiplied only in the winter season, seed needs to stored for 8 months. An adequate seed storage facility is required, an expensive challenge in a tropical country without reliable electricity. These costs would need to be absorbed by the seed multiplication program.

Irrigation. Disease pressure is lowest during the dry season, however, dry season production requires either irrigation or lands with sufficient residual moisture to grow a seed crop. There is relatively limited land available that meets these criteria, however there are opportunities to expand seed multiplication in river basin regions. Seed crop profitability needs to be competitive with crops currently grown in these areas.

Profitability. The costs of seed production and the returns need to be calculated in order to determine profitability. This information should be used to set the price for seed. This information should also be made available to seed producing farmers and associations so they can better understand the costs of production, seed inspection and storage, and to promote the business opportunities of certified seed production.

Developing a Sustainable Seed System

To assure the continuation of seed multiplication beyond a single development project, a Seed Multiplication Program needs to be institutionalized. Success of the program may be greater if it is set up in conjunction with an existing institution, such as the Agricultural College or the Ministry of Agriculture.

The Seed Multiplication Program would market seeds to generate funds for its operations. There are good opportunities for such a program to operate on a contract basis with research programs that require seed. Initial funds would be needed for the first years of production, and prices should be set to cover costs if possible. However, it may be unlikely that the price of seed will be sufficient to cover all costs, in which case salary support and primary infrastructure may be needed on an annual basis in order to sustain the program (such as occurs in the U.S.).

By establishing core funding for a seed multiplication program, a ‘revolving fund’ could be created that would enable the program to pay farmers immediately for their seed. By paying farmers immediately for their seed, more seed returns to the system, and more resource-poor farmers are enabled to participate in the system.

Training for Seed Multiplication. A key element of a sustainable seed system is the provision of training for new seed farmers and NGO and government staff. It is unlikely farmers, especially resource-poor farmers, will pay for training, however if the seed system becomes profitable, this should be explored. At this time, government, institutional and donor programs should cover the cost of farmer and staff training.

Seed Dissemination and Promotion. On-farm trials and NGO seed multiplication programs can provide good avenues for disseminating seed of improved varieties in target environments. Brochures and posters that promote new varieties should be developed and distributed through NGO and Extension programs at the village level.

NGO Seed Multiplication Programs. Many NGOs have farmer-based seed multiplication programs and they purchase foundation or certified seed for these programs. The NGO demand for seed has been high in Malawi and they have become a major seed purchaser. However, in Malawi we found that most NGOs have been unsuccessful in multiplying seed or in using their own seed to meet their on-going program demands. In follow-up studies we found that most NGOs attempted to purchase seed from farmers participating in their seed multiplication programs a month or more after harvest. By that time, most farmers had already sold their seed. Resource poor farmers tend to sell their crops to the first buyer who appears after harvest, even though the price is lower than they would receive from the NGO. Thus seed was not returned to the NGO seed multiplication programs and NGOs produced insufficient seed for their next cycle of production. In general there are several issues to consider regarding the NGO seed market:

1. Most NGO seed multiplication programs have on-going seed purchasing needs and they should not be viewed as a reliable contributor to seed multiplication. However, there are notable exceptions to this general finding, and seed multiplication programs should be investigated prior to drawing this conclusion.

2. It is difficult to anticipate/predict how much seed each NGO will request each year. Generally they request seed just before they wish to distribute it to their farmers for planting, and this is too late for planning on the part of seed producers.

3. Although NGOs may enquire about seed availability earlier in the year, these enquiries are non-binding. That is, at the beginning of the seed production cycle an NGO may indicate it would like a certain amount of seed, but after the seed is produced it does not purchase that seed.

4. There is a danger in relying on the NGO seed market for the long-term as NGOs change their program focus every few years.

Creating Awareness Regarding Seed Multiplication. A primary constraint to seed multiplication is the general lack of recognition among agricultural professionals of appropriate markets for foundation and certified seed. The Bean/Cowpea CRSP has sold foundation seed on a first-come first-served basis and has not been targeting seed sales based on actual end use. As a consequence, the seed system has been drained of its primary seed stock and potential for seed multiplication has been reduced. Seed sales need to be prioritized based on actual end use, that is, seed purchasers who have multiplied seed should be supplied with foundation seed while seed purchasers who have sold their bean crop as grain should be supplied with certified seed. Decision makers within NGO and government seed purchasing and seed multiplication programs need to be made aware of the differences and appropriate uses of foundation and certified seed.

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Experiences in the Production of Organic Seeds and Food in Panama

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Introduction: Explain in general terms the development of Organic Agriculture in Panama; historical precedents, areas, crops.

Objectives: Topics that will be developed during the exposition:

1. To give information about the production of organic seeds in Panama.
2. To exchange experiences about organic production.
3. To create alliances with farmers and enterprises from Oregon.

Content: The following items will be developed in detail.
Organic Agriculture: Producers

-- Production of organic seeds: experiences, management, limitations, and projections.
-- Production process: inputs (organic fertilizers, solid and liquid), crops, costs.
-- Commercialization; availability of products, markets, presentations, certification, demand.
-- Other examples of national organizations.
-- Organization framework of producers at the national, provincial, and community levels.

Legal Aspects: Government Agencies

-- Institutional Framework: the Agriculture Ministry's adoption of a program of organic agriculture, and the creation of the competing authority.
-- Legal Framework: Creation of Law 8 that regulates organic agriculture activities
-- Regulations of Law 8. Executive decree.

Current Challenges: Availability of

-- Organic seeds and fertilizers, foliar repellents.
-- Certification.
-- Technical assistance.
-- Financing.

Future Projections: To increase the

-- Production and research of organic seeds
-- Production of organic inputs.
-- Output and to raise awareness among citizens of the importance of consuming these products.
-- Organic production, at the local and national levels.
-- Promotion of the experiences obtained during the development of organic agriculture.

Conclusions: Highlight of the main points regarding the situation of organic agriculture in Panama, from several perspectives.

GORACE (**Grupo Organico de Agricultores Cerropuntenos**): The organization was formed 10 years ago in an effort to initiate an organic movement in the heart of Panama's agricultural center, Cerro Punta, Chiriqui Province. Since its inception, GORACE has been the leading organic producer and promoter in the Chiriqui Highlands. Though it is only a small group (organic produders represent well less than 1% of the production in the area), they have been very influential in expanding awareness and in providing seminars and training oportunities in order to expand the quality and availablity of organic produce in thier country.

Roger del Cid is current president and one of the founding members of GORACE. He has been a farmer for all of his 75 years and committed to organic farming 10 years ago. His contributions to the organization and the promotion of organic farming and sustainable seed cultivation in Panama include opening product markets with one of the major grocery chains in the country, maintaining "Finca Victoria", Gorace's working organic farm and training location, and working with international university and NGO programs to train students and associates in the ongoing promotion and instruction of sustainable organic agriculture.

Lourdes Gaitan serves as Secretary of GORACE and is also one of its founding members. In addition to managing her own 2 hectare farm, she is the administrator of the organization's business systems. She is actively involved in promoting the benefits of organic foods to consumer groups, and in many of the groups training activites around Panama.

Economics of Organic Seed Production

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The economic success of the business of organic seed production depends upon a proper balance among the needs of the producer, the consumer, and the environment. All seed producers must assess their financial situation accurately to plan profitable production and provide affordable, high quality seed to the customer. Organic seed producers have the additional responsibility to sustain a healthy environment.

Initial evaluation must consider appropriate seed crops for the existing soil, water, and climatic conditions. A viable seed production operation should be capable of replenishing soil and water resources, and creating a vibrant habitat within and around the farm.

The seed producer wants the highest price within reason that the market will bear. Organic farmers want the lowest price available for the seed they purchase. Organic seed companies need to satisfy both demands and depend on the economic viability of both the organic seed producers and organic crop producers.

Long term economic success in organic seed production requires that both the producer and consumer understand the real costs of providing high quality seed to sustain a healthy farm and community. The seed company plays a vital role in communicating the producer's needs to the customer and the customer's needs to the producer.

Keeping the environmental and customer needs in mind, the producer begins an assessment by considering overall financial stability, access to credit and land, and the ability to cope with risk. An appraisement of the farm's infrastructure is conducted. This includes calculating the productivity potential of the land, the quality and availability of labor, capital assets such as buildings and equipment, and the water delivery system.

Next is a realistic accounting of fixed and variable costs. Fixed costs include land payments, taxes, insurance, buildings and equipment and the associated maintenance costs, and miscellaneous expenses such as utilities and organic certification. Seed production may require special investment that cannot be amortized over other enterprises, such as seed cleaning equipment. Labor is the primary variable cost, with operations divided among field preparation, planting, weed control and other cultural activities, harvesting, and cleaning. Other variable expenses are the seed, soil amendments, weed, pest, and disease control products, and irrigation hardware. Because organic producers are required to use cultural and biological methods for pest, disease, and weed control, and most pesticides are prohibited for use in organic production, techniques to grow a given crop will be more labor intensive than with conventional practices. Unforeseen events that increase costs also need to be considered.

An evaluation of the economy of scale of the farm is then carried out to determine what the required gross and net returns must be per unit area of land to sustain financial viability. Is the farm the correct size with the appropriate technology to be an efficient producer of a particular type of seed? A small, manual labor-intensive operation is suitable for producing higher-value, specialty products, while an extensive, mechanized operation is best designed for lower-value, commodity products.

Seeds of Change contract growers were surveyed regarding their financial conditions. These growers' fixed and variable costs, and how each of them assesses their own financial needs are summarized. This is followed by a review of these growers' primary concerns, and what opportunities exist that will help them improve their future financial health.

Commercial Availability of Organic Seeds:
Certifier Perspectives

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Summary
The market for organic seed poses a great opportunity for both organic producers who want to diversify into new crops as well as for seed producers who want to enter into the rapidly growing organic market. While organic standards in the United States require the use of organic seed, organic producers are not able to find organic seed in sufficient quantity and of suitable quality to meet their production needs. Because commercial availability must be evaluated as part of the certification process, the certifying agents play an important role in assessing both the supply and demand for organic seed. Certifying agents were surveyed to identify how they assess commercial availability, what information resources are used, and what crops and varieties are considered commercially unavailable. More research is needed to forecast organic seed demand and overcome production obstacles.

Introduction
The growth of the market for organic food and standards that require organic seed, it stands to reason that the market for organic seed presents a great opportunity. Organic agriculture has grown to be a worldwide multi-billion dollar industry over the past dozen years, with global sales estimated at $40 billion in 2006, up from $23 billion in 2002 (Willer and Yussefi, 2007). While US market-share is between 1-2%, this market niche is widely regarded as profitable and rapidly growing. This growth has been almost entirely consumer driven. Most organic crops command a higher price than comparable conventional food; the premium varies according to the commodity and market conditions.

Standards that require organic seed are relatively new and have not been fully implemented. While consumers clearly expect organic food to not be produced using recombinant DNA techniques and genetic engineering, the requirement for organic seed does not appear to be as well understood or supported. The standard has been difficult to implement because of growers lack an understanding of commercial availability, overspecify varieties to exclude equivalent organic sources, don't know where to find organic seed sources, and do not value the importance of organic seed (Moyer, 2006).

The market for organic seed has been filled with great uncertainty over both the supply and demand. The organic market has been growing at approximately a 20% annual rate over the past twenty years with slower but strong and more sustainable growth expected to continue (OTA, 2005). Farmers who sell to the organic market in the United States are required to use organic seed when it is commercially available (USDA, 2000). The requirement is implemented by USDA Accredited Certifying Agents (ACAs). However, there is no consistent guidance as to what is considered 'commercially available' or what varieties may be considered 'equivalent.'

Lack of reliable statistics for both the demand and supply of organic seed have resulted in unpredictable market conditions. The organic seed market that existed prior to the NOP did not have the scale or diversity of the conventional seed sector that accounted for most seed purchased by organic farmers. The non-organic companies that sell to organic farmers found it difficult to predict demand, while the organic companies have not been able to provide the varieties or volumes needed. Organic farmers, their seed suppliers, and their certifiers have found it difficult to evaluate commercial availability. In the face of a rapidly growing market for organic food, organic farmers have stated that some organically produced seeds are in short supply while some organic seed suppliers claim that they have unsold inventories of organic seed of those same varieties.

The lack of a National Database of organic seeds has been identified as an obstacle for the adoption of organic seed and harmonization of the NOP with other standards (Sundstrom, 2004). The Organic Materials Review Institute (OMRI) developed an organic seed database in 2002 to provide a comprehensive organic seed database for USDA certified organic producers (DeCou, 2006). Other organizations have developed their own databases. How these databases are used by certifiers, producers, and seed companies, and what other information resources are available deserves further exploration. One aspect that deserves consideration is how ACAs implement the organic seed requirement.

Methods

OMRI conducted a survey of ACAs in Fall 2007. The survey was pre-tested on four certifiers prior to sending it out. All were based in the US. One was a medium sized state program in the Northeast; one was a private non-profit that had a long history of seed certification in the Southeast prior to getting accredited as an organic certifier, one was a medium sized for-profit certifier in the Midwest, and one is a large non-profit certifier based in the Western US and operating internationally. The original intent to ask questions that would provide an estimate of the area planted with non-organic seed and the quantity of non-organic seed planted was abandoned because the certifiers predicted a high non-response rate and unreliable estimates. The survey was redesigned to ask qualitative questions.

