Building on the Best: A Research and Education Partnership for Increased Competitiveness of Organic Grain and Vegetable Farms

Cornell University

Project director: Charles L. Mohler

Co-Project Directors: George Abawi, Leslie Allee, Anusuya Rangarajan and Janice Thies

Project Summary:
Recent research on exemplary organic farms in the northeastern U.S.A. identified a vegetable and a grain farm with particularly successful systems. These farms achieve consistently high yields and have low weed, insect and pathogen problems, despite minimal off-farm inputs. The strategy of the proposed project is to demonstrate that these farming systems can be duplicated and compare them with improved systems worked out through collaboration between the farmers and researchers.

The goals of the project are (1) to improve the overall health and competitiveness of organic farms, especially during transition and the first few succeeding years, (2) to determine experimentally how organic soil and nutrient management affects weed, insect and pathogen pressure and (3) to develop these cropping systems experiments as "living laboratory courses" for training extension personnel and organic farmer-mentors. The vegetable and grain systems experiments and an on-farm satellite trial will be regularly sampled for soil nutrients, soil physical structure, soil biota, insect pests and beneficials and weeds. Specific hypotheses on the relation of soil nutrients and soil physical conditions to weeds, insects and plant pathogens will be assessed through bioassays and micro-plot experiments. The system experiments will be used as field teaching laboratories in conjunction with distance learning tools to train extension personnel in organic systems and to broaden the knowledge of organic farmers that act as mentors to other growers.

(a) INTRODUCTION

(1) Statement of goals

The goals of this study are (1) to improve the weed, disease, insect and nutrient management of organic cropping systems through improved use of tillage and cover crops, (2) to better understand the biological dynamics of organic cropping systems and (3) to extend this knowledge to farmer-mentors and extension personnel through a "living laboratory course" built around the cropping systems experiments. The project thus fits most closely with Organic Transitions Program (ORG) Goals 1 and 4.

The project strategy is to take the best managed organic vegetable and grain farms we know of and test system modifications that these farmers and the participating scientists believe are likely to either (i) overcome residual problems these farms are experiencing, (ii) make their systems more usable by many organic growers, and (iii) speed the rate at which a field transitions biologically from a conventional to a mature organic cropping system. Although the National Organic Program (NOP) requires 36 months from last application of a non-approved material to harvest of a certifiable crop (NOP 2004), bio-physical transition may take longer, particularly if the soil has been degraded by conventional practices.

(2) Substantiation of need for the present project

Weed management

Weeds are generally considered the worst pest problem experienced by organic farmers (OFRF 1999, Bond and Grundy 2001), and the project has a special emphasis on weed management. Whereas "emergency" treatments are available to deal with many disease and insect problems (Caldwell et al. 2004), if early season weed control fails then costly hand weeding becomes the only alternative to yield loss. The severity of weed problems in organic agriculture is indicated by a recent intensive study of 11 mature organic farms. Picked by organic growers and certifying organizations as among the very best organic farms in the Northeast, these farms experienced a probable yield loss due to weeds in 25% of their crops (Rangarajan 2005). Moreover, weed problems are often worse during transition from conventional agriculture, and probably limit adoption of organic practices.

One hypothesis for why weed problems appear to decline during transition is that farmers become more skilled in choosing and operating cultivation equipment. Although we do not discount the importance of these factors, we hypothesize that several biophysical processes are also operating during transition.

First, we hypothesize that the improvement in soil physical characteristics during the transition from conventional to organic management improves the effectiveness of cultivators. Several studies have documented increased soil organic matter, decreased bulk density, improved water infiltration and other soil physical properties with organic systems (Reganold, 1988, Reganold et al. 1993, Gerhardt 1997, Liebig and Doran 1999). These changes result from green manure, compost and manure additions to the soil, reduced inversion tillage and avoidance of practices that contribute to compaction such as tilling or harvesting when the soil is wet (Magdoff and Van Ess 2000). We hypothesize that improvement in soil tilth during transition improves the effectiveness of cultivation:

(1) With improved soil conditions, cultivator shovels and tines more effectively shake soil loose from weed roots, thereby increasing the probability of desiccation and decreasing the probability of re-rooting.

(2) When "hilling up" in the row to bury young weeds, soil of high tilth flows in around the crop plants, and the absence of clods avoids problematic gaps in soil coverage that allows weed growth.

(3) Most weed seedlings emerge from the top 2-3 cm of soil (Chancellor 1964, Grundy and Mead 1998 and review by Mohler 1993). Tine weeders and rotary hoes control weeds in the crop row by breaking, uprooting and burying very small seedlings in the surface soil above crop rooting depth (typically 2-3 cm). In cloddy soil, many weed seedlings emerge in "windows" between clods, and are not effectively reached by these implements.

Although we have previously hypothesized some of these effects (Mohler 1996, Mohler et al. 1997), and have gathered limited experimental data indicating improvement in cultivation following compost addition (Joslin et al. 2000), these hypotheses have not been effectively tested. If cultivation does become substantially more effective as soil tilth improves during transition, this would greatly encourage transitioning farmers to continue the transition process.

Changes in nutrient management during conversion from conventional to organic systems probably also affect weed populations. Several common weed species germinate in response to nitrate including yellow foxtail (*Setaria glauca*) (Schimpf and Palmblad 1980), Powell amaranth (*Amaranthus powellii*) (Brainard et al. 2004), common lambsquarters (*Chenopodium album*) and shepherd's purse (*Capsell bursa-pastoris*) (Roberts and Benjamin 1979). For such species we hypothesize greater emergence following incorporation of low C:N legume cover crops relative to higher C:N ratio grass cover crops due to the more rapid release of N from the legumes (Stevenson 1986, pp. 164-166).

We further hypothesize that weeds will be more competitive relative to crops in systems with pulsed availability of nutrients shortly after planting relative to systems with a more constant rate of nutrient release. Concentrations of N, P, and K in weed tissues are typically 1 to 3 fold higher than in the crops with which they compete (Vengris et al 1953, Alkämper 1976, Qasem 1992, Blackshaw et al. 2004**)**. Weeds have very high relative growth rates (Mohler 2001) which allows weeds that begin life 1/100th to 1/1000th the size of competing crop plants to surpass the crop's root system within a few weeks (Seibert and Pearce, 1993) and eventually overtop the crop canopy. In contrast, because the seeds of many crops --beans, squash, cereal grains, corn, potato-- are much larger than those of agricultural weeds (Mohler, 1996), initial crop growth relies largely on seed reserves. Thus, large-seeded crops establish well under fertility levels that are less than optimal for competing weeds. Consequently, biological theory predicts that weed early growth rate and hence mature size of weeds should be less when nutrients are released slowly over the growing season than when most of the nutrients are highly available early in the growing season (Liebman and Mohler, 2001). Previous research supports this view (Dotznenko et al. 1969, Banks et al. 1976, Lawson and Wiseman 1979, Dyck and Liebman 1994, Dyck et al. 1995), but previous work has not compared organic systems with different nutrient supply and release regimens.

Weeds may also be partly controlled by the high diversity of invertebrates and microorganisms found in organic systems. Tillage immediately stimulates weed seed germination by exposing seeds to light, releasing inhibitory gasses from the soil, increasing soil nitrate levels, and raising soil temperature and the amplitude of diurnal temperature fluctuations (Mohler 2001). When cover crops are incorporated into the soil, however, they stimulate a brief fungi population spike such as *Pythium* spp. *Rhizoctonia* spp. and *Fusarium* spp. that act facultatively as both saprobes and parasites (Wall 1984, Dabney et al. 1996, Conklin et al. 2002). Organic farmers usually let cover crops decompose for 2-4 weeks before planting the field to facilitate seedbed preparation, allow allelopathic toxins to dissipate from the green manure **(**Barnes and Putnam 1986, Creamer et al. 1996, Weston 1996, Yenish et al. 1995) and allow pathogenic fungi to die off. Thus, although timing of planting protects the crop, we hypothesize that germination in response to tillage exposes weed seedlings to severe attack by the transitory pathogen populations and allelopathic toxins following incorporation of green manure. We expect stabilized compost to have less of an effect on weed populations. The effect of transitory pathogen populations on weed emergence following cover crop incorporation has not been previously tested.

Velvetleaf grows poorly on the Marten farm, except occasionally along field edges. A poorly understood disease complex involving Abutilon yellows and possibly a race of anthracnose infest velvetleaf on the Marten farm, but do not destroy velvetleaf on neighboring conventional farms. We hypothesize that susceptibility of velvetleaf to disease is affected by nutrient availability. Since velvetleaf is potentially a severe weed in grain systems, we would also like to determine whether the disease complex can be successfully introduced onto newly transitioning farms.