Results and Discussion

Out of 100 certifiers surveyed, 23 responded. The respondents included ACAs domestic to the United States as well as those located outside the US. Some were state agencies, while others were in the private sector.

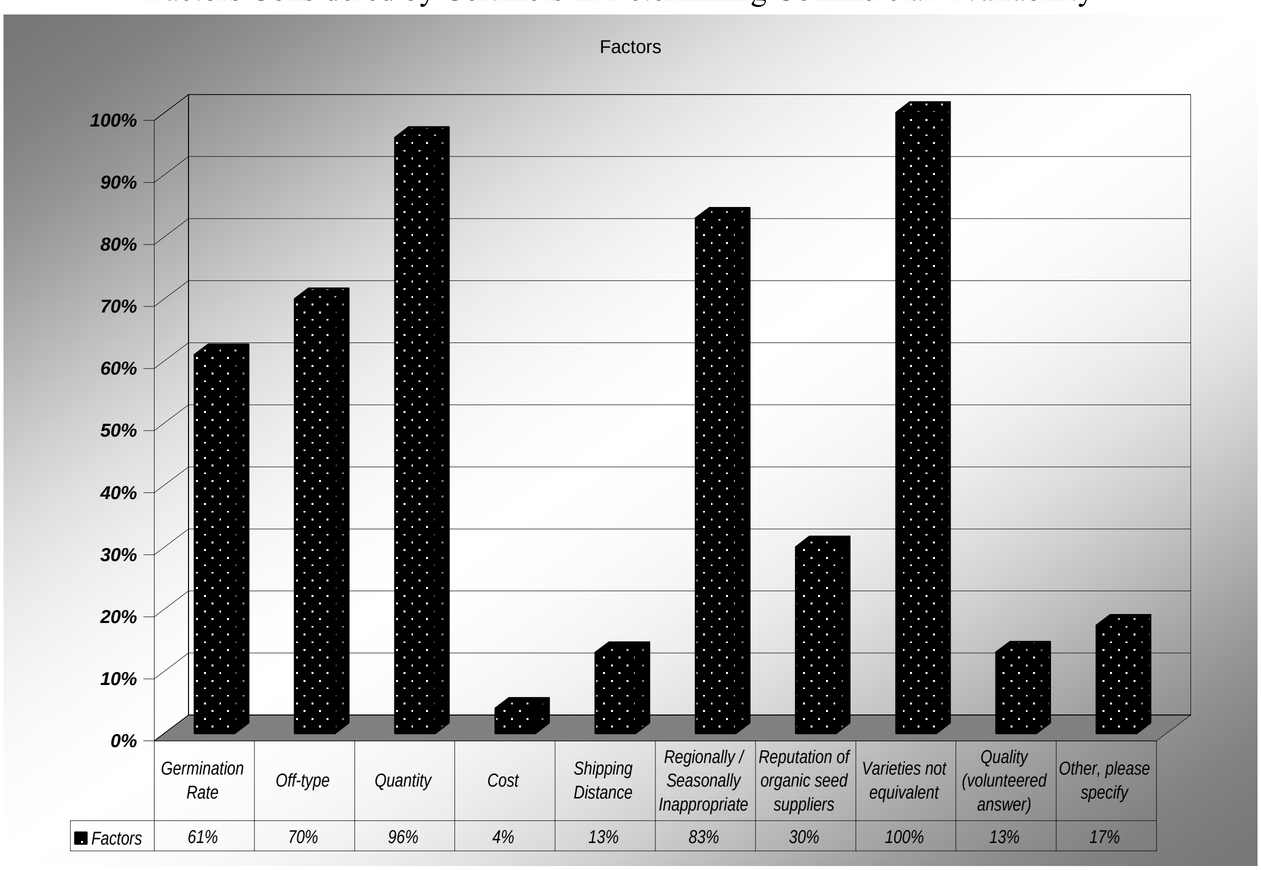
Table 1 looked at the methods that ACAs use to determine commercial availability. The two methods most commonly used by certifiers to check for the commercial availability of organic seeds are supplier letters and seed catalogs. Slightly over half use producer logs, while under half use the OMRI database. However, nearly three-quarters of all certifiers said that they include instructions to their producers that refer to the OMRI database.

Table 1 How do you currently determine commercial availability?		
Supplier Letters	17	74%
Seed Catalogs	17	74%
Producer log	12	52%
OMRI Seed Database	11	48%
Grower Letters	10	43%
Other	6	26%

Nearly two thirds (65%) of all certifiers surveyed said that they do *not* track what seeds they determine to be commercially unavailable. This fact is consistent with the information provided by the pre-test group that indicated that certifiers would not be able to reliably estimate the area planted to non-organic seed. When asked why not, certifiers gave a number of different reasons. Several suggested that the evaluation must be done every year and for that reason tracking is of no practical purpose. Another reason cited was the shortage of available resources, in particular a lack of staff time. One cited restrictions on certifiers performing a consulting role. Another stated that it was not possible to evaluate a negative statement. Seven of the eight certifiers who do track what varieties are commercially unavailable maintain their own databases.

Commercial availability is claimed by many ACAs to be a significant administrative burden already, and the survey showed that ACAs varied in how much time they spent. Two ACAs acknowledged that they did not spend any time evaluating claims made by producers regarding commercial availability of equivalent varieties. The ACAs who responded positively reported spending an average of 33 minutes per farm evaluating the commercial availability of organic seeds. The standard deviation of 31 minutes per farm was almost as great as the average, indicating great variability among the ACAs. One explanation about the variation in the amount of time spent appears to be related to the complexity of operations reviewed. Certifiers of field crops with large acreage of a few varieties would be expected to spend less time than certifiers of vegetable crops that have greater diversity.

Figure 1
Factors Considered by Certifiers in Determining Commercial Availability



The criteria used to assess what is commercially unavailable, shown in Figure 1, contained some consistent patterns. All of the certifiers said that they considered a variety that is not equivalent to be a valid reason to allow non-organic seed. However, equivalency is not well defined and has been subject to dispute. All but one certifier considered insufficient quantity to be a factor as well. More than half cited regionally or seasonally inappropriate varieties, and specific quality factors such as poor germination or off-type to be suitable reasons to not require organic seed. Three certifiers volunteered 'quality' as a general reason to grant a variance to the organic seed requirement.

Finally, certifiers were asked to estimate what crops and varieties accounted for the greatest number of claims that organic seed was not commercially available. All crops identified by more than one certifier are included in Table 2. The crop that accounted for the greatest number of claims was alfalfa, two specific alfalfa varieties cited as unavailable were Vernal and Ranger. One certifier stated that "Some producers question new alfalfa varieties since many have failed."

Table 2
Crops Most Claimed to be Commercial Unavailable

Crop	**Frequency**
Alfalfa	10
Wheat	9
Corn	7
Barley	6
Potatoes	4
Lettuces	4
Vegetables	3
Grasses	3
Cover crops	3
Clover	3
Tomatoes	2
Rye	2
Peppers	2
Oats	2
Brassicas	2

Wheat, corn, and barley were the next most cited crops. More ACAs named more varieties of wheat commercially unavailable than any other crop. Oats and rye were also cited by more than one certifier. On the other hand, at least one certifier considered open-pollinated grain crops to not qualify for a commercial unavailability claim given that farmers have the capacity to save seed if organic seed is not available on the market.

Certifiers did not consider vegetables to account for as many claims as field crops. Potatoes and lettuce were the most cited vegetable crops. One certifier identified that organic potato seed is not available in an early-planting window in the Southern US. Tomatoes were cited by three certifiers as accounting for among the greatest number of claims. Heirloom varieties of various vegetables were cited as generally unavailable. Relatively few specific vegetable varieties were named as unavailable, in part because of the great diversity of varieties planted. Peppers and brassicas were both cited by two certifiers. At least one certifier named onion, basil, cucumber, eggplant, pumpkin, beans, and carrots. Pasture crops and hay accounted for a significant number of claims as well. Cover crop seed was in the same range.

ACAs found the OMRI database useful but limited. Most ACAs wanted to see OMRI continue and expand the seed database and praised the service. Several respondents encouraged OMRI to work with the companies that were not participating in the database and named specific companies that either they certified or knew that their growers used as sources for certified organic seed. One ACA stated "[e]ither include all certified organic seed sources or don't do anything." In order to be effective, a database had to be mandatory and comprehensive. Unless there was full coverage of the entire market, a database would not provide sufficient information for an ACA to determine the availability of organic seed. OMRI's database was seen by one ACA as regionally oriented toward the Western United States.

A couple of the ACAs felt that the NOP was not doing enough to implement the requirement. One said "[t]ry and get the standards tightened up, too many loopholes, make it a requirement to use organic seeds." Another asked OMRI to "[p]etition the NOP to require organic seed."

Conclusion:
Certifiers have found the implementation of the requirement to plant organic seed to be difficult to implement. At present, ACAs are not required to regularly report what varieties are determined to be commercially unavailable. Most certifiers do not appear to have a standard system to determine and document what seeds are commercially unavailable. Less than half of the certifiers use databases developed by OMRI and others to determine what is commercially available. Commercial availability is difficult to evaluate given the dynamic complexity of the organic seed market. More reliable, accurate, and timely information on market conditions is needed in order for organic producers, seed suppliers, and certifiers to effectively implement the organic seed requirement.

Organic seed companies appear to have an expectation that demand will be driven by a top-down approach, but the survey results show that such demand will not be driven by ACAs. Valid market research is needed to identify the gaps in supply of organic seed that need to be filled. Possible methods to obtain the data would include review of certifiers' files, a survey at the organic farmer level, and estimates obtained through data provided to USDA. Seed dealers who sell non-organic seed to their organic customers are in a difficult position. Most lack a sufficient financial incentive to build inventories of organic seed and appear to resist efforts by their customers' certifiers to require organic seeds. For crops that are mostly grown as transplants, greenhouse demand may be a more important factor than farmers. Packer-shippers also may be contracting with growers to produce certain specific varieties.

The NOSB recommended that the USDA to issue guidance to certifiers to help them determine if organic seed was commercially available. The USDA has not acted on the recommendation and it appears from the survey that the recommendation is not being implemented, in particular the suggestion that they '[m]aintain and annually submit to the National Organic Program an up-to-date list of specific non-organic crop varieties permitted (NOSB, 2005).

A survey of organic farmers would be more likely to provide the market research needed to identify the current demand for organic seed and what factors, other than being forced by regulation, will convince organic farmers to purchase organic seed when it is commercially available. Such a survey can test anecdotal evidence of organic farmers' resistance to the purchase of commercially available organic seed. Information resources that organic farmers rely upon to determine what varieties are suitable for their conditions, where they source organic seed, and what barriers need to be overcome to increase organic seed's market share to be proportional to the demand for organic food can also be better understood. If organic farmers better understand the benefits of using organic seed, as well as where to find what they need, then the organic seed production can grow along with the rest of the organic market.

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Genetic Isolation and Contamination Issues for Organic Seed Production in Oregon's Willamette Valley

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The Willamette Valley (WV) in Western Oregon is a world-class place to grow seeds. A combination of good soils, a mild wet winter, moderate dry summers with a dependable dry harvest period, and ample irrigation water, makes this area uniquely suited to commercial production of high quality, disease-free seed. Biennial specialty crop species, including *Brassica* of four species, *Beta* of four types, spinach and relatives, onions and leek, radish, the parsley family, chicory and endive, and a huge variety of flowers are grown here for their seed. Seed companies the world over consider the WV a first-choice source for seed production for two other reasons aside from geography and climate -- the low incidence of diseases that are common or endemic elsewhere, and an effective industry-wide system for establishing pollen isolations and maintaining genetic purity of seed crops. A base of knowledgeable growers and concentration of specialized infrastructure are an additional attraction to seed companies.

This presentation is concerned with the maintenance of genetic purity within an area of commercial seed production, and the implications this has for organic seed production on various scales. Organic farmers and gardeners have a long tradition as seed keepers, and the organic seed trade has been sustained from its beginning by organic farmers that have dedicated part of a farm plan to growing some organic seed. Only in recent years -- since implementation of certified organic seed requirements by the National Organic Program (NOP) for organic growers -- has certified organic seed been produced by long-standing commercial seed companies. Several of these have now created organic subsidiaries and are expanding organic seed acreage on a 'combine scale'. Regardless, the niche for many small lots of many specialty varieties will always endure in the organic seed trade, because the organic community embraces diversity as an asset, both as producers and consumers. The organic seed trade will likely always be based on a conglomeration of garden plot, farm field, and 'combine' scales.

All seed growers understand the need for isolating seed crop varieties of the same species from one another to prevent cross-pollination between varieties. The distance required to assure this isolation has been long studied and long debated by farmers, scientists, and seed companies. In production districts like the WV, companies and growers often form associations to help promote their industry and to settle disputes between industry interests. The Willamette Valley Specialty Seed Association is a voluntary member organization, originally created to establish standards and rules for isolation distances that will help ensure that the Willamette Valley is known for genetic coherence in the high quality seed grown here. Members are required to follow a protocol for placing flagged pins indicating crop species (and producer) on a large map of the valley that is maintained in Cooperative Extension Service office space, a kind of common ground to stake and maintain 'claims' on production isolations. A Rules Committee has established standard isolation distances that are required between crops of a species and type, and a seniority-based system of awarding priority to long-standing producers within a species.

This is not a process without contention and disagreement, and provisions have been accorded that allow negotiated variances to the rules between consenting parties. These negotiations may hinge on several factors, including local geography, prevailing winds, crop timing, intended markets, genetic similarity, etc.

It is important to note that these isolation rules and standards have no weight of law or administrative rule. They represent the best efforts of commercial competitors to create agreeable conditions to share a limited amount of area to produce a quality product with efficiency and predictability. For this reason, organic seed producers, gardeners, fresh market, and field scale or any seed growers that are not members of the WVSSA represent a discomforting unknown risk of genetic contamination to the industry. During rule-making sessions of the Pinning Rules Committee, issues related to the farmers' right to grow their own seed for replanting (a 10,000 year old seniority) and questions related to plot size versus necessary isolation distances were tabled for some future round of rule amendments. Meanwhile, it was agreed that farmers and gardeners saving (non-commercial) seed should be allowed to place pins for their small plots following the proper protocols for pinning, but it was not agreed how to handle conflicts between commercial growers and non-commercial seed savers, other than tactfulness.

A new layer of complexity has been added to seed production in the WV in the form of the introduction of genetically modified (GM) field and seed crops. Depending on pollination system, these have the potential to mate with conventional varieties and wild relatives, resulting in the spread of GM traits into the conventional crop. Some conventional growers do not care whether this happens, but growers and food processors with organic or foreign markets, and organic seed growers are extremely concerned. NOP prohibits the use of GM varieties for certified organic production, and foreign export markets in Asia and Europe have set tolerance limits for GM contamination.

Several seed crops grown in the WV are potentially impacted by current or future introductions of GM crops for seed or food. Already grown on a wide scale is GM field corn for silage for local dairies. Wind blown pollen from these fields may contaminate organic sweet corn for seed, and organic fresh and processed production. The introduction of canola (*Brassica napus*) into the WV for biofuel production has been controversial because of the cross compatibility with *B. napus* and *B. rapa* vegetable seed crops (rutabaga, turnip, Chinese mustards and cabbages). Until recently, an Oregon Department of Agriculture control order kept canola out of the valley except for production as a seed crop. Widespread planting of canola could be problematic to the organic vegetable *Brassica* seed crop from a GM stand point as well. While those interested in introducing canola into the WV have stated that they would favor the prohibition of GM canola, studies in Canada on conventional canola seed lots have shown that a number of them are already contaminated by GM traits (Hall et al., 2003). Another point of tension is between sugar beets on the one hand, and table beet and chard on the other. All are cross-compatible and wind pollinated with a three mile buffer required between fields. Traditionally, table beets have been grown in the north end of the valley and in southern Washington, sugar beets in the central and south valley, and chard around the margins. As land available for seed production is restricted through conversion to uses other than agriculture, segregation is harder to maintain. In 2008, almost the entire U.S. sugar beet seed supply will be converted to Roundup resistance, presenting a risk to certified organic seed producers of chard and table beets. In the near future, a GM cabbage with BT resistance insect may be produced in the region. Nearly half the acreage of arable land in the WV is devoted to the production of grass seed. Problems have already been encountered with the escape of a GM bent grass in Eastern Oregon. While this grass cannot be legally planted in the WV, the fact that it can survive in a free living form suggests that it is only a matter of time until it is spread as a weed into this valley. Also in the offing is a GM fescue. The threat to organic production from GM crops will continue to increase, increasing the need for mediation. Generally, the court systems have not supported individual farmers who have suffered loss due to contamination from a neighboring crop.

What can an individual organic grower do to protect themselves? First, participate in the pinning system. Secondly, there are technologies accessible to the grower that can be used to detect GM contamination. These are immunology-based systems that are designed to detect the unique proteins produced by specific GM traits. Some require that a sample be sent in to a laboratory, but others can be performed in the field by the grower. Depending on the system, they can detect one GM seed in a 1,000 seed sample. These systems have mainly been designed for field corn and soybean, but with experimentation, can be adapted to other crops.

The regulatory and legal climate for GM crops continues to be in a state of flux. With some exceptions, crops that are viewed as commodities are those for which the development of GM varieties is proceeding. Most people are not aware that the soy margarine on their breakfast toast is GM, likewise for the high fructose corn syrup in their soft drink, or the canola in their salad dressing. Beet sugar will probably fall into the same category. Some commodity crops such as wheat have rejected the use of GM traits because of foreign market demands. There has also been poor acceptance of GM fruit and vegetable varieties, where purchase and use of the product is a much more personal issue. Three lawsuits in the past year have successfully challenged the introduction of GM crops. The lawsuits challenged the environmental impact findings under the National Environmental Policy Act when USDA approved deregulation of a GM crop. What effect this will have on the introduction of GM crops remains to be seen.

Seed production issues have been and will continue to be controversial. More formal systems of coordinating plantings for seed need to be instituted and may need the force of law rather than being done on a strictly voluntary basis. GM crops add a new dimension to seed production and represent an additional challenge to production of organic certified seed. There are new technologies that can help detect contamination and assure varietal purity.

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University-based Public Plant Breeding:
Past, Present and Future Role of Public Institutions in Crop Improvement

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"The plant is the irreducible core of crop production on the farm and the most fundamental agricultural unit." –Kloppenburg, 2004

An Historical Perspective: In the early years following the establishment of the United States of America, crop genetic improvement was achieved mainly through the introduction of germplasm from abroad, with the goal of finding those varieties that were adapted to growing conditions in the New World. Most of the introductions came from private individuals but in the mid 19th century, the nascent United States Department of Agriculture began underwriting collecting expeditions. Soon thereafter, government-sponsored seed distribution to farmers was instituted, and this popular program continued up until the early 20th century. Little plant breeding as we know it today was conducted by either public or private entities. The private seed sector was weak because seed companies found it difficult to compete with the public seed distribution programs, there was no quality control on seeds and seed scams were rampant. As a result, farmers mostly saved their own seed.

At the end of the 19th and beginning of the 20th centuries, publicly supported agricultural research on seeds and breeding received strong legislative support. The Morrill Acts of 1862 and 1890 established the land grant universities that provided the institutional basis for public agricultural research. The Hatch Act of 1888 established and funded the state agricultural experiment stations, and the Smith Lever Act of 1913 established and funded the cooperative extension service. At this same time, Mendel's laws were rediscovered, which established a scientific basis for plant breeding. Many public plant breeding programs were established, which began to actively improve and release varieties. This program was tremendously successful; it is estimated that publicly supported agricultural research and development produced a 90% return on investment from 1959 to 1989.

In the meantime, seed companies were not very happy with the situation. They felt that government meddling in an area better left to private enterprise had prevented them from developing strong programs, and as such, lobbied for legislation that strengthened private enterprise in agricultural research and development at the expense of public programs. The governmental seed distribution program was halted. A major impact on plant breeding and genetics research was the institution of laws that protected intellectual property. This began with the Plant Patent Act of 1930, which protected clonally propagated crops. It was followed by the Plant Variety Protection Act of 1970 that extended intellectual property protection to seed propagated crops, and provided major stimulus to seed companies to develop their own breeding programs. In 1980, the Supreme Court found that living organisms could be protected with a utility patent and this was extended to plants in 2000. Technology also played a part with the development of F_1 hybrids that allowed seed companies to maintain their inbreds as trade secrets, and sell the F_1 seed, which could not saved to plant again. The convergence of technology and intellectual property protection has converted seed from a public good to a privatized commodity.

From the last half of the 20th, public plant breeding grew and reached its zenith in the late 1960s, and from about the mid 1970s has been in decline. The decline coincides with political and economic climates that have favored private enterprise. Agricultural companies became larger through consolidation and have developed considerable political clout.

Agricultural trends for farmers have followed a similar trajectory. In the late 19th century, farmers were essentially self sufficient, producing most of their inputs on farm, growing most of their own food and selling the surplus. By the 1990s, conventional farmers had become nothing more than a conduit through which inputs were converted to raw product, that was further processed before being sold to the consumer. Inputs included the capital to fund the enterprise, fuel, fertilizers and pesticides, and the seed; the farmer provided solar energy and water, and produced the grain. Much of this change in farming has resulted from policies that favor capitalism. In capitalistic systems, specialization of workers in a supply chain is encouraged as it increases short term efficiency. Thus, workers are separated from their full livelihood, and no longer work in self-sustainable, closed systems. As stated by Lewontin (quoted in Kloppenburg, 2004, p. 32), “Farming has changed from a productive process that originated most of its own inputs and converted them into outputs, to a process that passes materials and energy through from an external supplier to an external buyer.”

While organic farming has been a developing discipline through much of the 20th century, it became much more mainstream beginning in about 1980. The federation of the National Organic Program in 2002 gave us a national standard for certification of organic production. Access to improved varieties specifically adapted to organic production has lagged though. Organic agriculture is something of an aberration as it does not fit the privatization model. Rather than simply being a conduit through which inputs are transformed into raw product, organic production in its purest form seeks to close the loops so that fewer off farm inputs are added, with increase in sustainability of the system. The label does not apply to industrial organic, but other organic farmers are revolutionaries because they are bucking the mainstream trends of capitalism.

The Present: As a result, a deca-millennial tradition of seed as a public good has gradually been eroded. Farmers have been separated from their role in the active stewardship of seed. And public institutions are in a decline. We have reached a point where large seed companies have become worried about the ability of public plant breeding programs to train future plant breeders for industry: witness the establishment by Monsanto and Pioneer Hybrid of large endowments for graduate research assistantships at North Carolina State University and University of Wisconsin in 2007.

The Future: In attempting to discern the future of public breeding research, we must recognize forces in addition to the economic ones that are acting on human society over which we have little control. These include changing climate, increasing population, globalization, and energy. In “The End of Agriculture in the American Portfolio”, Steven Blank (1998) describes what has become the end result of our agricultural policies that favor the private sector over the public good. Land use shifts to the highest monetary value, which is in real estate, not agriculture. Consequently, agriculture moves to developing countries where production costs are cheapest (lowest labor costs). The only significant “agriculture” to remain in the U.S. will be golf courses, turf farms and nurseries. If this vision of agriculture in America comes to pass, there will be no future in it for a self sufficient food system.

My vision is not as bleak. What happens to American, and ultimately world agriculture is a societal decision. If we want farms in America, then society may need to subsidize them, such as currently happens in regions of Europe. Blank also overlooks the entrepreneurial and innovative abilities of American farmers, who substitute knowledge and technology for labor. This is particularly true in organic farming where some of our best and brightest entrepreneurs are concentrated. There are also positive trends such as renewed public interest in food and health with emphasis on fresh, flavorful, local, organic/sustainable, and healthy. The private sector and USDA have recognized the neglect of plant breeding. Recent efforts to rectify the situation include the USDA-CSREES plant breeding and education grant program, the specialty crops program, and private dollars to fund plant breeding at universities.

If there is no societal decision to support American agriculture in the next 50 years, we will see continued privatization of public services and a reduction in the universities' traditional role of training, research, and extension. We will see continually dwindling Federal and state budgets. Positions will not be replaced, and departments will shrink. As departments shrink, they are eliminated altogether, or are merged into super-departments that continue to shrink. We will see a reduction in the number of land grant universities, with just a few regional hubs representing the various production areas of the U.S. Another trend will be the privatization of agricultural research, such as has happened in Great Britain and Australia. One way to resist these trends is to preserve positions through the development of endowments and sponsorships.

In the near term, I see organic producers as being some of the strongest supporters of the traditional land grant system. Philosophically, the organic movement is much more in tune with traditional public agricultural research than with the current proponents of privatization. There is much that the public sector can contribute to better organic farming. For example; public breeders can develop varieties in and for organic systems, thereby reducing the yield discrepancy that is now apparent between organic and conventional agriculture. For public institutions to remain viable and conduct the type of research and develop the technologies needed by organic growers, the stakeholders need to support public institutions. They should tell legislators and government agencies of their needs. It is a partnership that can take us into a sustainable future.

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Strategies for Plant Breeding in the Public Interest

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Plant breeding at public universities and international research centers can be designed to assist farmers and local communities rather than to be used as a subsidization avenue for multinational life science corporations that seek a vertically integrated model of a 'modern' agriculture utilizing proprietary varieties.

What strategies can be employed by public breeders to help farmers directly while protecting their basic right to plant back the seed that they grow? And what can be done to develop varieties adapted to local conditions and needs?

For millennia farmers bred their own varieties. In many areas of the world they still do (Ceccarelli and Grando, 2007). Farmers bring a knowledge of their crop and environment that is probably impossible for an off-site researcher to attain (Ceccarelli et al., 2000). In direct contrast to modern varieties, farmer bred varieties and landraces house genetic diversity and are developed and grown in relatively narrow environmental ranges. They also are developed with a lack of ownership issues to deal with as the farmer may replant what he or she has developed on their own farm.

The idea that these varieties are inherently low yielding is a myth. It is farmers, not public or private breeders that provided the incredible array of germplasm that breeders have improved upon over the last 100 years or so. Using wheat as an example it was farmer bred varieties like Turkey Red, Kharkov, Pacific Bluestem, Jones Fife and Little Club that established the US bread basket areas. And it is farmers today, if they are willing, that can produce varieties that meet their own needs and the needs of their communities through a participatory breeding approach.

As breeding became institutionalized at the US Land Grant Universities (LGUs) in the early 1900s the association with the farmers was still very strong. Varieties were released much earlier in the generational process and they still possessed much variation. This variation was then utilized by farmers and acted upon by the environment through natural selection to develop varieties highly adapted to a given location. As the century progressed, the association between farmers and researchers became less and less as the LGUs found more lucrative partners in seed companies and more recently biotech hyper fueled multinationals. The benefits of new varieties more recently have come with the caveat of ownership issues and contractual agreements to use this or that chemical. In developed countries the era of individual farmers actually having a say in research priorities and directions is practically gone.