*Crop disease management and soil biology***.**

Soil biota are indispensable for efficient nutrient cycling, organic matter turnover and maintaining soil physical structure. Rhizosphere microorganisms greatly influence the ability of plants to acquire macro- and micronutrients (Griffiths, 1994) and can suppress plant pathogens such as *Fusarium* (Hebbar et al., 1992) and *Colletotrichum* (Kloepper et al., 1992). Bacteria, fungi, protozoa, and free-living nematodes play major roles in colonizing crop residues and initiating decomposition and nutrient turnover (Coleman and Crossley, 1996). Soil microbial populations respond differently to many environmental factors including C and mineral nutrient availability, moisture, temperature, oxygen level, heavy metal concentrations and pH. Agricultural management practices used during transition, such as cover cropping, crop rotations, reduced tillage, or organic matter amendments will alter the nature of the soil environment and may therefore influence the composition and activity of the microbial community (Abawi and Widmer, 2000). The aim of many of these practices is to develop a community of beneficial soil organisms to aid in the natural suppression of plant pathogens. We hypothesize that (1) increasing soil organic matter from reduced tillage and long term incorporation of cover crops and compost results in a more abundant, active and diverse beneficial soil microbial population that can better suppress transitory plant pathogens, and (2) soil biological quality will improve substantially as soil physical properties improve.

New approaches to understanding soil biology use molecular techniques to distinguish changes in soil biological populations that result from shifts in soil management (Theron and Cloete, 2000). We will employ this molecular approach together with traditional biochemical analyses (soil respiration, microbial biomass, N-mineralization) to assess change in beneficial populations. The density of soil-borne pathogens, e.g., plant parasitic nematodes, and soil suppressive capacity are two additional soil biological measures used as indicators of soil health (Pankhurst et al., 1997). The density and diversity of total nematodes have received special attention as a soil health indicator (Neher, 2001) and will be used as such in this study to assess the various systems' abilities to keep pathogens in check.

Insect Pests, Beneficials, and Insect Damage to Crops

Differences in soil nutrient levels, cover crops, tillage, and weed populations may have direct or indirect effects on pest insects and their ability to damage crops and decrease yield. Beneficial insect populations including predators, parasitoids, and weed seed predators may also be affected by differences in these management practices. To detect effects, numbers of insect pests and beneficials, damage to plants, regrowth after damage, and yield will be monitored and compared between treatments in each crop.

Soil nutrient levels can effect how attractive plants are as hosts to their insect pests. For example, European corn borers lay fewer eggs on corn plants grown in organically managed field soil than on plants grown in conventionally managed soil (Phelan et al. 1995). Correlations with leaf-mineral profiles, and biochemical profiles measured by near-infrared (NIR) spectroscopy showed host preference was at least in part mediated by plant mineral balance (Phelan et al. 1996).

The soil nutrient treatments we propose will be monitored and analyzed for differences in host preference. We will also pursue the possibility of higher leafhopper damage in fields with high or low K, as reported by the Martens. They find that applications of fish or kelp foliar fertilizer seem to help plants withstand damage.

Soil nutrient management treatments may also influence the ability of crop plants to withstand damage by pests or re-grow after damage, and thereby affect yield. Allee and Davis (1996b) found that after damage by corn rootworm larvae, field corn plants in manured plots grew new roots faster and in greater quantity than corn plants in nonmanured, conventionally fertilized plots. Finally, beneficial insect populations, particularly in the soil, often increase and change in diversity when organic inputs are increased (e.g.,, Borcard 1987, Allee & Davis 1996a, Pfiffner 2003).

Tillage, weeds, and cover crops can have complex and variable interactions with insect pests and beneficials. Several studies have found no difference in ground dwelling beneficials between no-till and moldboard-plowed environments (e.g., Cardina et al. 1996, Cromar et al 1999), yet in one study the chisel-plowed environment reduced predation on weed seeds whereas in no-till the type of crop residue influenced predation (Cromar et al 1999). In another study, effects of tillage on weed seed predation varied between weed species (Nurse et al. 2003). In the long term, the effect of the weed cover on beneficials may be more important than the direct effect of tillage (Anderson 2003). Generally higher levels and diversity of beneficials are found in fields with more weeds or more weed diversity (Pavuk et al. 1997, Anderson & Eltun 2000, Luka et al. 2000, O'Sullivan & Gormally 2002). Cover crops can also significantly increase beneficial insect populations (Carmona & Landis 1999). In the various tillage, weed management, and cover crop treatments of the systems experiments we will monitor beneficials and look for correlations with pest numbers, damage to plants and yields.

Soil fertility

Organic producers face unique challenges in managing soil fertility. Organic soil amendments (e.g., green manures and composts) used as nutrient sources vary greatly in nutrient concentrations (Tisdale et al. 1984; Reider et al. 2000). Organic farms that use substantial nutrient rich soil amendments may sometimes apply excess nutrients that are lost to the environment. Although soil testing is often used to assess soil fertility, there is a growing consensus that traditional fertility tests may not accurately reflect nutrient availability for nutrients that are converted to plant-available forms by soil biological processes (Drinkwater et al.1995). Soil fertility management is particularly challenging in the early years of transition when labile pools of soil organic matter (SOM) may be depleted from previous management practices (Liebhardt et al. 1988; Drinkwater et al. 1995).

It is well documented that organic soil fertility amendments increase SOM and the abundance of bacteria, fungi and secondary consumers (Doran et al. 1987; Reganold et al. 1993; Scow et al. 1994; Wander et al. 1994; Drinkwater et al. 1995). These changes reflect the increased role of decomposers and labile SOM pools in determining the availability of nutrients that cycle with carbon in organic cropping systems. Under organic management, the overall capacity of the soil to supply nutrients such as N and P through mineralization generally increases (Wander et al. 1994; Drinkwater et al. 1995). However, the chronology of these changes during transition from conventional to organic management has not been characterized. Nor is relative contribution of compost versus cover crops/green manures to changes in SOM and nutrient availability understood. Although relatively heavy applications of composts during the transition years is a common practice, it is not clear whether or not these inputs are necessary in all cases. Our two cooperating farms are particularly interesting because they are operating very close to balance between P inputs and exports. Nitrogen is also relatively close to being balanced although since they rely on legumes for a substantial portion of their N, there are some significant uncertainties in quantifying N inputs from biological N fixation (Peoples et al., 1995).

Another consideration is management of the time course of decomposition. Optimizing the timing of net N-mineralization relative to crop uptake is central to the development of cropping systems that can achieve viable yields while minimizing environmental impacts. Whereas incorporation of amendments by tillage before planting results in excess N release prior to crop demand, in green-manured systems without primary tillage, mineralization of adequate N for uptake by the cash crop at the appropriate time is a major concern (Doran 1980; Groffman et al., 1987; Power et al., 1991; Sarrantonio and Scott 1988; Varco et al., 1989). Our sampling conducted during the 2003 field season in the Nordells' and Martens' fields demonstrated that net mineralization of incorporated cover crops in both of these farms occurred prior to crop demand (Drinkwater, unpublished).). Developing management schemes which adjust the timing and intensity of primary tillage and soil disturbance can greatly improve synchronization of N mineralization, and will be instrumental in optimizing N mineralization (Wagger, 1989; Drinkwater et al., 2000). Several studies have attempted to manipulate the timing of N-mineralization through choice of cover crop species combined with strategic use of tillage with some success (Ranells and Wagger, 1997b; Drinkwter et al., 2000,Yadvinder-Singh et al., 1992; Ranells and Wagger, 1997). For example, the decomposition of rye-legume bicultures slowed N release by as much as three weeks relative to legume monocultures in some years (Ranells and Wagger, 1997b). The proposed cropping systems studies will allow comparison of nutrient release rates from various types of organic amendments and various tillage regimens.

(3) Recent activities and publications

Reference to relevant studies by the Co-PD's and key personnel Mohler, Abawi, Allee, Caldwell, Drinkwater. Rangarajan, Brainard, DiTommaso and Van Es are integrated into section 2 immediately above. Additionally, several of the Co-PD's have extensively documented the two exemplary farms that are the focus of this proposal (Rangarajan 2005).

(4) Magnitude of issues and relevance to stakeholders

The exemplary farms.

Due to the success and exposure of the two exemplary farms, growers and researchers are interested in how and why their systems work. The two focal farms are extraordinary. Eric and Anne Nordell support themselves on a small, horse-powered vegetable farm in northern Pennsylvania. Their primary field is divided into twelve 0.5 acre strips that pass through a regular 4 year rotation. Alternate years have only cover crops to build SOM and a cultivated fallow period to reduce weed pressure. The cash crops in years 2 and 4 of the rotation alternate between an early season crop such as onion or pea and a late or full season crop such as carrot or tomato, and the tillage program varies through the cycle as well (Grubinger 1999). This system allows good yields with only minor use of compost. Pest pressure is minimal. Using only a minor amount of cultivation and hoeing in the cash crops, the farm is virtually weed free. Their extraordinary handling of cover crops and tillage allows them to grow vegetables without irrigation.

Klaas and Mary Howell Marten farm 1300 acres of cash grains, soybean and processing vegetables near Penn Yan, New York. Their basic rotation begins with a tofu soybean variety followed by winter grain. In the spring of year 2 the winter grain is over-seeded with a red clover cover crop, which is left to grow after grain harvest. In year three the clover is plowed down and planted with corn or a processing vegetable. Through careful attention to crop timing, innovative use of cultivation equipment and minimal but carefully targeted nutrient additions, their costs are low and their yields are high. Their success and willingness to share their expertise has led to the conversion of about 20 nearby farms, and they are now at the center of an 8,000 acre organic farming community.

A common concern about the Nordell's summer fallow system is the trade-off between reducing weeds and improving soil quality. Land-limited growers also desire achieving the same benefits of this cover-crop based system without taking land out of production. Additionally, researchers are interested in how the Nordell's cover crop intensive system prevents the buildup of excessive nutrients as is common in organic vegetable operations relying on compost for fertility and soil conditioning. How the good match between nutrient needs of the crops and nutrient supply (Rangarajan 2005) affects weeds relative to farms with excess soil nutrients is also of interest.

Field crop farmers in transition to organic production wonder how they can realize the excellent weed control practiced by the Martens while they are developing cultivation skills. There is also concern about whether a cover crop-based system can meet a large percentage of fertility needs of heavy feeding grain crops during the transition years. Providing adequate levels of P and K for winter grains is one problem the Martens have identified. A major question is how to do this economically during the transition when growers are receiving conventional prices for winter grains such as wheat and spelt.

Both the Nordells and the Martens are interested in experimenting with reduced tillage, particularly ridge-tillage. The Martens feel that restricted wheel traffic would prevent potential problems with compaction due to heavy equipment. Ridge-tillage would also allow for more timely planting of spring crops such as corn. We hypothesize that a ridge-till system will also delay nitrogen release of the clover cover crop since the clover between rows would not be incorporated until first cultivation. This should make N availability more synchronized with the growth of the corn.

The Nordells have been using a mix of reduced tillage techniques as part of their weed and moisture management program. Their tillage rotation includes light disking of cover crops, skim plowing, vertical furrow plowing, and ridge-tillage. They are interested in developing a semi-permanent ridge-till system to see if restricting traffic in a surface-tillage system improves soil and crop health.

This cropping systems study addresses all of the basic issues of organic crop production, namely management of weeds, soil health, nutrient cycling and pest and beneficial insects. We propose to do this by replicating the Marten's and Nordell's systems at two experiment station farms, and by comparing their systems with a more typical set of organic practices and two potentially improved systems. The potentially improved systems were developed through a lengthy collaboration between the farmers, researchers and NOFA-NY's farm education coordinator. In addition to documenting the reproducibility of these successful systems and exploring the possible next steps in their development, the experiments also allow testing a variety of specific hypotheses about how organic systems work, as detailed below. Thus, the magnitude of the issues addressed by the proposed research and the relevance of the research to organic crop producers is very high.

Extension: the "living laboratory course"

The education/extension program for this project is designed to produce the maximum long-term benefit for the organic farming community. The strategy relies on the Martens, Nordells, and Brian Caldwell, NOFA-NY's farm education coordinator. All are acknowledged leaders in the organic farming community and are regularly invited to speak at farmer meetings throughout the United States. With help from the researchers, they will use the systems experiments as tools for training farmer-mentors and committed cooperative extension personnel how to teach the holistic nature of organic farming. Most efforts to enhance the organic expertise of agricultural professionals use the traditional single meeting/in-service education format. Most of these lecture-styled trainings are organized by discipline, taught by researchers, and provide little interdisciplinary perspective on organic system design and implementation. We propose to use the cropping systems experiments as a basis for a ‘living laboratory course’ to foster holistic thinking about organic systems. The course will revolve around field days at the experiments, supplemented by web based learning modules that take an integrated approach to issues important in organic transition. Because experienced farmers are critical to the informal network that currently provides knowledge to less experienced farmers, the course will target these people as well as extension personnel. The course will give them a firm grounding in the scientific basis of their profession and a broader perspective than can be obtained from personal experience on their farm.

Our extension and education effort will:

- provide an opportunity for experiential learning on challenges of transitioning to an organic production system,
- foster discussion and debate among educators, researchers and organic farmers on organic transition and systems design,
- provide the research team with regular project evaluation as well as suggestions to improve system design and implementation and
- strengthen the ties between agricultural professionals and organic farmers.

A key factor in the future success of agencies serving organic farmers is the strengthening the ‘organic network’ among Extension, NRCS, other organizations and organic farmers. This program will facilitate farmer access to information, and help promote research, demonstration and policies appropriate to organic agriculture.

We estimate that the extension effort will increase by 50% the number of "teaching farmers" in the central part of the Northeast and increase the knowledge base of 30% the current "teaching farmers" by 30%. We expect the course will roughly double the organic expertise of extension personnel in the central part of the Northeast.

(5) Role of stakeholders in problem identification and implementation of results

NOFA-NY and two leaders of the organic farming community, Eric Nordell and Klass Marten, have been central to the design of the project from its inception. They determined many of the basic questions to be asked, such as the role of soil nutrition in determining weed problems, and largely determined the design of the cropping systems experiments. A group of 5 growers and 5 extension personnel that are course participants will act as an advisory panel to the whole project, further increasing stakeholder involvement. NOFA-NY will take the lead on using the results from this project for farmer education and the Martens and Nordells will participate as trainers. Moreover, the basic strategy of the extension work is to train farmer-teachers who will in turn support their colleagues in developing advanced skills as organic growers. Thus, stakeholders are at the very core of the implementation plan.

(b) OBJECTIVES

1. Develop more productive and competitive organic systems by building on practices of experienced organic growers to improve overall system health during and after transition from conventional agriculture.

2. Determine the impact of soil quality and nutrient levels in organic systems on weed, disease and insect populations. Hypotheses to be tested include:
   a. effectiveness of cultivation will improve with improving soil physical quality,
   b. weed density and growth rates will be greater in systems with higher early soil nutrient levels,

c. weed seedling density will be reduced in soil with recently incorporated cover crop organic matter and this will correlate with pathogenic fungi populations,
d. soil biological quality (abundance, activity and diversity of beneficial organisms) will improve with improving soil physical quality and soil organic matter status,
d.populations of disease organisms (plant-parasitic nematodes and plant pathogenic bacteria and fungi) will be suppressed as soil biological quality improves,
e. increasing levels of soil organic matter, reduced tillage and increased rotation with cover crops will reduce populations of and damage by soil-borne pathogens, especially in vegetable production systems,
f. higher soil quality and nutrient availability will result in lower insect pest density and lower insect pest damage to crops.
g.increasing soil organic matter and cover crops will increase beneficial insect diversity and population size.

3. Develop a "living laboratory" course based on the cropping system studies for training agricultural professionals and leading organic farmers to work more knowledgably with beginning organic farmers, and to strengthen the network of individuals providing extension support to organic farmers.

(c) METHODS

Table 1 (p.18) gives the timeline for the proposed research and extension activities. Milestones and indicators of research progress are given by objective.

Objective 1: cropping system studies to improve overall system health

Vegetable Systems Experiment

The vegetable experiment will take place on Cornell's new organic farm near Freeville, NY. The farm will be certifiable under NOP standards by the end of 2004. The experiment will be set up as a randomized block design with 4 cropping system treatments, two entry points into the rotation and 4 replications (32 plots). Plots will be 30' by 80'. The first entry point plots were planted this spring (2004) with sweet corn (see below). Early initiation of the experiment was supported by a small Hatch seed grant. The second entry point plots are in cover crops for the 2004 growing season.

Insects will be managed using row covers in cabbage to protect against cabbage root maggot and flea beetles. If action thresholds for insect pests in other crops exceed recommended levels (http://www.nysaes.cornell.edu/recommends/), we will use Bt, Entrust or nnem sprays. We will control corn earworm with oil and Bt applied to ears.

Treatments use the same basic rotation of cash crops to facilitate comparisons, but differ in cover crops, compost additions and tillage regimen. Brian Caldwell of NOFA-NY largely chose the crops as ones that are practical to grow in a large-scale experiment. Many vegetable crops grown by organic farmers (including the Nordells) require more hand labor than can be accommodated in a large experiment. The rotation sequence was designed in accord with the Nordell's practices. The treatments are as follows.

1. Intensive production, high compost/low cover crop, conventional tillage .

Year 1: Rye & hairy vetch (over-wintered) /sweet corn /rye
Year 2: Rye / cabbage
Year 3: Potato /snap pea
Year 4: Lettuce / buckwheat / spinach

Compost will be used as the primary N source. This treatment is essentially a control treatment representing intensive production on a farm with a limited land base and heavy compost application.