The winter wheat breeding program at Washington State University strives to support all famers in the state with a mix of nonproprietary traditional, organic, sustainable and farmer directed breeding (Murphy et al., 2008; Murphy et al., 2007). One of the more innovative approaches is evolutionary/participatory breeding (EPB) (Murphy et al., 2005).

The principle of EPB is to get variation into a farmer's field much sooner in the breeding process, much as was done 100 years ago. The EPB method emphasizes the utilization of natural selection in combination with site-specific farmer selection in early segregating generations of a heterogeneous 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 (Allard, 1999; Allard et al., 1992; Suneson, 1956). It is based on a mass selection technique used by farmers for over 10,000 years of crop improvement. Participatory plant breeding programs originated to meet the needs of low-input, small-scale farmers who were often overlooked by conventional crop breeders.

By exploiting the powerful combination of farmer knowledge, genetic diversity, natural selection and traditional plant breeding methods, resilient varieties optimally and uniquely adapted to sustainable farming systems can be developed to horizontally integrate local farms with healthy and productive community food systems.

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Plant Breeding and Quality of Life in Rural America

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Since the 1930s U.S. farmers with the help of plant breeders and other agricultural scientists have been phenomenally successful in increasing crop yields. Corn yields, for example, have increased roughly five fold over that time. While science has been instrumental in these increases the role of federal farm policies cannot be underestimated. As a result of these increases commodities such as corn, soybean, and cotton and products produced from them are abundant and inexpensive. Corn grain is now so cheap we use it in thousands of industrial and food products and, in essence, burn it to fuel our automobiles.

While cheap commodities are the underpinning of our industrial food system, there are obvious downsides. The abundant and incredibly cheap simple carbohydrates and fats produced by our agricultural system are obviously <u>one</u> part of the epidemic of obesity plaguing Americans today. And devoting essentially all farmland in entire regions to the production of cheap commodities has negative affects on rural communities. Since commodities are only valuable if they are cheap, individual farmers are forced into growing more and more acres, which results in fewer and fewer farmers. Furthermore since the product of the community is exported as a raw material or lightly processed material (oil, starch, ethanol), the wealth of the community is exported. Thus many American farming communities bear the hallmarks of extractive economies. Communities based on extractive such as mining or oil drilling communities are characterized by low incomes, depopulation, and environmental damage.

Recognizing that breeding of commodity crops for high yield will continue, how can other plant breeders and farmer breeders help improve the quality of life in rural America? Rural communities need to have cultivars that will allow the communities to keep more of the wealth of the land in the community. Rural communities need crops and cultivars that will allow them to diversify and add value to their agricultural systems. There are numerous examples of these kinds of endeavors. To help create more success stories, plant breeders need to work with farmers, consumers, and agricultural communities to develop value added enterprises. Plant breeders need to develop cultivars that can fit the needs of value added enterprises.

Organic Potato Seed Production

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Seed potato certification programs are well-designed and very important but they are only the beginning of the discussion about the quality of seed potatoes, most especially about the quality of organic certified seed potatoes. Seed potato production is still highly decentralized and this workshop will teach you why knowing where and who your seed potatoes come from is critical to your success.

Nitrogen Management for Organic Vegetable Seed Production

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In many cases nitrogen is the most challenging nutrient to manage for an organic seed grower. This presentation will:

- Present options for managing nitrogen (N) in an organic system (Sullivan)
- Introduce the Organic Fertilizer Calculator, a tool comparing the cost, value and nitrogen availability of organic materials (Andrews)
- Provide practical advice for obtaining optimum seed yields and quality (Reiten)

Options for managing nitrogen in an organic system (Sullivan)
Five questions summarize the N management decision-making process:

1. Source. What source of organic N should be used?
2. Rate. How much N needs to be applied for this crop? How much of the N needed by the crop is already present in the soil?
3. Timing. When should organic fertilizer or soil amendments be applied? How long after application will plant-available N be released?
4. Method of application. What equipment is suitable for organic fertilizer application? What method(s) of application can be used for a given organic fertilizer material?
5. Monitoring. What soil and plant tissue tests are best for monitoring the result of my choices for N source, rate, timing and application method? How do I interpret monitoring data?

Source

Two major kinds of N inputs are used in organic systems: rapidly-available N sources and composts. Rapidly-available N sources decompose rapidly in soil, and provide most of their plant-available N (PAN) in the first month after application (if soil is warm and moist). Composts are used for long-term soil building (adding organic matter to soil). Composts decompose slowly in soil, and they provide small amounts of PAN for a long time after application. Crops also recycle N or provide N (legumes) in organic systems. Crop residues that are young, leafy, and high in N decompose rapidly. They behave like rapidly-available N inputs. First-year release of PAN from rapidly-available N sources is discussed in the "Organic Fertilizer Calculator" section of this presentation.

Rate

You can use university fertilizer or nutrient management guides to get a general idea of N needs of different crops. The amount of PAN required from rapidly-available organic fertilizers will usually be less than the amount of fertilizer N (rate) recommended in guides for conventionally grown crops.

Timing
If you need to apply a rapidly available organic N source, this should typically be done 3 to 6 weeks before the crop begins rapid vegetative growth, in order to allow time for microbial conversion of fertilizer organic N to plant-available ammonium and nitrate-N.

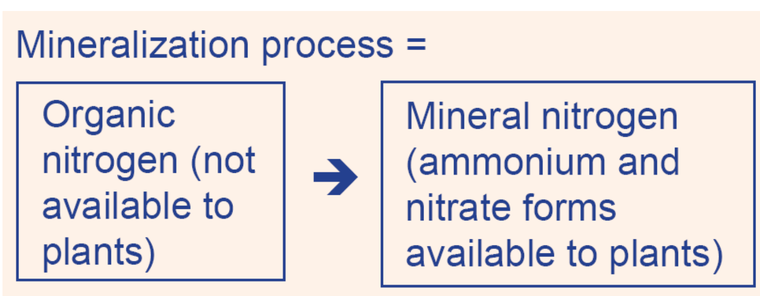
Method of application
Because it is usually expensive and difficult to apply organic N fertilizers at mid-season (side-dressing), more of the N for organic crops has be applied preplant than in conventional systems.

Monitoring
Each year, the decision process begins anew. Progress in N management can be made rapidly when soil and plant tissue monitoring data are used to:

- Assess the effectiveness of the N management system
- Adjust N management practices for next year

The N management process (source, rate, timing, method of application, and monitoring) are discussed in detail in the next section, along with some basics about the nitrogen cycle. This discussion takes the form of questions and answers.

What is mineralization?
Decomposition of soil organic matter into plant-available N is called mineralization. A simple way to think about mineralization is:



The quantity and timing of soil N mineralization depend mainly on:

- Organic matter content of the soil
- Soil temperature
- Soil moisture
- Crop rotation

Mineralization occurs most rapidly in soils that are warm and moist and have high organic matter content. N mineralization is increased when high-N crop residues (legumes) are tilled into the soil.

Do plants grown organically contain the same amount of N as plants grown conventionally? The amount of plant N uptake required to produce a given yield is usually similar in conventional and organic systems. But, organic systems rely more upon N mineralized (released) from soil organic matter to supply crop N needs.

Is the timing of plant N need similar in conventional and organic systems? Timing of plant N need is similar in conventional and organic systems. So you can use plant N uptake information like that shown for seed carrots (Figure 1; adapted from OSU Guide EM 8879-E) to predict when the plant requires plant-available inorganic N. In the seed carrot example, plant N uptake of nitrogen is most rapid during May and June. Seed carrot plants take up 1 to 3 lb N per acre per day during May and June. At harvest, the seed carrot crop biomass (tops + seed) contains approximately 200 lb N per acre. About 15 to 25 lb N per acre is contained in the seed. The remainder, 175 to 185 lb N per acre, contained in the above-ground plant, is returned to the soil at harvest in crop residue.

How much N mineralizes from western Oregon soils for summer crops like potato (planted mid-May, harvested end of August)? Recent research (www.ospud.org) measured potato crop N uptake in the absence of current season fertilization on 10 organic farms during 2006 and 2007 growing seasons. Unfertilized potato crops took up 100 to 250 lb N per acre from mineralization. Farms with a long history (10+ years) in organic production had very high N mineralization amounts (>200 lb N/acre).

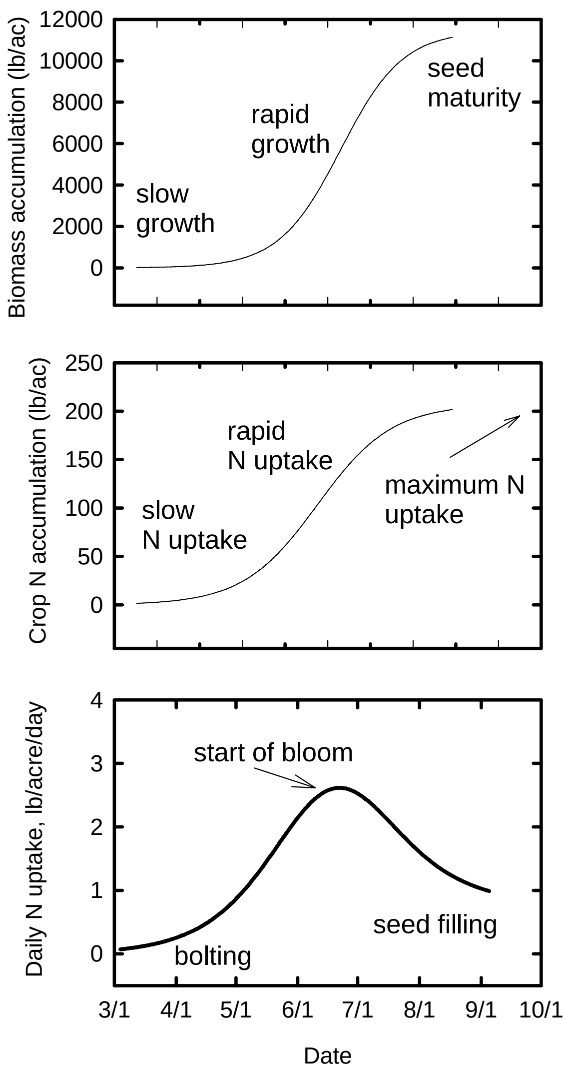


Figure 1. Aboveground plant biomass accumulation (top graph), crop nitrogen accumulation (middle graph), and daily nitrogen uptake rate (bottom graph) for a conventionally grown seed carrot crop. Madras, OR. Adapted from: Hart and Butler, 004. OSU Nutrient Management Guide for Hybrid Seed Carrot (central Oregon), EM 8879-E.

Do all organic materials mineralize to release PAN at the same rate? No. The kind of organic matter makes a big difference in how much N is present (N % in organic matter) and how fast the organic N mineralizes to plant-available N. Finished composts decompose slowly in soil, and release N over many years (Figure 2). In contrast, rapidly-available sources (poultry litter, seed meals, blood meal, fish products etc.) release N rapidly after application. Cover crop residues from legumes (peas, vetch) that are rich in N (contain over 3% total N; young plants) decompose rapidly and release PAN from mineralization rapidly (like poultry litter, Figure 2). High-rate applications of stable composts can be used for soil building (provided salts are not excessive) because they release N slowly for many years.

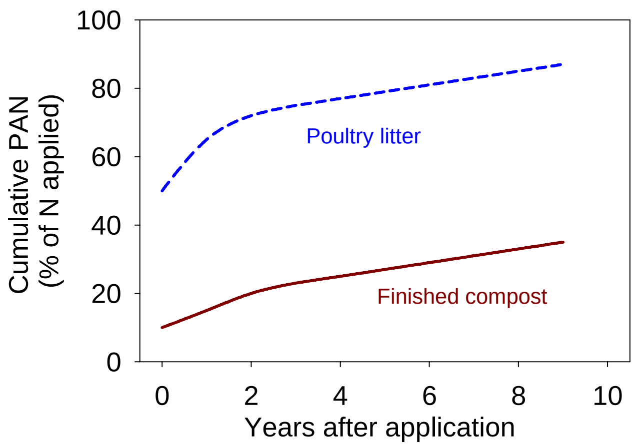


Figure 2. Cumulative plant-available N (PAN) provided by a one-time application (Year 0) of finished compost vs. poultry litter. Most of applied N that is not mineralized to PAN remains in the soil as organic matter.

How can I tell if I have "finished poultry compost" or "poultry litter"?

If you can smell ammonia in broiler litter, it probably is not thoroughly composted. Dry-stacking of broiler litter does not provide adequate moisture for composting. Most broiler litter offered for sale as "compost" in western Oregon smells of ammonia and behaves more like fresh litter than compost in terms of N availability.

How can I if my organic fertility program supplies too much nitrogen? Since soil nitrate is the end-product of the mineralization process in soils, when soils or plants contain high concentrations of nitrate, you know that N mineralization has supplied a lot of plant-available N. For the seed carrot example (Figure 1), if soil nitrate samples were collected 3 times (in March, June, and at harvest) and soil nitrate-N remained above 20 ppm in all samples, then the crop had more than enough N to support an adequate seed crop. Similarly, if plant tissue samples show high nitrate concentrations relative to recommended levels, then N supply is likely excessive.