<u>2. Low compost/high cover crop, mixed tillage</u>

Year 1: Rye & hairy vetch (over-wintered) /sweet corn / rye & hairy vetch
Year 2: Rye & hairy vetch (over-wintered) / cabbage /inter-seeded with soybean & Japanese millet
Year 3: Potato / oat & field pea
Year 4: Lettuce / red clover

Cover crops will be used as the primary N source, with compost added for P and other nutrients. Despite the heavy use of cover crops, a cash crop is produced every year. Japanese millet and a soybean cover crop will be inter-seeded into the cabbage at last cultivation to allow sufficient growth before winter. They will winter kill, allowing early planting of potatoes to avoid late blight as in the other treatments. The Japanese millet is expected to help suppress *Rhizoctonia* in potato (Steven Johnson, unpublished research). A mixed tillage system will be used, with disking before potatoes and ridge planting of lettuce. Ridges will be built during the planting of oat and pea in year 3.

<u>3. Nordell's: alternate year fallow, low compost/high cover crop, mixed tillage</u>

Year 1: Rye & hairy vetch (over-wintered) / summer fallow / rye & hairy vetch
Year 2: Rye & hairy vetch (over-wintered) / cabbage /rye & spelt
Year 3: Rye & spelt (over-wintered) / summer fallow / oat & field pea
Year 4: Lettuce / rye & spelt

This system has cover crops as the N source and minimal use of compost for P and other nutrients. Intensive use of cover crops builds soil quality, especially the multiple cuttings of high carbon rye and spelt in year 3 (and year 5). Bare fallow in alternate years controls weeds, and supplementary weeding in the cash crop years will be used to prevent weed seed production. Cover crops before fallow will mowed 2 to 3 times and then be disked and chisel plowed to keep residues on the soil surface for erosion control during the cultivated fallow period. Rye and hairy vetch before cabbage will be skim plowed in the spring and allowed to decompose for 4 to 6 weeks. This will also allow elimination of some weed seeds. Lettuce will be planted on ridges built during the planting of oat and pea at the end of the second fallow in year 3.

<u>4. Low compost/high cover crop, ridge tillage</u>.

Year 1: Rye & hairy vetch (over-wintered) / sweet corn /rye & hairy vetch
Year 2: Rye & hairy vetch (over-wintered) / cabbage / interseeded with soybean & Japanese millet
Year 3: Potato / oat & field pea
Year 4: Lettuce /red clover

This treatment will use the same crop sequence as treatment 2 except that crops will be grown using a ridge tillage system in all years. Cover crops in the fall of years 1 and 3 will also be ridge till planted, and the ridges immediately rebuilt for the next year's cash crop. In addition to reducing tillage intensity, the ridge system will allow a controlled wheel traffic pattern to further improve soil quality. Hand weeding will supplement cultivation to prevent weed seed production. This will represent an attempt to extend the Nordell's preventive weed management strategy to a system that has a cash crop every year. It is particularly appropriate to examine this in the ridge-till system since weed seeds will not be plowed up from deep in the soil column. Hence exhausting the surface seed bank may prove practical.

The basic philosophy of the experiment is to retain the weed management, nutrient, and soil quality benefits of the Nordell's high cover crop system but grow more cash crops for the many farmers who are land limited. Comparison of treatment 2 vs. 3 allows us to examine the benefits of fallow for weed control. It will also allow us to assess whether the additional time in cover crops offsets the fallow in development of soil quality. Comparison of 1 vs. 2 will reveal effects of the type of nutrient inputs on various physical and biological parameters of the systems. Treatment 2 vs. 4 allows us to examine the potential benefits of even further reducing tillage relative to the Nordell's system to see if this accelerates development of soil quality.

Cash Grain Systems Experiment

The experiment will take place at Cornell's Musgrave Farm near Aurora, NY. The farm is currently managed conventionally so the experiment will explicitly examine the transition process. The experiment will be set up as a randomized block design with 4 cropping system treatments, two entry points into the rotation and 4 replications (32 plots). Plots will be 40' by 120'.

For all treatments, the crop rotation will follow the Marten's basic rotation, namely,

Year 1: Corn
Year 2: Soybean / spelt
Year 3: Spelt / over-seeded with red clover.

The first year in transition to organic will be in soybeans, so we will start in a field that had corn in it in 2004. The treatments are as follows.

1. High nutrient input: The clover cover crop will be as needed based on soil tests. Nutrient additions will target overcoming potential P and K limitation in spelt and corn. Typical appropriate tillage will be used: moldboard plow to incorporate clover before corn; chisel plow and disk before soybeans; disk before spelt. Cultivation will be rotary hoe or tine weeder 2 to 3 times followed by row crop cultivator twice.

2. Typical practice: primarily cover crops with minimal use of composts as nutrient sources. Tillage and cultivation as for 1.

3. Intensive weed management: Nutrient inputs as in 2. Spring fallow to reduce weed seed bank before soybean. Marten's row crop cultivator configuration. Flame weeding of corn if necessary to get good weed control. This program follows Eric Nordell's dictum of "weed the field not the crop". Although weeds are not a problem in the Marten's fields, other organic grain growers experience severe weed problems (Rangarajan 2005), and weeds can be particularly problematic during transition.

4. Ridge tillage: Ridges will be built initially in the corn by cultivation. Soybeans will be ridge-till planted. If weed pressure is low in soybean then spelt will be over-seeded at leaf yellowing. If weed pressure is high, the ridges will be scraped off and spelt planted during re-ridging. Clover will be inter-seeded in early spring as in the other systems. Corn will be ridge-till planted into the clover. Clover in the inter-rows will be killed by cultivation, which will also re-create the ridges. The two-stage killing of the clover is expected to produce a more even release of N that is better timed to the needs of the corn. Reduced tillage and controlled wheel traffic should benefit soil structure.

Logic of treatment comparisons is similar to those in the vegetable experiment. Comparison og treatments 2 vs. 3 indicates the benefits of intensifying weed control. Comparison of treatment 1 vs. 2 determines whether nutrient limitations that the Marten's sometimes see can be overcome. It will also allow us to examine the hypothesis that weeds are more problematic in the system with higher nutrient availability. In addition, it will allow us to determine how extra compost additions affect soil life during the transition process. Comparison of treatment 2 vs. 4 indicates benefits of reduced tillage for rapidly building soil quality. Delayed incorporation of much of the clover may improve the timeliness of the peak release of N. In the standard system, much of the N is released in the first few weeks before the corn is well established (Sarrantonio and Scott 1988,Wagger 1989). and can be lost if the weather is wet. Shallow incorporation may also slow decomposition thereby preserving more N for the spelt that is planted 15 months later. Carry over to the spelt may be particularly important during transition when transient organic matter pools are still low.

Crop growth and yield

A subset of individual crop plants in each plot will be repeatedly measured for height, stem diameter or other parameters that characterize size for the particular crop to establish growth curves. Growth data will be correlated with soil nutrient data, insect and pathogen attack and weed competition. Yield will be measured by methods appropriate to each crop, and crop quality will be assessed on an appropriately sized subsample by standard criteria (e.g., ear size and percentage insect damage to sweet corn, bushel weight for spelt etc.).

Economic analysis

We will do an economic analysis of each treatment plot in the two cropping systems experiments. Plot-by-plot computations will allow statistical comparison of the treatments. The intent of this analysis is to evaluate relative competitiveness of various treatments rather than to simulate actual farms. The latter is inappropriate due to the limited selection of crops in the rotation and lack of crop diversity within a given year.

Variable costs of field operations and inputs will be computed by standard methods. Cost of field operations will be taken from custom field operation tables (Pennsylvania Agricultural Statistics Service 2004), and price of inputs will be computed as over-the-counter costs of inputs at the time of use, scaled for a 700 acre grain farm or a 6 acre vegetable farm. These are typical sizes for successful organic grain and direct market vegetable farms in the Northeast. Value of the crops produced will be computed as crop yield multiplied by value per pound or other appropriate unit. Crop values will be set at the mean value received for that type of produce by the Martens or Nordells during the given year. The price received by the Martens and Nordells may or may not be typical but will not affect the *relative* advantage of a particular cropping system since the crops are similar across systems.

Research milestones for objective 1

Annual milestones will include successful completion of crop production and data collection in each year. Economic difference between treatments will become apparent at the end of the first cycle for entry point 1 (year 3). See also milestones for objective 2. Progress toward goals of the cropping systems experiments will be indicated by positive annual evaluations from the project's advisory group.

Objective 2. Determine the impact of soil quality and nutrient levels in organic systems on weed, disease and insect populations

We will monitor each plot in the grain and vegetable experiments by regular intensive sampling of a wide range of physical and biological characteristics. Observations will be organized within the plots to avoid excessive impact of observations on successive observations.