How can I tell if my fertility program does not supply enough nitrogen? Soil nitrate-N concentrations for organic crops can be low (less than 10 ppm), but the crop can be getting enough N through mineralization. The best way to determine if N supply is adequate is to conduct on-farm trials to determine if fertilization (adding rapidly available N products like fish, feather, or seed meals) improves seed yield and/or quality. In the seed carrot example, you could try organic fertilizer rates that supply 40 or 80 lb plant-available N (PAN) per acre for the first trial(s). Then, if 40 lb PAN/acre appears sufficient, try reducing rates to 20 and 40 lb PAN /acre in subsequent trials. For some crop rotations on some farms, no N inputs from rapidly-available sources are required to meet crop N needs. But, all farms are different, go slowly in drastically reducing N rates.

Organic Fertilizer Calculator: a tool for comparing the cost, value and nitrogen availability of organic materials (Andrews)

Choosing between different organic fertilizers can be difficult. Nutrient ratios, nitrogen (N) availability, ease of use, and cost vary widely between different materials. An Excel-based organic fertilizer calculator was developed to help compare the cost, nutrient value and nitrogen availability of organic fertilizers. It can be used to help plan a cost effective program that avoids excessive or deficient fertilizer applications.

The percent nitrogen as listed on a fertilizer label indicates the total percent nitrogen in the material. This nitrogen is mineralized and made available to plants over time, and only a fraction becomes available to plants the year of application. The organic fertilizer calculator includes a mineralization model that uses total nitrogen to estimate plant-available nitrogen. These predictions are useful but since nitrogen mineralization is influenced by many factors including fertilizer application rates and their C/N ratio, soil temperature, moisture etc., they are estimates only.

The calculator can be used to make fertility plans for one season. It was written in Excel and is available with instructions (OSU Extension Publication EM 8936-E) at http://smallfarms.oregonstate.edu/organic-fertilizer-calculator. The calculator has five worksheets:

1. "Fertilizer analysis" – enter the percent dry matter and nutrient analysis for the fertilizers, the calculator will estimate percent plant available nitrogen (PAN).
2. "Nutrients provided" – enter nutrient requirements and fertilizer application rates and get estimates for each nutrient provided including PAN after 28 days and by the end of the season.
3. "Costs" – enter the price/lb of each fertilizer and see the cost of the program being considered and the price/lb of each nutrient.

4&5. "Table 1" and "Data set" show the background information used to estimate the percentage of total N that will be mineralized and made available to crops (PAN).

Nutrient values and costs are calculated on an "as-is" (or fresh weight) basis throughout the calculator so that guaranteed nutrient analyses on fertilizer labels can be used. The calculator estimates nutrients supplied by fertilizers and their cost. It compares the nutrients supplied by an individual fertilizer or fertilizer program with targeted nutrient application rates.

Plant Available Nitrogen (PAN) is an estimate of the amount of N a given organic fertilizer will release through mineralization over a certain time period. It is expressed as a percentage of the total % N (as found on the label). The calculator incorporates a simple linear regression model to estimate PAN that was developed by researchers at Oregon and Washington State Universities. In order to generate PAN estimates on an "as-is" basis, the calculator asks for an estimate of % dry matter of the material used. Typical dry matter estimates are provided in the calculator, your fertilizer supplier can also provide estimates.

The N in most conventional fertilizers is available to plants very quickly, but non-synthetic or organic fertilizers gradually release their N as microorganisms break them down. The rate of mineralization varies with the C/N ratio of the fertilizer. Nitrogen from high N materials (low C/N ratio) is more rapidly available than from lower N materials (high C/N ratio). Percent carbon (C) in organic materials is generally around 35-40%, while percent N varies from 0-10% or more. Therefore, changes in C/N ratio are mainly due to changes in the %N, and the data shows that total % N as provided on a product label can provide a useful estimate of N availability.

Table 1 shows the model used to estimate %PAN. Figure 3 (the "data set" worksheet in the calculator) shows the relationship found between total % N and the % PAN in the materials tested. Eleven compost and manures were tested and nineteen specialty products (i.e. feather, blood and fish meal) were tested in the field and/or in the lab. The calculator estimates PAN after 28 days and a full season (approximately 125 calendar days). For example (in Table 1), an organic fertilizer with an analysis of 4% total N (dry weight basis) is estimated to:

- release 30% of its total N (24 lb PAN per dry ton) in the first 28 days
- release a cumulative total of 45% of its total N (36 lb PAN per dry ton) during a 125 day growing season.

Table 1. PLANT-AVAILABLE NITROGEN (PAN) ESTIMATES

Amendment total N	Amendment C:N	Plant-available N estimate	
		28 days	full season
% dry wt.		% of total N	% of total N
	Uncomposted materials		
1	35	< 0	0
2	18	0	15
3	12	15	30
4	9	30	45
5	7	45	60
6+	less than 6	60	75
	Composts		
1	30	0	5
2-3	15 to 10	5	10

Adapted from Gale et al. (2006) and Sullivan (personal communication)

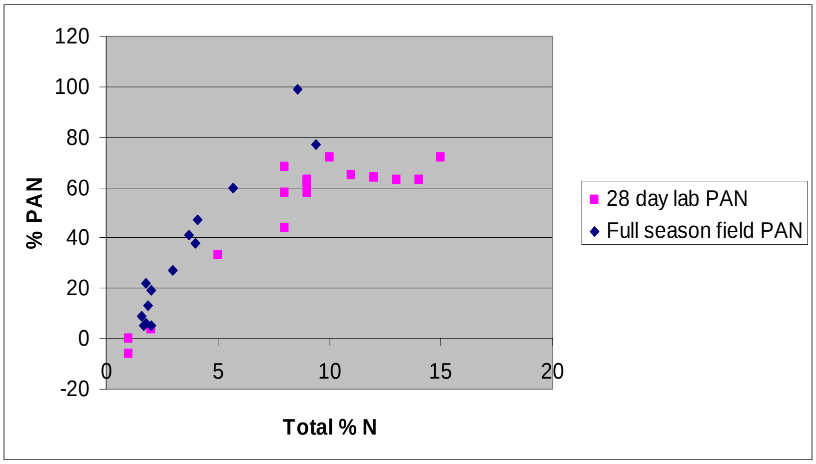


Figure 3. Research data demonstrating the relationship between the total N percentage in an organic fertilizer (dry wt. basis) and the amount of plant-available N (PAN) released after application to soil. Each data point represents one organic fertilizer material. Data from laboratory incubations (squares) or field trials (diamonds). Description of experimental methods provided in Gale et al, 2006

Composted materials are more stable than uncomposted materials and the release of N is generally slower. In this calculator we have listed some commercial chicken manure-derived products as uncomposted materials. Processed manures are sometimes sold as "compost", but may contain significant portions of mineral N. Our use of the term "compost" here refers to the stability of the N in the product. The National Organic Program (NOP) definition of compost is based on time and temperature requirements for pathogen reduction, many materials can meet this NOP definition and still have significant mineral N contents. Without maturity testing this distinction is somewhat subjective, if you are unsure whether your material should be considered uncomposted manure or compost, contact your supplier. If the product looks like manure, smells of ammonia, or heats up when stacked, it is likely to release N more like manure. Nutrient values in manures vary considerably; values provided in the calculator represent averages from some suppliers in Oregon. We highly recommend nutrient analysis for manures; many suppliers will have this information readily available.

Changing units is easy with the calculator. It is written for lb/acre and US$; however, none of the formulas rely on units used. Be sure to remain consistent with units through all calculations. A small farm and garden version of the calculator is available online that makes calculations on a square foot basis.

Limitations of the Organic Fertilizer Calculator

- The calculator does not estimate environmental losses to evaporation or leaching.
- Calculated values are estimates only since nutrient content of organic materials and their availability vary considerably. Results from this calculator should not be considered exact.
- Nutrient analyses in organic fertilizers are variable; the values shown in the calculator may not be the same as those in the fertilizer you are using. **Be sure to check the guaranteed analysis on the product label or lab tests of the exact product you are using and adjust values accordingly.**

- Data for the PAN model were from solid organic fertilizers applied to soil. These PAN estimates are not designed for use with liquid fertilizers, but calculations for other nutrients based on guaranteed label analyses are valid.
- For an amendment with lots of non-organic material (i.e. compost made with soil), C:N ratio is more useful than total N in estimating PAN.

Please try the Organic Fertilizer Calculator and let us know how it works for you. We will continue to update the calculator based on your input and new research findings, so be sure that you're working with the most recent version by checking the OSU Small Farms website.

Practical advice for obtaining optimum seed yields and quality (Reiten)

In the organic ecosystem nitrogen is added to the soil in several ways. Legumes, colonized by certain strains of Rhizobium bacteria, take nitrogen gas from the air and "fix" it, making it available for plants. Small amounts of N in rainfall can add nitrogen to the soil. Organic farmers add organic amendments to the soils in the form of composts or organic fertilizers. The most significant additional source of nitrogen for the crop comes from the biological breakdown of soil organic matter (mineralization). The buildup of soil organic matter is the nitrogen "in the bank" that continuously breaks down from biological activity and provides ammonium and nitrate that the plants can use to grow and reproduce.

This portion of the session will show some practical ways to ensure that you have adequate amounts of nitrogen available. A copy of the PowerPoint will be available.

For More Information

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Organic Potato Seed Quality and Seed Certification

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Double-certified organic seed potatoes have been produced for more than two decades in the USA yet one still hears skepticism from some quarters that organic seed potato production is even possible. This confusion hints at the many challenges that are faced by pioneering organic seed potato producers. In this workshop, Jim Gerritsen, who with his family have raised organic seed potatoes on their Wood Prairie Farm in northern Maine for over 20 years will explain his methods for producing high quality early generation seed potatoes for the organic market.

Examples of Current Breeding Research for Organic Farming Systems in the Netherlands

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In the Netherlands, two research institutes are involved in breeding research for organic farming systems: Louis Bolk Institute (LBI) in Driebergen and Plant Research International (PRI) in Wageningen. In 2005, Wageningen University founded a chair of Organic Plant Breeding so that also fundamental research with PhD students and student courses is now running. Recently LBI and PRI have completed a four year pre-breeding research program (2004-2007) to support the development of improved varieties for organic farming in the Netherlands. This research program was focused on reduced susceptibility of thrips in cabbage, black spot diseases in carrots and fusarium in spring wheat, and also on the development of new selection strategies for better adapted onion varieties. Public breeding programs no longer exist in the Netherlands. Public funding is only allocated for non-competitive pre-breeding research.

The research program does not aim directly at commercial applications, but on basic pre-breeding research and the development of parent material for breeders. The primary result is knowledge that can be used by breeders to improve their programs. It includes knowledge on additional plant traits that can lead to reduced susceptibility and on the genetic background of such characteristics, and also on the possibilities to exploit the traits in breeding programs and on new selection methods. The program has also delivered some information derived from variety trials that can be of direct use to farmers and producers of organic seed to make up their choice of varieties. In all projects there has been a close cooperation with farmers and with breeding companies. Below is a summary of the results.

Onion – mycorrhizas (PRI)

A previous research project indicated that symbiotic soil fungi such as arbuscular mycorrhizas have a positive effect on the growth and development of onions. Not yet known was whether mycorrhizas can also support tolerance to diseases in onion and whether or not breeding for an improved interaction between plant and mycorrhizas is possible.

In our project we have gained insight on mycorrhiza fungi present in soils of organic and conventional onion farms in two regions of the Netherlands (Flevopolder and Zeeland). In pot trials large varietal differences in the interaction with mycorrhizas have been shown, e.g. in relation to bulb forming. We also found large variation among progenies of a cross between onion and a related species (*Allium fistulosum*) for response to mycorrhizas (Galvan et al., 2007). The identification of genetic variation suggests that breeding for such improved interaction should be possible. We also found preliminary indications for an effect on disease tolerance, especially to fusarium. For breeding companies it is necessary to gain more insight in the effects of mycorrhizas on the growth and development of plants. They also need to know more about the rooting system under field conditions and heritability of mycorrhizal response before breeding programs can benefit from such an approach. A planned follow-up project (2008-2011) will focus on such questions.

Onion and selection environment (LBI)
Conventional breeders wonder if it really makes much difference to breed varieties for organic agriculture while selecting under organic or conventional growing conditions. Do they really need to exploit additional organic selection fields or would it be sufficient to add some additional selection criteria to the program in conventionally managed fields? We also focussed on the question of whether conventional breeders could learn from the variety concept of organic farmer-breeders. As an onion breeder was already coping with such questions, onion was chosen as the model crop for these questions. In addition, some organic farmers were also actively involved in onion breeding in the Netherlands.

By interviewing professional and farmer onion breeders we found that farmer breeders put more emphasis on the evaluation of field characteristics than most of the professional breeders in their ‘normal’, conventional breeding program. Farmer breeders gave higher priority to earliness to escape from attacks by downy mildew. Also, a longer neck was regarded as an important trait by them to enable easier falling down of the leaves at ripening stage and thus to support better ripening and closing of the neck (Tiemens-Hulscher et al., 2006). Conventional breeders mostly focussed their selection efforts after storage. However, in interviews professional breeders indicated that they would pay more attention to field selection in case they would select for organic varieties. At present they do not select varieties specifically for organic production.

A field trial was set up to compare the selection in three newly made onion base populations in an organically managed environment versus selection in a conventional environment (Lammerts van Bueren et al., 2005). A second trial was set up to compare the results of selection by a professional onion breeder in an organic and conventional field and by two organic onion farmer breeders in their own organic environment. The question whether the broader variety concept of the farmer breeders and the organic selection environment will contribute to a better adapted variety for organic agriculture cannot yet fully be answered after one generation with a two-year crop. Therefore, we need more generations of selection. The involved breeders are anxious to collaborate further and will continue in the follow-up project (2008-2011). At the end of this period we will compare the selection results.

Carrot and black spot (PRI)
The question was: can we find useful resistance against black spot diseases of carrots? Black spots are a mayor problem in carrots in the Netherlands. It is known that there are several fungi involved. A literature search revealed that *Alternaria radicina* is the most common one and is seed borne, while *Rhexocercosporidium carotae* also occurs widely; both these fungi infect the crop in the field. In addition carrots get infected by other fungi when washed. We developed practical methods to test harvested and stored carrots for resistance to three important fungi, see figure 1. Unfortunately, for *Rhexocercosporidium* the method is sensitive to the condition of the

carrots. For all three diseases these tests can discriminate the most resistance varieties. In this project new genetic resources of resistance have been identified, but absolute resistance was not found.

We evaluated a collection of carrot varieties widely used in organic agriculture on susceptibility for the black spots, see figure 2. The project leads to the conclusion that there is a good perspective for breeding for resistance to *Alternaria radicina* and that a breeder can make adequate choices in their selection material (Voorrips, 2006). However, the multitude of fungi causing black spots will make the development of a completely black spot resistant carrot very difficult.

Figure 1. Lab test for resistance against *Rhexocercosporidium carotae*, 5 weeks after inoculation

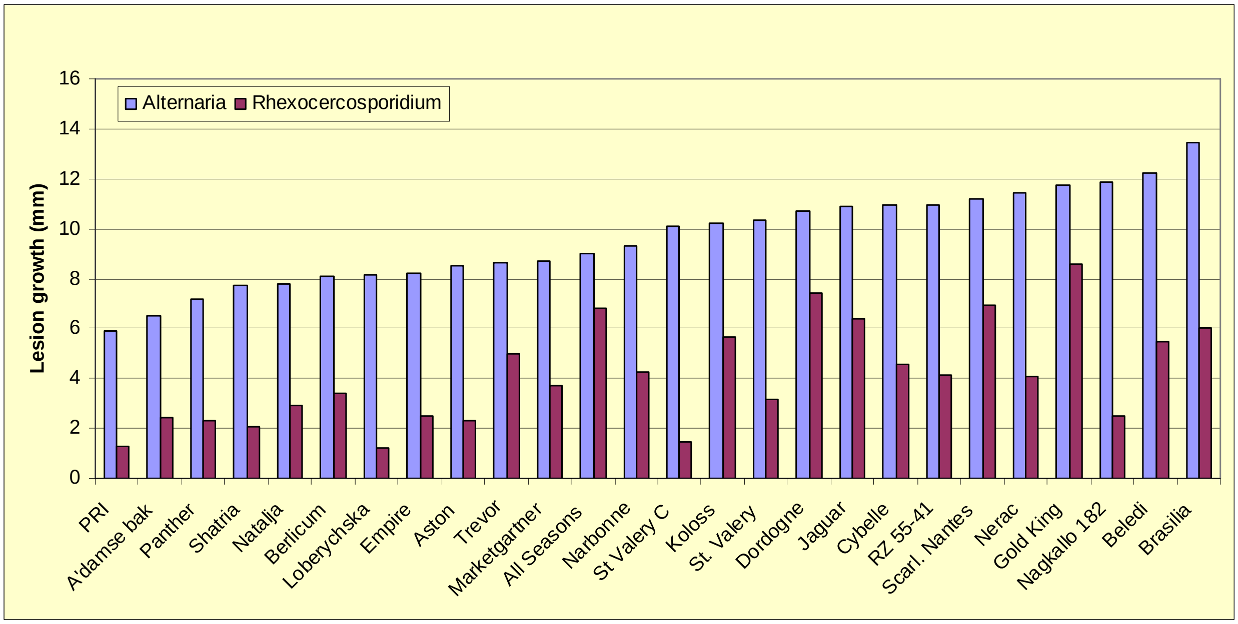

Figure 2. Varietal differences in resistance against black spot fungi *Alternaria radicina* and *Rhexocercosporidium carotae*, average of results in 2005 and 2006.

Cabbage - thrips (PRI, LBI)

Thrips in cabbage is an increasing problem before and after storage. Breeders experience differences among varieties but did not have any knowledge on inheritance or on plant traits relevant to resistance against thrips. An enquiry among organic cabbage growers on their experience with growing cabbage provided some starting points for the research. In field trials with a collection of old and modern varieties, several characteristics have been identified that influence the thrips resistance, such as the wax layer on the leaves, the compactness of the cabbage head and earliness (Voorrips et al., 2006). We also found an old Dutch farmers' selection that was more resistant to thrips than the best modern variety.

To better understand the inheritance of thrips resistance, several crosses were made between high and low resistant varieties. To be able to breed successfully and efficiently for thrips resistance this project will continue in the new program (2008-2011). We will also develop test methods to evaluate thrips damage among different cabbage varieties in an easier way.

Spring wheat – fusarium (PRI, LBI)

Worldwide a lot of research has been conducted on fusarium in cereals. There is more knowledge, but the problem hasn't been solved yet. There was little knowledge on resistance against fusarium and the DON production of new spring wheat varieties. Screening of a set of current spring wheat varieties showed large differences and can directly be used by farmers to make a good choice. In the current variety assortment there seems to be large variation in resistance and stability of the resistance over the years (Scholten et al., 2007). The seed producers already use this knowledge to decide which variety they will propagate for organic agriculture. We also searched for a correlation between reduced susceptibility and morphological traits. The project showed that varieties with a compact ear are more sensitive to fusarium contamination. This gives breeders insight in the choice for crossing parents.

In the new research program (2008-2011) some of the topics will be continued as described above and others will start. One of the new issues is selection methods for nutrient efficiency in potato.

Potato – nutrient efficiency (LBI)
The yield and yield stability of organic potatoes are limited by a) low nitrogen input, b) a variable nitrogen dynamic and c) late blight. The organic sector needs well adapted organic potato cultivars, specifically cultivars which can deal with low nitrogen input and variable nitrogen availability, and cultivars which can recover after a period of nitrogen stress. However, breeders lack knowledge about genetic variation in nitrogen response under low input growing conditions, and about traits and physiological mechanisms behind such genetic variation. Therefore, it is hard for breeders to select for plants which have a certain level of nitrogen 'plasticity'. The objective of this new project is to identify plant traits that are correlated with the ability to deal with low and variable availability of nitrogen. These traits will be transformed into selection criteria.

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Participatory Approaches to Breeding Organic Crop Varieties for Genetic Resiliency

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Summary

The environments and cropping systems employed by organic growers are often more diverse than those used by conventional farmers. Crops produced with low input organic farming practices are frequently exposed to a greater set of environmental challenges including variable nutrient availability, drought conditions, and weed or pest pressure than crops grown under high input conventional systems. Developing crop genetic resources adapted to low input, diverse organic cropping systems is essential for the continued improvement of organic agriculture. Genetically elastic, heterogeneous crop varieties have proven to produce higher, more dependable yields in low input, subsistence agricultural systems than the more narrowly selected, genetically homozygous crop varieties of modern agriculture. Through the use of population improvement methodology conducted under the challenges of environmental stresses in low input systems it is possible to breed genetically diverse, heterogeneous varieties with greater adaptive advantage to the environmental variables and cultural practices of organic farming than many existing commercial crop varieties. Examples from two ongoing, pilot population breeding projects in zucchini and kale will be discussed with an emphasis on participatory breeding models that meet individual farmer's needs for environmental adaptation and market acceptance.

Introduction

The development of regional seed systems for organic agriculture is a very important component in the health and stability of the agricultural economy of any distinct agricultural region. It is a well-accepted idea that agricultural genetic resources, crops and livestock that are adapted to the environment and cropping systems of a particular region are more likely to thrive and provide an economic return for the farmer than those plants and animals that are not genetically suited to that region. Breeding crops for the "area of intended use" is a time-tested concept used by some of the most successful seed companies in the last century (Satterlee 1996). Certainly, genetic selection of crops that excel under given seasonal temperatures, fluctuations in precipitation, and the particular types of soils native to a region will usually produce varieties that perform better than varieties bred in other climates. If these varieties are also selected to withstand the biotic and abiotic stresses of drought, heat or cold stress, native diseases or insect pests then they have the potential to perform better than other varieties (Ceccarelli 1994). This is in sharp contrast to the trend among large seed companies, where company consolidations have resulted in an increasingly narrow breeding focus, abandoning many regional market segments and breeding and testing new varieties only in the highest profile agricultural market areas.

It is also possible to breed for the higher degree of variability and the lower rate of external inputs found in most organic cropping systems. Murphy et al. (2007) compared 35 wheat cultigens grown in paired conventional and organic systems and the highest yielding cultigens in the organic systems were not the highest yielding cultigens in the conventional systems. This indicates that the development of crop varieties for better performance in organic systems will require breeding in that system. For example, the important role of root morphology in efficiently utilizing soil nutrients under field conditions must be considered when breeding crops for organic agriculture. Gahoonia and Nielsen (2004) have found heritable genetic variation for root hair length and root hair density in several crops, which translates to increased phosphorous (P) uptake in the field. Breeders could take advantage of this variation to develop varieties that thrive in organic cropping systems where much of the P (and other macronutrients) is derived from the mineralization of organic matter from compost or cover crops.

Organic farms in many regions of the developed world tend to be smaller, more diversified operations than their commercial counterparts. The location of a considerable number of organic vegetable farms is not central to the large-scale production areas and consequently they often have more environmental variability in terms of climate, soil type and availability of irrigation water (Grube 2007). Breeding for these diverse, heterogeneous environments may be best accomplished through the use of decentralized selection across a number of sites within a region (Ceccarelli and Grando 2007; Dawson et al. 2007). These sites should be representative of the environmental challenges with the lower inputs and environmental variability found on organic farms.

Many breeders avoid selection in low input environments, as there is often a marked decrease in the genetic variance of their breeding materials due to a greater environmental effect in genotype by environment (G x E) interactions. However, most experimental evidence of this is when breeding materials from high-input environments are tested in low-input environments. Ceccarelli (1994) surveyed the data from a number of breeding studies in marginal agricultural environments where the heritable genetic variance was not necessarily lower in low-input systems when local germplasm adapted to these systems were tested. Plant breeders who breed for these challenging environments have found that locally maintained “farmer varieties” that are selected in low-input systems can be an excellent source of genetic material in this effort (Whitcombe 1996). The genetic diversity within many of these farmer varieties can often include the necessary genetic components for resistance to diseases, pests, cold, heat, drought or any other stresses that may be endemic to that agroecosystem (Ceccarelli 1994.) A number of breeders working in low input environments now recognize that preserving as much of this diversity as possible is desirable to buffer the crop from these challenges as they fluctuate across seasons.

A breeding method that has been gaining favor for breeding crops found in marginal agricultural environments of developing countries is called participatory plant breeding (PPB). Much of the development of PPB over the past thirty years has involved breeding non-commercial, subsistence crops of small grains and pulses in areas “that have been bypassed by the benefits of formal breeding efforts” (Ceccarelli 1996). It is a collaborative breeding effort that enlists the support, expertise, and judgment of the farmer. In fully realized PPB projects the farmers are true participants in the research process. Their role as a full partner can involve all aspects of the breeding process, from setting the objectives, determining the traits for selection, execution of selection, determining the final genotype to advance at the conclusion of the project, and finally replicating and genetically maintaining the variety for distribution.

Objectives
Essential to the success of PPB projects is identifying farmers as collaborators who have a vested interest in a successful outcome in any plant breeding project that they participate in. Many of the most experienced organic farmers that work with the Organic Seed Alliance are frustrated by the lack of appropriate commercial varieties for their climate, their cropping systems, or their markets. They often voice the opinion that some of the older standard varieties were more resilient or "field tough" and were often better adapted to their environment and their low-input cultural practices. They frequently complain of fewer choices for their unique market niches as the list of available varieties shrink with seed industry consolidations. These growers usually have a deep understanding of the both the agronomic and quality traits that they need in the crops they grow. Some are highly motivated to participate in field breeding work to remedy this situation.

A number of organic farmers that work with Organic Seed Alliance (OSA) are actively growing seed of crop varieties that fulfill certain needs in their farming operation. These varieties are usually either older, standard varieties that are not readily available or "farmer varieties" that they have generated from a conscience cross or that may have originated serendipitously from a chance outcross, seed mixture, or mutation. In either case the germplasm that they are working with is transforming due to their own selection pressure and through natural selection. In both instances it is adapting to the cultural techniques and environment of that farm. If grown for commercial purposes in fairly large populations this germplasm usually has more genetic diversity and phenotypic variability than comparable crop varieties that are available from the seed trade.

In our educational outreach OSA has had the privilege of working with several farmer breeders who have identified source germplasm and performed the initial breeding work appropriate to the environmental conditions of their farm as with the pilot PPB study described here. As this project was our first foray into PPB we were interested to discover if we could strike a good balance with the farmer, having a true partnership with mutual respect and trust, in all aspects of the critical decision necessary to be successful in plant breeding. If a productive working partnership could be forged then OSA would be willing to further develop this pioneering work with vegetable crops in North America.