Soil physical properties

Soil physical characteristics are necessary to document improvement in soil quality during transition, its effects on crop yield and on the effectiveness of cultivation for weed control. Soil penetrometer measurements will be taken in the field (Karunatilake et al. 2000). Intact soil cores will be collected in early spring and analyzed by Cornell's Soil Physical Quality Lab for:

- dry aggregate size distribution,
- wet aggregate stability,
- saturated hydraulic conductivity,
- bulk density and total water-filled porosity,
- soil strength at 30 kPA potential and
- macroporosity
- mesoporosity
- microporosity
- residual porosity
- available water capacity,

- van Genuchten and Campbell parameters (parameters that characterize the water retention curve).

Soil biological properties

- respiratory activity in intact cores at field capacity (alkali trap; Zibilske, 1994),
- biomass associated with respiration (respiratory quotient) (chloroform fumigation extraction; Vance and Brookes, 1987),
- N mineralization potential of the measured biomass (water-logged incubation; Bundy and Meisinger, 1994),
- glomalin as a measure of arbuscular mycorrhizal activity (ELISA protein assay (Wright, and Upadhyaya 1999),
- structure of soil bacterial and fungal communities by molecular fingerprinting (PCR-denaturing gradient gel electrophoresis; Muyzer and Smalla, 1998).

Soil health

A soil bioassay with snap beans will be used to assess the general soil pathogen suppressive capacity of soils. Beans are susceptible to several major root pathogens including *Rhizoctonia, Pythium, Thielaviopsis, Fusarium* and others. The method consists of placing each well mixed composite soil sample in containers, planting them with beans and maintaining them for 4-6 weeks in a glasshouse. Washed roots are rated for root rot severity/root health on a scale of 1 (no visible symptoms) to 9 (75% of the roots affected, reduced in size or at different stages of decay). If needed, the density and severity of individual root pathogens will be assayed as above and isolates made on appropriate selective media.

Soil samples from all test sites will be collected and analyzed twice – at each entry point and in the final year. Free-living and plant-parasitic nematodes will be extracted by a modified Baerman funnel method (pie-pan) and morphometrically characterized under a dissecting microscope. As needed, nematodes from roots will be extracted by the shaker, maceration or NaOCl techniques. If warranted, soil samples will be analyzed for the various trophic groups of nematodes (fungivores, bacterivores, hervivores, omnivores and predators) and maturity or diversity indices calculated as appropriate.

Soil fertility

Composite soil samples will be collected from plots (0-20 cm) six times during the growing season, with emphasis on the month immediately following tillage. These samples will be analyzed for NO_3^-, NH_4^+ and N-mineralization potential (Drinkwater et al. 1996) to track net mineralization of the incorporated amendments. Anion resin-extractable P will also be determined (Olsen and Sommers 1982). Sampling will also be done in the fall (after crop senescence) and spring (before tillage) to quantify the full range of SOM pools, especially the more labile pools that we expect to impact through management during these early years. We will determine total C and N (Carlo Erba), particulate organic matter C, N and P (POM), N-mineralization potential (Drinkwater et al. 1996), dissolved organic C, N and P (Olsen and Sommers 1982; Wander et al. 1994), inorganic N and P. To distinguish POM in terms of location inside (occluded POM) or outside (free POM) of stable aggregates we will use the procedure developed by Golchin et al. (1994) which we have modified further (Puget and Drinkwater 2001). This will allow us to quantify SOM pools and key organic N and P pools. All soil amendments and harvested crops exports will be analyzed for nutrient composition so that mass balances for N, P, K, Mg and Ca can be determined.

Weeds

As a general assessment of weeds in each crop, weed counts and above-ground biomass will be clipped by species in four quadrats per plot. Quadrats will be sized appropriately to the density of the weeds but will span one inter-row center to the next to insure a representative sample.

The weed seed bank will be sampled each spring to assess overall changes in weed populations of each treatment. Twelve 7.6 cm by 15 cm deep soil cores will be bulked and a 2.5 kg sample taken. This is a larger sample than is normally used for such studies (Forcella 1984, Jones 1998). Seeds will be extracted using a high volume column elutriator (Gross and Renner 1989), sorted, and counted by species.

The effect of soil physical quality on the effectiveness of cultivation for weed control will be explored (1) by correlating changes in soil quality and cultivation effectiveness through time and (2) within a given year, by comparing soil quality and cultivation effectiveness across treatments and with nearby conventionally managed fields. Cultivation effectiveness will be evaluated by weed counts by species before and after cultivation (Mohler et al. 1997). Evaluation of cultivation effectiveness of rotary hoe or tine weeder before crop and weed emergence will be accomplished by fastening boards to the soil surface with pins to prevent local action of the cultivator. After cultivation, the boards will be removed and weed density in quadrats placed in the protected areas will be compared with weed density in quadrats placed in adjacent unprotected areas. For each cultivation event and weed species, the relation between % kill and soil characteristics will be evaluated by multiple regression.

Effects of soil nutrient status on weed populations will be evaluated by multiple regression of the several weed counts and biomass measures described above on soil nutrient values across treatments. The relation of mature weed size (i.e., biomass/number) will be similarly evaluated

We will test the hypothesis that a massive die-off of weeds occurs prior to emergence during the period between cover crop incorporation and crop planting in organic systems. Soil samples will be taken from selected treatments with no organic amendment (compost treatment before compost addition), compost addition, or cover crops addition at 5 day intervals after the tillage operation. Subsamples of the initial soil collections will be processed by elutriation to establish background weed seed densities. Weed seeds of known viability will be planted in flats of these soils and the same soil after autoclaving. Emerging seedlings will be counted for 4 weeks and then residual seeds extracted, counted and tested for viability by tetrazolium staining (Sawma and Mohler 2002). If we show differences between autoclaved and untreated soil, further tests will be made to identify causal agents.

We will attempt to transfer the disease complex that attacks velvetleaf on the Marten's farm to the grain experiment. We will do that by transplanting diseased plants into populations of velvetleaf that escape cultivation. Escaped velvetleaf will again be scored for the presence of the disease before introduction of diseased plants and one month later to see if the disease spreads within the season. Since the disease is currently not present at the Musgrave farm, presence of the disease prior to the annual transplanting will indicate successful establishment of the disease at this site.

Insects

Populations of pest insects that are expected to be present at our farm locations and additional species that we expecte to show differences between treatments will be monitored by standard procedures (Appendix 1). Damage will be monitored for each crop and pest using rating scales as in http://www.nysaes.cornell.edu/recommends/.

To evaluate the effect of the untreated pests on yield, untreated microplots (30’ x 10’) will be left in each plot and monitored separately as for the main plots.

We will monitor all beneficial insects with special attention to the specific beneficial insects that control the pest species present in the experiment. Benerficial insects are described by http://www.nysaes.cornell.edu/recommends/ and in Hoffmann and Frodsham (1993).

Pitfall traps will be used to assess the activity density of surface-dwelling predaceous ground beetles (carabids and staphylinids), other beetles, spiders, crickets, ants, slugs, centipedes, and sowbugs. Pitfall catches are also expected to include known and potential weed seed predators. Four pitfall traps per plot will be left open for 48 hr, four times from planting to harvest.

The abundance and diversity of beneficial insects including coccinellid (lady beetle) larvae, pupae, and adults will be compared between treatment plots using visual surveys and yellow sticky cards (Stephens 2002). Four times per growing season we will place four yellow 'Olson' 15 cm x 15 cm sticky traps on 4'dowels at four locations per plot.. At each sampling traps will be left out for one week and then frozen until insect counting.

For each pest or beneficial species, mean population or mean damage per plant will be calculated and treatments ompared by ANOVA (PROC MIXED), and over time using the repeated measures option (SAS Institute 1996). Differences fro a species will be compared by correlation to prey or predator abundance yield data for correlation.

On-farm nutrient satellite experiment

The Marten's initiated a study to examine effects of compost rates on their cropping system in spring 2004 in collaboration with some of the CoPD's. Field operations are supported by the Marten's and compost is donated by two suppliers. Baseline sampling was supported by a small, one-year grant from a foundation. Since this experiment provides an ideal arena for testing hypotheses on the relationship between soil fertility and weed and pathogen pressure, we propose to incorporate the experiment into this project to support the necessary sampling.

The study consists of two parallel randomized complete block experiments. One experiment uses a compost with low C:N ratio (5.0-5.0-2.0) N-P_2O_5-$0K_2O$. The other uses a high C:N ratio compost (1.9-4.9-2.0). Each compost is applied in the fall at 5 rates: 0, 0.75, 1.5, 3 and 6 ton/a, with three replicates of each treatment. Plots are 60 by 180 ft (0.25 a), with plot corners marked by GPS. Corn was planted in 2004.

Without additional support, yield may be the only data that will be collected from this experiment. We propose to sample the experiment yearly for P, K, Ca, Mg, S, pH, SOM, and micronutrients in the and to sample weed number and biomass by species near grain filling. Together, these data will test the hypothesis that excessive nutrient addition in organic systems tips the competitive balance in favor of weeds. In addition we plan to place an undergraduate research student at the farm for several weeks in spring/early summer of years 1 and 4 to do detailed growth studies on major weed species. These will test the hypothesis that high nutrient rates increase weed growth more than crop growth early in the season, that this allows more weeds to escape cultivation, and makes escapes more competitive due to increased size. Velvetleaf will be scored for severity of the indigenous disease complex to test the hypothesis that lower soil nutrient status favors the disease.

In year 4, soil from treatment rates 0, 1.5 and 6 ton/a will be tested for fungal pathogens and nematodes by bioassays as described above. This will test the hypothesis that excess soil nutrients favor pathogenic organisms. Alternatively, it may prove that better soil nutrition confers partial immunity on crops.

Research milestones (a selection)

Year 1: significant differences in N mineralization patterns between treatments; significant difference in weed seedling emergence between unamended, cover crop amended and autoclaved cover crop amended soil.
Year 2: significant difference in insect attack on cabbage correlated with soil nutrients
Year 3: treatment differences in soil physical quality indicators; significant difference in cultivator performance between treatments and relative to year 1.
Year 4: significant changes from baseline and differences between treatments in indicators of soil health and soil community composition.
Progress will be indicated by positive evaluations of specific subprojects from the project's advisory group.

Objective 3: The "living laboratory course" and other outreach and evaluation.

The core of the extension program is the "living laboratory course". This will consist of an annual two-day field experience at the two systems experiments, and two self-study modules per year, followed by conference calls. One module in the winter will deal with the science of organic agriculture; the second will relate to project design and hypotheses and will precede the field days. An example module might be "Soil microbial diversity: Which organisms matter on organic farms?" On-line self-administered tests will follow each module and the annual field days. Self-tests will assess lesson effectiveness and appropriateness of this teaching method for organic farmers and farm advisors. Formats will changed annually based on feedback from learners and the Cornell Organic Production and Marketing Working Group.

The course targets extension personnel interested in organic agriculture and farmers who play a teaching role within the organic farming community. To help insure continued participation by the latter we propose to offer scholarship/honorariums to a core group of 10 farmers.

Year one

Throughout year one, we will share the transition experiment design with Northeast organic farmers and agricultural professionals, via conferences, newsletters, the Cornell Organic Production and Marketing Working Group and a website. The website will overview the project and outline the course.

In year one, we also will establish a project advisory group comprised of 10 individuals (extension/agriculture service providers, consultants, farmers) who have a commitment to supporting organic agriculture. These individuals will participate in the living laboratory course. In addition, this group will meet annually (winter) with the project team to evaluate the project and help refine planned treatments.

Field days organized by NOFA-NY will occur each summer. These will involve a day at each of the systems experiments and will include presentations by invited speakers, team farmer experts and researchers. In year one, researchers will present treatments and methods and engage the participants in a critique of the design.

Course participants will lead discussions in small groups that include farmers, educators and researchers. These groups will be challenged to evaluate each system, list expected problems and outcomes, and to 'wager' on the 'best' system. These expected outcomes and 'wagers' will be used in project evaluation and shared at future field days. We hope that by involving participants in active evaluation of the project at the start, they will want to attend future events. The field day group strategy will also help build a network between farmers, educators and researchers (Staver 2001).

For individuals unable to attend the field days, a detailed description and photos will be posted on the project website. This site will also solicit feedback from visitors on the experiments, and encourage them to vote on which system they believe will be most successful and why. The learning modules will be available to all web site visitors. We will encourage visits to the web site via publications and articles in newsletters.

We have the following specific Year One evaluation criteria:

1. After reviewing the web-based teaching modules (weed management, soil microbiology), 30 of 40 visitors will score 75% or better on the self-tests.
2. Of the 60 people who attend the field days, 40 will register ‘wagers’ on the transition system most likely to succeed.
3. The project advisory group will suggest four strategies or mini-experiments for the project team, to increase likelihood of success for transition

Year Two

Additional web-based modules will be produced on soil health and nutrient management. These will use new formats based upon evaluation of the year one modules. The advisory group will again meet with the project team to assess and refine plans for the coming year, and participate in quarterly conferences. At the field days researchers will demonstrate methods used to collect data and share results from the first field season. The two project team expert farmers will provide their assessments of research progress. Course participants will again lead field day attendee teams who will evaluate systems treatments. These teams may suggest changes to rotations or management. Changes will be debated and implemented to the extent that does not compromise the overall principles being tested by the experiments.

Specific Year Two evaluation criteria are:

1. After reviewing the web-based teaching modules, 30 of 40 visitors will score 75% or better on the self-tests.
2. Of the 60 field day attendees, 30 will be return visitors interested in progress of the experiment and in modifying their ‘wagers’ on the system most likely to succeed.
3. The project advisory group will evaluate year one data with the project team and suggest new strategies to increase likelihood of success for transition.

Year Three and Four

Efforts with the course, field days and the advisory group will continue as described in year one and two. Previous field day attendees will be invited back to the field days to reevaluate the systems. Farmer presentations will be paired with researcher discussions to provide in-depth examination of principles demonstrated in each of the systems.

Presentations at scientific conferences (2) and farmer conferences (3) will share results from the systems experiments with a broad audience of farmers, researchers and other agriculture professionals. These presentations will integrate evaluations from the field day participants, course participants and project advisory group. Example grower meetings include annual conferences of the chapters of the Northeast Organic Farming Association, New England Vegetable and Berry Grower Conference, and local Minimum Tillage Conferences.

Additional web learning modules will include insect management, disease management, crop rotation planning, and crop cultural practices for organic production. These will again be improved based upon previous year web feedback and assessments at focus groups.

At the end of the project, the advisory group and project team will assess the first rotation cycle and determine which transition strategy was most successful based upon multiple criteria. They will also consider changes in management as the fieldss approach more “mature” states. This information will be shared with course participants, published on the website and in organic farming newsletters. Course participants will be surveyed to determine how the organization of the course and course materials could be improved. The advisory group will evaluate whether we have successfully engaged diverse partners in extension pf organic agriculture.

(d) COOPERATION AND INSTITUTIONAL UNITS INVOLVED

This project is a cooperative effort between Cornell University, Northeast Organic Farming Association of New York (NOFA-NY) and the New York Agricultural Experiment Station at Geneva (NYAES). The lead institutional unit is the Department of Crop and Soil Sciences (CSS) at Cornell. Other Cornell departments involved include the Department of Horticulture and the Department of Entomology. NOFA-NY is leading the extension portion of the project in cooperation with the other units.   NYAES is leading the soil health initiative in collaboration with CSS, and is coordinating the nutrient study at the Marten farm. Entomology is coordinating the insect work and Horticulture is coordinating the vegetable experiment. Except for the subcontract to NOFA-NY ($33,335), the budget will be handled cooperatively with resources allocated to various aspects of the project as need for travel, soil analyses, sampling etc.

(e) FACILITIES AND EQUIPMENT

Cornell's Organic Research Farm, where the vegetable experiment will be performed, and the Musgrave Research Farm, where the grain experiment will take place, are both well equipped with the necessary tractors, planters, cultivators and other machinery necessary for the work. We do request funds for construction of a cultivator similar to the Marten's and row cleaning attachments for the planter at the Musgrave farm (see Budget Narrative). The Cornell departments and NYAES have the drying ovens, refrigeration and freezer facilities needed for the work. Cornell's soil and tissue analysis service labs are well equipped for the standard analyses, and more technical analyses such as the soil DNA fingerprinting, soil health bioassays, and N-mineralization studies will be performed in suitably equipped labs of the investigators.

Table 1. Timeline for the proposed research and extension.

Winter 2004-2005	Summer 2005	Winter 2005-2006	Summer 2006	Winter 2006-2007	Summer 2007	Winter Year 4	Summer Year 4
Analyze data from vegetable entry point 1 Hire technician Form advisory group Set up web site Solicit course participants Initiate course with first 2 modules	Plant, maintain, and sample vegetable entry points 1 & 2, grain entry point 1 and the on-farm experiment. First field days, including project evaluation	Analyze data and summarize on web site Advisory group evaluates first year's work & team revises plans Continue living laboratory course with modules 3 and 4	Plant, maintain, and sample all entry points in grain and vegetable experiments and the on-farm experiment Second field days, including project evaluation	Analyze data and summarize on web site Advisory group evaluates second year's work & team revises plans Continue living laboratory course with modules 5 and 6 Presentations at scientific and grower meetings	Plant, maintain, and sample all entry points in grain and vegetable experiments and on-farm experiment Third field days, including project evaluation	Analyze data and summarize on web site Advisory group evaluates third year's work & team revises plans Continue living laboratory course with modules 7 and 8 Presentations at scientific and grower meetings Prepare manuscripts	Plant, maintain, and sample all entry points in grain and vegetable experiments and on-farm experiment Fourth field days, including project evaluation Summary evaluation by advisory group, course participants and team members

REFERENCES

Abawi, G.S. and T.L. Widmer. 2000. Impact of soil health management practices on soilborne pathogens, nematodes and root diseases of vegetable crops. Applied Soil Ecology 15: 37-47.