The practical goal of this PPB project is to develop a fresh market class zucchini (*Cucurbita pepo* L.) for organic production in the western USA. The essential traits (the ideotype) for commercial zucchini production in this market include dark green, cylindrical fruit, early and steady fruit set, open plant habit, and relatively few leaves with petioles that have relatively short spines. Bill Reynolds of Eel River Farm is an organic vegetable farmer in northern California that produces several acres of this type of zucchini for the San Francisco market each year. For several seasons in the 1990s Bill was unable to procure seed of the market standard variety 'Raven' F1 (Syngenta) and was not able to find a suitable replacement. This led Bill to initiate an on-farm breeding effort to develop an open-pollinated (OP) zucchini in this class that could be produced on-farm.

As Bill did not have enough 'Raven' he decided to plant 'Black Beauty' ('BB'), an older OP market standard dark zucchini, along with the 'Raven' seed he had. Bill found 'BB' to be typical of many OP vegetable varieties that lack genetic selection (as most seed companies put their R&D resources into hybrid production). While 'BB' is definitely a dark fruited type, he found too much plant to plant variation for a commercial variety. The flaws of 'BB' included a "busy" closed canopy with too many petioles/leaves with spines that easily damaged fruit during windy episodes or during harvest. Many 'BB' plants also have fruits that are bulbous, tapered, or curved with only 20-30% of the plants having cylindrical fruit acceptable by the market. However, there are two traits in 'BB' that were advantageous to Bill's system. Bill practices something he calls "dry land zucchini farming." He plants his crop into moist soil at the end of the spring rainy season and then relies on the tap-root reaching the water table as the dry coastal California summer commences. The plants must be sustained for the rest of the season on this water as he does not irrigate. 'BB' has a robust, large plant with an extensive root system that becomes well established and Bill suspected was able to readily reach the water table. Secondly, Bill was impressed that 'BB' has a harvest period that lasted several weeks longer than 'Raven.' This was especially important for his system as he is not able to plant multiple crops in succession as is common in commercial zucchini production.

During the first season growing both 'BB' and 'Raven,' Bill decided to harvest seed from the 'BB' plants with marketable fruit and a less "busy" plant habit. This would assure some seed for next season if 'Raven' continued to be in short supply. As the 'BB' rows were adjacent to the 'Raven' rows there was considerable crossing. Seed harvested from the 'BB' plants was massed used the next season for Bill's commercial crop and again. As Bill used the segregating zucchini population for his crop over several years he was fortunate to find segregants with all of the market traits of 'Raven' and the robustness of 'BB.' He also discovered a number of agronomic traits in select individuals of the population that better suited them to his production system.

After several years of breeding effort by Bill with support from Seeds of Change, the Organic Seed Alliance (OSA) became a cooperator and initiated a PPB project. The combined vision of these partners has been to breed a commercially viable, open-pollinated, western style zucchini adapted to low-input production practices for the organic market. It was mutually agreed that breeding activities would be on-farm with Bill's standard organic production practices and most importantly that the effort would be participatory in nature with Bill Reynolds and John Navazio as equal partners in all breeding decisions. It was also agreed that any resultant varieties would be as genetically diverse as possible while having adequate phenotypic uniformity to satisfy commercial growers. Finally, all agreed that a strict, traditional pedigree breeding program would not be used in favor of a population breeding effort to retain allelic diversity and genetic resiliency.

Methods

In a fresh market production field Bill Reynolds planted both 'Raven' and 'Black Beauty' ('BB'), an older standard OP variety, for comparison. From this field Bill harvested seed from the best 'BB' plants. This seed, which was allowed to open-pollinate with 'Raven,' was used for the next 3 to 4 seasons with mass selection for the best plants/fruit for Bill's cultural practices and market. The resultant OP population was named 'Black Eel.'

In 2003, the first year (YR 1) of the PPB project, an acre of 'Black Eel' was planted with 'Raven' planted as a check (it was used as the check variety in all subsequent years.) The 'Black

Eel' was harvested for 3+ weeks in order to evaluate the fruit quality as well as the plants' agronomic qualities. Self-pollinations of 26 plants with the best combination of desired traits were made. In 2004 (YR 2) two replicates of 26 full-sib progeny rows were planted and evaluated as in YR 1. When all of the important traits were considered only 4 of the 26 progeny rows had a preponderance of plants with a majority of these traits. We agreed that rows to be selected had to have at least 70% of the plants with a majority of favorable traits. The 22 non-selected rows were tilled up as were the 30% unfavorable plants in the selected rows. The favorable plants in the 4 selected rows were allowed to open-pollinate after all fruit that had set before selection were eliminated. Seed from each of the full-sib family row was harvested separately. As seed was open-pollinated the resultant seed of each row would represent a half-sib family.

In 2005 (YR 3) two replicates of the 4 selected half-sib rows were planted with 4 rows of each accession and evaluated with regular harvests as in YRs 1 and 2. Upon evaluation only one of the 4 half-sib families was found to have a preponderance of favorable plants. This half-sib family, #41(41 S_1), was surprisingly uniform with many plants superior to 'Raven.' selection to type was strident. We agreed to practice strident selection to the ideotype (see Objectives) keeping 55-60% of the best plants from 41 and eliminated all of the other plants in the family as well as all plants in the 3 other half-sib rows. The selected plants of 41 S_1 were allowed to openly pollinate and seed was bulked. This seed (41 S_1M_1) was planted as a single population in a ¾ acre field in 2006 (YR 4). Upon evaluation of 41 S_1M_1 in YR 4 two breeding strategies were pursued. The first was to further select the mass population from 41 S_1M_1. After 3+ weeks of commercial harvest a majority of the plants were allowed to open-pollinate, after selection, for another cycle of massing (41 S_1M_2). The second strategy was to self-pollinate a small subset (16 plants) of the population with the best combination of desirable traits. The seed of these 16 plants was harvested as full sib families. In 2007 (YR 5) two replicates of these 16 full-sib families were grown adjacent to the population mass, 41 S_1M_2, and evaluated.

Results and Discussion

This pilot PPB project was conducted much like a commercial breeding project. Selections were made based on the phenotypic performance of the progeny rows as judged by the breeders Bill Reynolds and John Navazio. Data was taken on fruit type, fruit color and plant type. We set a predetermined percentage of acceptable plants per row in order for a progeny row to be deemed promising. Yield data was not measured. It must be remembered that in many high value vegetable crops both quality and agronomic traits are frequently more important than yield, especially when there is great disparity in other traits existing commercial varieties.

In YR 2 of the PPB project many of 26 full-sib family rows being evaluated had plants showing deleterious recessive traits that had largely been hidden by dominant genetic factors for the years that Bill had only practiced mass selection. Some of these rows had a preponderance of plants with the vining habit, excessive leaves, as well as yellow or misshapen fruit. There were also a number of half-sib rows with stunted plants that Bill recognized as plants with taproots that did not reach the water table. Yet 4 of the full-sib families were exceptional with a majority of acceptable plants with dark green fruit, open habit, low incidence of spines, and vigorous plants. This was an indicator of the quality of the germplasm and the ability of Bill to gather these traits in the original population. These 4 families would constitute the genetic breadth of the resultant population.

In YR 3 we were encouraged when the progeny of all 4 of these selected half-sib families had plants and fruit that were either commercially acceptable or close to acceptable. The gain from selection from intermating the 4 best full-sib families in YR 2 was striking. The most striking feature of many of these plants in comparison to 'Raven,' was how robust they were in their seedling vigor, stature, and leaf size. Many of the plants had more vigor than 'Raven,' a hybrid. Bill also noted a stockiness, or "stoutness" in many of the plants for the first time. This stoutness translated to plants with shorter petioles and an erect stature, allowing the plants to hold their fruit off the ground and to minimize the degree of movement during windy periods, thus lowering the amount of damage to the fruit due to rubbing against the petiole spines or the soil. This was also coupled with a low incidence of spines in many cases. Bill also found that many of these plants also set fruit for 2 to 4 weeks longer than 'Raven.' Fruit color and shape were also improved across all 4 families, as was their open plant habit. However upon close scrutiny it was clear that only one of these 4 half-sib families, 41 S_1M_1, had a majority of plants superior in a combination of these traits.

In YR 4 a field of 41 S_1M_2 had a high percentage of plants with a favorable combination of traits. It was decisively superior to 'Raven' in several field comparisons; 1) robust plant type, with vigor and ability to reach water under dryland farming practices, 2) stout, upright plant for "wind resistance, and 3) ability to set fruit for several weeks longer than 'Raven.' While it was definitely more uniform than the 'Black Eel' population that we started with it was not as uniform as the hybrid. Off-types included plants with lobed versus pointy leaves and silvered versus green leaves. These are variations that would not be present in a modern variety developed through a selfing series. Other variation was more troubling as about 3% of the plants had poor foliar traits, i.e. closed habit or too many petiole spines ("busy") and close to 7% of the plants had fruit that did not make the high quality grade for the San Francisco market. At this point we decided to use two strategies; 1) self-pollinate 16 of the best plants to start another recurrent selection cycle and 2) perform another round of mass selection on the rest of the 41 S_1M_2 population after strident selection.

In YR 5 we compared the 16 full-sib families derived from 41 S_1M_2 to the 41 S_1M_3 population and we were happily surprised to find that the average performance from a commercial perspective was as good or better than all of the 16 full-sib family rows. The 41 S_1M_3 population had improved with less than 2% "busy" plants and only 4 to 5 % off type fruits. Three of the full-sib families were very good, but did not prove to be commercially superior to the population. We saw this as an encouraging sign that the population as a whole was approaching its peak of performance. As a commercial farmer Bill was pleased and felt that for his operation this degree of uniformity was quite acceptable. As with all OP versions of cross-pollinated crops that are not "line bred," there will usually be a percentage of off-types that will occur in each generation as deleterious recessive genes are revealed with recombination. It is important to determine how much variability is acceptable to the farmer, especially if the farmer stands to gain from the genetic diversity that can exist within a well-bred "population variety."

Conclusions

This PPB project was a success in two regards. The interaction of the farmer breeder and the formal breeder was a great success. The partnership was well balanced with the farmer taking the lead on the choice of germplasm and the selection of traits, while the breeder determined the breeding methodology and fine tuned the timing of the selection. We both took part in the selection and reevaluating objectives as we went along. It has been a dynamic, productive relationship that has given OSA a strong message that PPB can be a very powerful tool in the development of crop varieties for organic agriculture.

The second success of this PPB project is that it is possible to develop a commercially viable "farmer variety" with an emphasis on retaining adequate genetic variability to meet the challenges and variable conditions of low-input, organic cropping systems. Despite the fact that the 41 S_1M_3 population that is the result of this effort has a small percentage of off-type plants, Bill Reynolds is now using it for several acres of market production in Northern California and a leading organic winter producer, Sam Beckish, has planted close to 50 acres in Baja California. Sam had grown several rows of the previous populations in observation plots in the past two winters and was impressed with its ability to withstand the wind near the coast in Baja. Both growers recognize that it has the standard commercial traits (fruit type, color, open habit) and that the traits developed in our breeding effort (robustness, stout plant, deep early taproot development. longevity of production) make it superior for their low input systems. Certainly our selection, on-farm in a low-input, challenging environment, is responsible for revealing these latter traits, enabling us to select for them.

These encouraging results have prompted OSA to move forward into several other PPB projects in broccoli, kale, and sweet corn across several climates of North America. One of the main questions that we will be asking is can we breed for variability that translates to environmental stability while attaining a degree of uniformity in vegetable crops that is acceptable to the farmers and the markets of the developed world?

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Organic Seed Alliance: Past and Future

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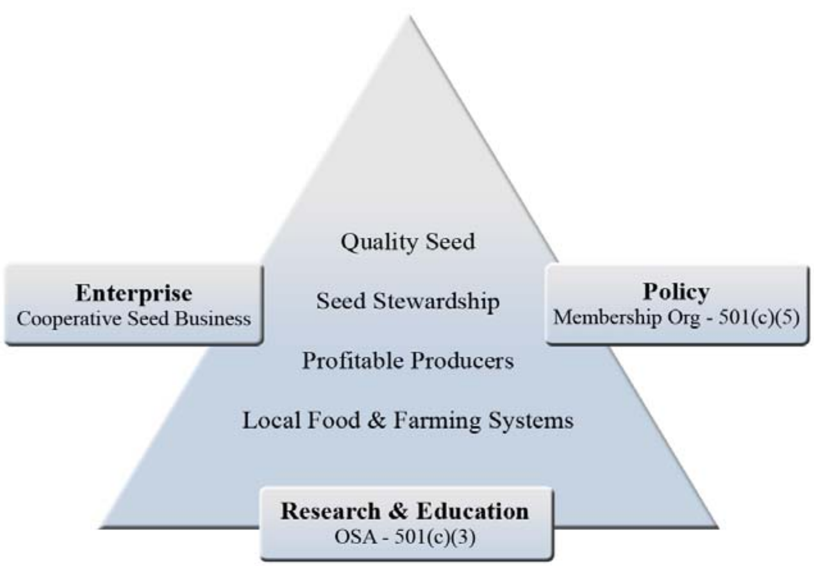
Agriculture in the United States has a rich history of movements. In 1880 the Northwest Farmer Alliance was formed as the strongest of all the Farmer Alliances in this country. The Fundamental objective of the Alliance was elimination of railroad abuses, but it also embarked on a program of crop improvement, extending educational opportunities to farm families, creation of cooperatives, regulation of public utilities, anti-trust legislation and election of government officials. The Farmer Alliances eventually formed the platform of the Populist Party and the Grange and National Farmers Union were formed to advance their causes.