Alkämper, J. 1976. Influence of weed infestation on effect of fertilizer dressings. Pflanzenschutz-Nachrichten Bayer 29: 191-235.

Allee, L. L. & P. M. Davis. 1996a. The effect of manure and corn hybrid on survival of western corn rootworm (Coleoptera: Chrysomelidae). Environ. Entomol. 25(4):801-809.

Allee, L. L. & P. M. Davis. 1996b. The effect of manure on corn tolerance to western corn rootworm (Coleoptera: Chrysomelidae). J. Econ. Entomol. 89(6):1608-1620.

Andersen, A. 2003. Long-term experiments with reduced tillage in spring cereals. II. Effects on pests and beneficial insects. Crop Protection 22(1): 147-152.

Andersen, A & R. Eltun 2000. Long-term developments in the carabid and staphylinid (Col., Carabidae and Staphylinidae) fauna during conversion from conventional to biological farming. J. Appl. Entomol. 124(1): 51-56.

Banks, P. A., P. W. Santelmann and B. B. Tucker. 1976. Influence of long-term soil fertility treatments on weed species in winter wheat. Agronomy Journal 68: 825-827.

Barnes, J. P. and A. R. Putnam. 1986. Evidence for allelopathy by residues and aqueous extracts of rye (*Secale cereale*). Weed Science 34: 384-390.

Blackshaw, R. E., R. N. Brandt, H. H. Janzen, and T. Entz. 2004. Weed species response to phosphorus fertilization. Weed Science 52: 406-412.

Bond, W. and A. C. Grundy. 2001. Non-chemical weed management in organic farming systems. Weed Research 41: 383-405.

Borcard, D. 1987. Influence of some fertilizers on the carabid communities coleoptera carabidae of a maize field I. Research plots and global results. Bull. Soc. Neuch. des Sciences Naturelles 110: 89 –100.

Brainard, D. C., A. DiTommaso, and C. L. Mohler. 2004. Ecotypic variation in germination response of Powell amaranth seeds to ammonium nitrate. Northeastern Weed Science Society Proceedings 58:165.

Bundy, L. G. and J. J. Meisinger. 1994. Nitrogen availability indices. *In* S. H. B. Mickelson, J.M. (Ed.), Methods of Soil Analysis, Part 2, Microbiological and Biochemical Properties (pp. 951). Madison, WI.

Caldwell, B., Brown-Rosen, E., Sideman E, Shelton, A., Smart, C. 2004. Resource Guide to Organic Insect and Disease Management. NYS Agricultural Experiment Station, College of Agriculture and Life Sciences, Cornell Univ.: Ithaca, NY. In press.

Cardina, J., H.M. Norquay, B.R. Stinner, and D.A. McCarthy. 1996. Postdispersal predation of velvetleaf (*Abutilon theophrasti*) seeds. Weed Sci. 44:534-539.

Carmona, D. & D. Landis. 1999. Influence of refuge habitats and cover crops on seasonal activity-density of ground beetles (Coleoptera: Carabidae) in field crops. Environ. Entomol. 28(6): 1145-1153.

Chancellor, R. J. 1964. The depth of weed seed germination in the field. In: Proceedings of the Seventh British Weed Control Conference, pp. 599-606.

Coleman, D. C. and D. A. Crossley. 1996. Fundamentals of Soil Ecology. Academic Press, San Diego, CA

Conklin, A., M. S. Erich, M. Liebman, D. Lambert, E. R. Gallandt and W. A. Halteman. Effects of red clover (*Trifolium pratense*) green manure and compost soil amendments on wild mustard (*Brassica kaber*) growth and incidence of disease. Plant and Soil 238: 245-256.

Creamer, N. G., M. A. Bennett, B. R. Stinner, J. Cardina and E. E. Regnier. 1996. Mechanisms of weed suppression in cover crop-based production systems. HortScience 31: 410-413.

Cromar, H.E., S.D. Murphy, and C.J. Swanton. 1999. Influence of tillage and crop residue on postdispersal predation of weed seeds. Weed Sci. 47:184-194.

Dabney, S. M., J. D. Schreiber, C. S. Rothrock, and J. R. Johnson. 1996. Cover crops affect soghum seedling growth. Agronomy Journal 88:961-970.

Dotzenko, A. D., M. Ozkan and K. R. Storer. 1969. Influence of crop sequence, nitrogen fertilizer and herbicides on weed seed populations in sugar beet fields. Agronomy Journal 61:34-37.

Drinkwater, L.E., C.A. Cambardella and C.W. Rice. 1996. Potentially mineralizable N as an indicator of active soil N. IN: Handbook of Methods for Assessment of Soil Quality. Doran, J. and A.J. Jones, Eds.

Drinkwater, L.E., Janke, R.R., Rossoni, L.L., 2000. Effects of tillage intensity on nitrogen dynamics and productivity in legume -based grain systems. Plant Soil 227, 99-113.

Drinkwater, L.E., Workneh, F. Letourneau, D.K., van Bruggen, A.H.C. and Shennan, C. 1995. Fundamental differences in organic and conventional agroecosystems in California. Ecolog. Applic. 5:1098_1112.

Drinkwater, L.E., M.W. Wagoner & M. Sarrantonio. 1998. Legume_based systems have reduced losses of nitrogen and carbon. Nature. 396:262_265.

Dyck, E., and M. Liebman. 1994. Soil fertility management as a factor in weed control: the effect of crimson clover residue, synthetic nitrogen fertilizer, and their interaction on emergence and early growth of lambsquarters and sweet corn. Plant and Soil, 167: 227-237.

Dyck, E., M. Liebman and M. S. Erich. 1995. Crop-weed interference as influenced by a leguminous or synthetic fertilizer nitrogen source: I. Doublecropping experiments with crimson clover, sweet corn, and lambsqarters. Agriculture, Ecosystems and Environment 56: 93-108.

Forcella, F. 1984. A species-area curve for buried viable seeds. Australian Journal of Agricultural Research 35:645-652.

Gerhardt, R.-A. 1997. A comparative analysis of the effects of organic and conventional farming systems on soil structure. Biological Agriculture and Horticulture 14: 139-157.

Golchin, A., J.M. Oades, J.O. Skjemstad, and P. Clarke. 1994. Study of free and occluded particulate organic matter in soils by solid state 13C CP/MAS NMR spectroscopy and scanning electron microscopy. Aust. J. Soil Res. 32:285-309.

Griffiths, B. S., M. I. I. Van Vuuren and D. Robinson. 1994. Microbial grazer populations in a ^{15}N labelled organic residue and the uptake of residue N by wheat. European Journal of Agronomy 3:321-325.

Groffman, P.M., Hendrix, P.F., D.A. Crossley, J., 1987. Nitrogen dynamics in conventional and no-tillage agroecosystems with inorganic fertilizer or legume nitrogen inputs. Plant Soil 97, 315-332.

Gross, K. L., and K. A. Renner. 1989. A new method for estimating seed numbers in the soil. Weed Science, 37: 836-839.

Grubinger, V. P. 1999. Sustainable Vegetable Production from Start-Up to Market. Natural Resource Agriculture and Engineering Service (NRAES), Ithaca, NY.

Grundy, A. C. and A. Mead. 1998. Modelling the effects of seed depth on weed seedling emergence. Aspects of Applied Biology 51: 75-82.

Hebbar , K. P., D. Atkinson, W. Tucker and P. J. Dart. 1992. Suppression of *Fusarium moniliforme* by maize root-associated *Pseudomonas cepacia*. Soil Biology and Biochemistry 24:1909-1920.

Hoffmann, M. P., and A. C. Frodsham. 1993. Natural Enemies of Vegetable Insect Pests. Cornell Cooperative Extension. 64 pp.

Jones, N. E. 1998. The number of soil cores required to accurately estimate the seed bank on arable land. Aspects of Applied Biology 51:1-8

Joslin, K. M., C. Mohler, A. DiTommaso. 2000. The effect of soil tilth on weed control by cultivation. Report to the Toward Sustainability Foundation.

Karunatilake, U., H. M. van Es, and R. R. Schindelbeck. Soil and maize response to plow and no-tillage after alfalfa-to-maize conversion on a clay loam soil in New York. Soil and Tillage Research 55:31-42.