We face many of the same challenges today in the seed industry, but we also have unprecedented opportunities before us. These challenges and opportunities, many of which have been discussed here this week, require us to think of ourselves as a movement in order to produce the best possible outcomes for farmers, consumers and the national food system. Unlike the old farmer alliances we have diverse interests in our community including the growers, breeders, University personnel, seed companies and other businesses related to the trade. We also have the advantage of historical insight, geographic representation, and deep skills, knowledge and experience.

The intention of Organic Seed Alliance is to help form this movement though a comprehensive, collaborative and integrated approach that will establish quality organic seed as the very foundation of healthy local food and farming systems. Upon completion of our strategic plan last spring, we have been devoting much effort to strengthening our organizational systems, refining our program methodologies, and positioning ourselves to work on a national level. This process has led to the creation of two new independent organizations that will enable us to work on the policy and economic sides of seed development: a 501(c)(5) membership organization we are calling Organic Seed Growers and Trade Association and a cooperatively owned seed growers' enterprise we are calling Growers Organic Seed Cooperative. Here is a diagram of what we envision:



OSA's Research and Education programs form the critical foundation of this triangle. Over the last four years OSA has provided over 600 farmers with information, training, mentorship, and in-field consultation for plant breeding and seed production projects. And through our Participatory Breeding Program and advisory services we are developing new models and new genetics for healthy, organic seed systems.

The left side of the triangle is a producer-owned enterprise that is in the feasibility and business planning stages. We anticipate that this entity will be involved in breeding and producer support services as well as some level of seed sales.

The right side of the triangle is Organic Seed Growers and Trade Association (OSGATA). This membership organization was incorporated in January of this year and will allow us to address issues of mutual concern on business and policy levels. We hope that this will be a venue in which we can resolve differences and create strategies to improve the seed trade on a national level.

We expect the next several years to be transformative ones for organic seed and we sincerely look forward to working with you all as friends, members, partners, and colleagues.

Seed People: A Journey into the Organic Seed Movement

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Through his photographs, interviews and writing, Scott Vlaun has been chronicling the organic seed movement for over 15 years, primarily on behalf of Seeds of Change for their catalog and "Cutting Edge" electronic newsletter. He will share glimpses of his journey through an informative and inspiring slide presentation featuring many of the conference speakers.

Breeding Winter Wheat for Association with Nitrogen-Fixing Bacteria

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Abstract
Obtaining sufficient plant available nitrogen in organic dryland wheat cropping systems is difficult. This study was conducted to determine whether inoculation of wheat with *Azospirillum* could improve nitrogen uptake and increase crop yield, and whether differences exist among wheat cultivars in the ability to associate with and benefit from inoculation with these diazotrophic bacteria. Seed from twenty historic and modern wheat cultivars were either left untreated, or treated with a commercial inoculant of *Azospirillum*, and planted at two locations under certified organic management. In one location, inoculation significantly increased yield and protein, and clear differences existed among individual cultivars in response to the inoculant. In another location, none of the cultivars responded as favorably to the inoculant, and yield in some cultivars was reduced. Plant breeders should be able to select for beneficial cultivar interactions with *Azospirillum* to increase wheat yield and protein levels. However, additional research is needed to determine the impact of site-specific soil conditions on the effectiveness of *Azospirillum* inoculation in organic systems.

Introduction
In low-input organic dryland grain cropping systems, obtaining sufficient plant available nitrogen (N) can be problematic. One alternative to help supplement N is through exploitation of diverse diazotrophic bacteria capable of biological nitrogen fixation (BNF). Associative BNF can contribute 10-50% of the total N requirement of wheat (Solimon et al., 1995; Kennedy and Islam, 2001). In addition to BNF, these bacteria may increase plant growth through production of phytohormones, phosphorous release, increased nutrient uptake, enhanced stress resistance, biocontrol of both major and minor plant pathogens (Dobbelaere et al., 2003), and improved water status (Creus et al, 2004). However, these plant-microbial interactions are dependent on plant genotype (Iniguez et al., 2004) and site-specific soil conditions (de Oliviera et al., 2006).

Historically, plant breeders have not selected directly for interaction with beneficial soil bacteria, yet in Brazil sugarcane breeders selecting for high yield under low-input conditions inadvertently selected for interaction with native diazotrophic bacteria (Baldani et al., 2002). Prior to the advent of chemical fertilizers containing high plant available nitrogen, breeding programs of other graminaceous crops, like wheat, may also have indirectly selected for this association. However, after decades of cultivar selection under conditions that utilize chemical fertilizers, modern cultivars may not interact efficiently with these bacteria and relevant levels of native diazotrophic bacteria may no longer be present in the soil.

This study was conducted to determine whether inoculation with *Azospirillum* could improve nitrogen uptake and increase wheat yield, whether differences exist among wheat cultivars in the ability to associate with and benefit from inoculation of these diazotrophic bacteria, and to identify cultivars for use in organic production systems.

Materials and methods

Field trials were established in September 2006 using seed from twenty historic and modern wheat cultivars. Seed was either left untreated or treated with a commercial inoculant of *Azospirillum* (EMD Crop Bioscience), and planted at two locations under certified organic management. A previous winter pea plowdown provided approximately 36 lbs of N per acre. Plant emergence, leaf greenness using a SPAD chlorophyll meter, and plant height were recorded in summer 2007 and yield and protein were determined following harvest in August 2007. Soil samples were analyzed for total carbon (C) and nitrogen (N), inorganic N, and potentially mineralizable N, and organic matter (OM) was estimated. Field plot locations were recorded permanently using GPS coordinates to track survival of the introduced bacteria in the soil over time.

Results and Discussion

Our results indicate that *Azospirillum* inoculation can improve wheat yield and protein level, but this interaction is dependent upon plant genotype and site-specific soil conditions. In location A, overall crop yield was increased by 8 bu/ac; however, yield increase ranged from 2 to 18 bu/ac among individual cultivars, and was significantly increased in only five cultivars (Figure 1). Percent protein in location A was significantly increased in six cultivars by 1.4-2.2% (Figure 2). In location B, yield data was compromised due to harvest difficulties resulting from the slope of the land, but in general, the cultivars did not respond as favorably to the inoculant, and yield was decreased in some cultivars (data not shown). Soil tests indicate that total C and N, and OM were greater in location B than A, and may have contributed to the insignificant response of wheat to the inoculant.

To better meet our objectives, we expanded our field trials in September 2007 to include advanced lines from our organic breeding program, and regions of low and intermediate rainfall. Greenhouse trials are underway to evaluate the impact of N fertilizer rate on the wheat cultivar – *Azospirillum* interaction, and to quantify root abundance and nitrogen fixation by *Azospirillum* among individual cultivars. The abundance and diversity of native diazotrophic communities will be evaluated in soils from across Washington State.

Conclusions

Inoculation of wheat with *Azospirillum* can increase yield and protein under organic management, but is dependent upon genotype and site-specific soil conditions. Wheat breeders may be able to select for cultivars that associate with and benefit from associations with these bacteria, but additional research is needed to determine the impact of site-specific soil conditions before recommending this to organic farmers as a management tool.

Acknowledgments

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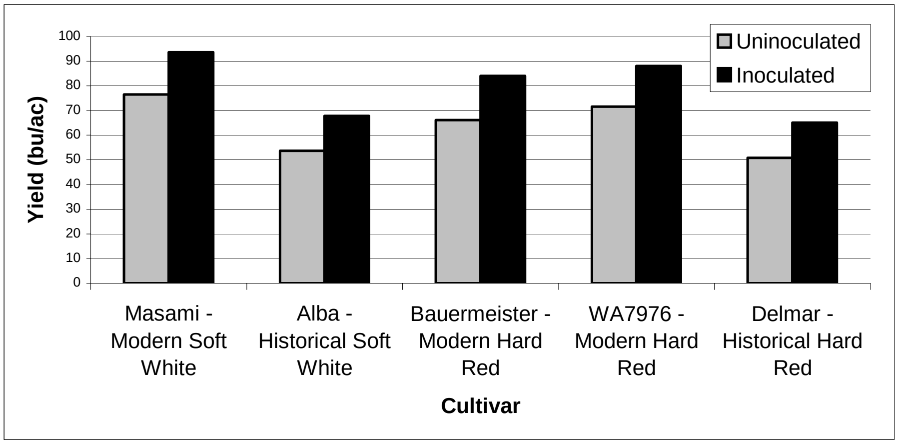

Figure 1: Wheat cultivars with significantly increased yield as a result of *Azospirillum* inoculation in location A (P<0.05).

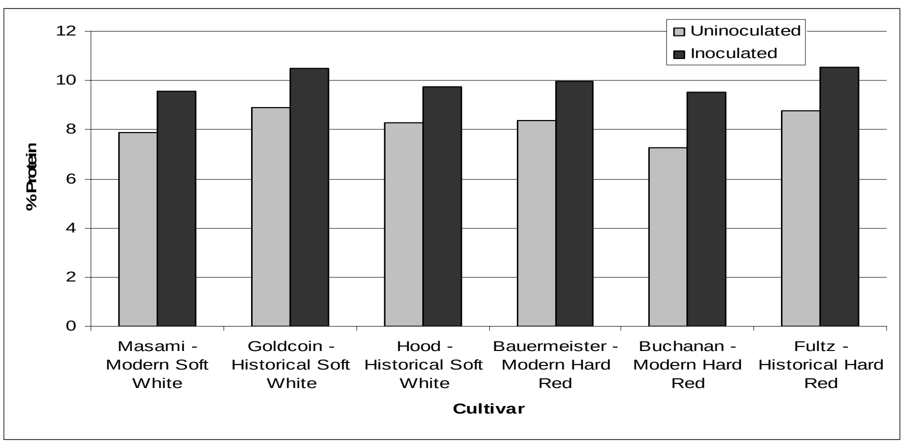

Figure 2: Wheat cultivars with significantly increased protein as a result of *Azospirillum* inoculation in location A (P<0.05).

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Genetics of Weed Competitiveness in Sweet Corn: First Year Report

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Weeds are a major issue for organic farmers. If crop varieties can be developed that compete well against weeds, yields can potentially be improved and weed management expenses reduced.

To create the groundwork for breeders to be able to develop weed-competitive sweet corn varieties, we need to ask the following questions: what traits affect weed competitiveness and are these traits heritable? To help answer these questions, the University of Wisconsin Sweet Corn Breeding Program is evaluating a set of sweet corn crosses for heritable differences in plant morphology and phenology. Additionally, we are assessing yield loss tolerance and weed suppressive ability in these crosses using sorghum as a model weed. This poster reports on our first year of trials in this two year experiment.

In 2007, we planted 22 sugary sweet corn hybrids in trials at Madison and Arlington WI. Of these 22 hybrids, 21 represented a complete set of crosses from 7 inbred lines and Jubilee, our check, being the 22nd hybrid. The trials were each planted in a split block randomized complete block design with 3 replicates. Each split block had all of the sweet corn hybrids and were either planted normally or densely interplanted with short-stature silage sorghum.

In the course of the season, we measured plant height, leaf area and leaf height, leaf angle, number and heights of tillers and growing degree days to tasseling. We measured yields of dried ears and calculated yield loss by comparing yields of entries between the sorghum and non-sorghum plots. We additionally measured sorghum height and biomass.

Using an Analysis of Variance (ANOVA), we found that, in our first season, there were significant ($p<0.05$) hybrid effects at both locations for: plant height, leaf area and leaf height, tiller number and tiller height, growing degree days to tasseling, yield and sorghum biomass.

To help determine which traits might lead to weed suppressive abilities, we calculated correlations between sweet corn traits measured in the sorghum-free hybrid plots and sorghum biomass in the corresponding sorghum-interplanted plots. At both locations, growing degree days to tasseling was strongly negatively correlated (r^2=-0.71 and $p<0.001$) with sorghum biomass, and early leaf area was also strongly negatively correlated (r^2=-0.79 $p<0.001$).

An important component of our experiment is to look at the heritability of these morphological and phonological traits. One approach that we are taking is to measure the differences in general combining ability for the 7 inbred parents. General combining ability (GCA) is the difference between the mean of all the offspring which share a common parent and the mean of all of the hybrids. At at least one location and one treatment, we found significant ($p<0.05$) differences in GCA for: plant height, leaf area and height, leaf angle, tiller number, growing degree days to tasseling, yield and sorghum biomass.

This poster is only summarizing the preliminary results from the first year of a two-year project. However, we can make some tentative conclusions. First, we can see some significant differences between hybrids for traits that are commonly thought to play a role in weed competitiveness. Second, at least two of these traits - earliness and early leaf area – do appear to suppress sorghum growth. Third, many of these traits appear to vary based on the hybrid's parentage.

Data from another year's worth of trials will help to clarify our results and to see how many of the conclusions made from our first year will continue to be born out. Ultimately, we hope that this study will help to clarify the genetics of weed competitiveness in sweet corn. By determining which traits affect weed competitiveness and by assessing the inheritance of these traits, perhaps a foundation of research can be laid. This foundation might then aid farmers and breeders in developing varieties that will best serve the needs of low-input and organic growers.