Kloepper, J. W., G. Wei and S. Tuzun. 1992. Rhizosphere population dynamics and internal colonization of cucumber by plant growth-promoting rhizobacteria which induce systemic resistance to *Colletotrichum orbiculare*. *In*, Biological Control of Plant Diseases: Progress and Challenges for the Futrue. E. C. Tiamos, G. C. Papavizas and R. J. Cook, eds., pp. 185-191. Proceedings on a NATO Advanced Research Workshop, May 19-24, 1991, Cape Sounions, Athens, Greece.

Lawson, H. M. and J. S. Wiseman. 1979. Competition between weeds and transplanted spring cabbage: effects of nitrogen top-dressing. Horticultural Research 19: 25-34.

Liebhardt, W.C., Andrews, R.W., Culik, M.N., Harwood, R.R., Janke, R.R., Radke J.K. and Rieger-Schwartz, S.L. (1989) Crop production during conversion from conventional to low-input methods. *Agronomy Journal* 81, 150-159.

Liebig, M. A. and J. W. Doran. 1999. Impact of organic production practices on soil quality indicators. Journal of Environmental Quality 28: 1601-1609.

Liebman, M., and E. Dyck. 1993. Crop rotation and intercropping strategies for weed management. Ecological Applications, 3: 92-122.

Liebman, M. and C. L. Mohler. 2001. Weeds and the Soil Environment, in M. Liebman, C. L. Mohler and C. P. Staver (Eds), pp. 210-268. Cambridge University Press: Cambridge, UK.

Luka, H., Pfiffner, L. & U. Niggli. 2000. Auswirkungen verschiedener Ackerkulturen auf die Laufkafer (Coleoptera, Carabidae)[Impact of various crops on ground beetles (Coleoptera, Carabidae)] Mitteilungen Entomol. Gesellschaft-Basel. 50(1): 18-38.

Mäder, P., A. Fließbach, D. Dubois, L. Gunst, P. Fried, and U. Niggli. 2002. Soil fertility and biodiversity in organic farming. *Science* 296:1694-1697.

Magdoff, F. and H. Van Es. 2000. Building Soils for Better Crops, 2nd Edition. Sustainable Agriculture Network (SAN): Beltsville, MD.

Mohler, C. L. 1993. A model of the effects of tillage on emergence of weed seedlings. Ecological Applications 3: 53-73.

Mohler, C. L. 1996. Ecological bases for the cultural control of annual weeds. Journal of Production Agriculture 9: 468-474.

Mohler, C. L. 2001. Weed life history: identifying vulnerabilities. Ecological Management of Agricultural Weeds, in M. Liebman, C. L. Mohler and C. P. Staver (Eds), pp. 40-98. Cambridge University Press: Cambridge, UK.

Mohler, C.L., J.C. Frisch and J. Mt. Pleasant. 1997. Evaluation of mechanical weed management programs for corn (*Zea mays*). Weed Technology, 11: 123-131.

Muyzer, G. and K..Smalla. 1998. Application of denaturing gradient gel electrophoresis (DGGE) and temperature gradient gel electrophoresis (TGGE) in microbial ecology. Antonie van Leeuwenhoek International Journal of General & Molecular Microbiology 73(1): 127-141.

Neher, D.A. 2001. Role of nematodes in soil health and their use as indicators. Journal of Nematology 33: 161-168.

NOP. 2004. National Organic Program: Program Standards. http://www.ams.usda.gov/nop/NOP/standards.html

Nurse, R. E., Booth, B. D. & C. J. Swanton. 2003. Predispersal seed predation of *Amaranthus retroflexus* and *Chenopodium album* growing in soyabean fields. Weed Research. 43(4): 260-268.

Olsen, S.R. and L.E. Sommers. Phosphorus. IN: Methods of Soil Analysis, Part 2-Chemical and Microbiological Properties. 2nd Edition. Page, A.L., R.H. Miller and. Keeney, eds. Pp. 403-30.

Organic Farming Research Foundation. 1999. Final Results of the Third Biennial National Organic Farms' Survey. OFRF.

O'Sullivan, C. M. & M. J. Gormally. 2002. A comparison of ground beetle (Carabidae: Coleoptera) communities in an organic and conventional potato crop. Biological Agriculture and Horticulture 20(2): 99-110.

Pankhurst, C., B.M. Doube and V.V.S.R. Gupta. 1997. Biological Indicators of Soil Health. CAB International.

Pavuk, D. M., Purrington, F. F., Williams C. E. & B. R. Stinner. 1997. Ground beetle (Coleoptera: Carabidae) activity density and community composition in vegetationally diverse corn agroecosystems. American Midland Naturalist 138(1): 14-28.

Pennsylvania Agricultural Statistics Service. 2004. Custom machinery operation rates. http://www.nass.usda.gov/pa/custrate.htm

Peoples, M.B., Herridge, D.F., Ladha, J.K., 1995. Biological nitrogen fixation: An efficient source of nitrogen for sustainable agricultural production? Plant Soil 174, 3-28.

Pfiffner, L. & H. Luka. 2003. Effects of low-input farming systems on carabids and epigeal spiders: A paired farm approach. Basic and Applied Ecology. 2003; 4(2): 117-127.

Phelan, P. L., Mason, J. F., B. R. Stinner. 1995. Soil-fertility management and host preference by European corn borer, *Ostrinia nubilalis* (Huebner), on *Zea mays* L.: A comparison of organic and conventional chemical farming. Agriculture Ecosystems and Environment 56(1): 1-8.

Phelan, P. L., Norris, K. H. & J. F. Mason. 1996. Soil-management history and host preference by *Ostrinia nubilalis*: Evidence for plant mineral balance mediating insect-plant interactions. Environ. Entomol. 25(6):1329-1336.

Power, J.F., Doran, J.W., Koerner, P.T., 1991. Hairy vetch as a winter cover crop for dryland corn production. J. Prod. Agric. 4, 62-67.

Puget, P. and L.E. Drinkwater. 2001. Short-term dynamics of root and shoot-derived carbon from a leguminous green manure. Soil Sci. Soc. Am. J. 65:771-779.

Ranells, N.N.,Wagger, M.G., 1997. Winter annual grass-legume bicultures for efficient nitrogen management in no-till corn. Agric. Ecosyst. & Environ. 65, 23-32.

Rangarajan, A. 2005. Real World Organics: Case studies of Eleven Exemplary Farms. NRAES, Ithaca, NY. In preparation.

Reganold, J. P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. American Journal of Alternative Agriculture 3:144-155.

Reganold, J. P., A. S. Palmer, J. C. Lockhart, and A. N. Macgregor. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. Science 260: 344-349.

Reider, C., W. Herdman, L.E. Drinkwater and R. Janke. 2000. Yields and nutrient budgets under composts, raw dairy manure and mineral fertilizer. Compost Science and Utilization. 8:328-339.

Roberts,H. A. and S. K. Benjamin. 1979. The interaction of light, nitrate and alternating temperature on the germination of *Chenopodium album*, *Capsella-bursa-pastoris*, and *Poa annua* before and after chilling. Seed Science and Technology 7:379-392.

Sarrantonio, M., Scott, T.W., 1988. Tillage effects on availability of nitrogen to corn following a winter green manure crop. Soil Sci. Soc. Am. J. 52, 1661-1668.

Sawma J.T. and C.L. Mohler. 2002. Accuracy and precision of a quick method for testing seed viability. Weed Technology 16: 781-786.

Schimpf, D. J. and I. G. Palmblad. 1980. Germination responses of weed seeds to soil nitrate and ammonium with and without simulated overwintering. Weed Science 28: 190-193.

Seibert, A. C. and R. B. Pearce. 1993. Growth analysis of weed and crop species with reference to seed weight. Weed Science 41: 52-56.

Staver, C. P. 2001. Knowledge, science, and practice in ecological weed management: farmer-extensionist-scientist interactions. In Ecological Management of Agricultural Weeds, M. Liebman, C. L. Mohler, and C. P. Staver, pp. 99-138. Cambridge University Press: Cambridge, UK.

Stephens, E. J. 2002. The Coccinellidae of New York State: Effectiveness of sampling methods for estimating coccinellid densities and for rare species surveys. MS Thesis. Cornell University.

Stevenson, F. J. 1986. Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients. Wiley Interscience:New York.

Theron, J. and T. Cloete. 2000. Molecular techniques for determining microbial diversity and community structure in natural environments. Critical Reviews in Microbiology 26: 37-57.

Vance, E. D., P. C. Brookes and D.S. Jenkinson. 1987. An extraction method for measuring soil microbial biomass C. Soil Biology & Biochemistry 19: 703-707.

Vengris,J., M. Drake, W. G. Colby and J. Bart. 1953. Chemical composition of weeds and accompanying crop plants. Agronomy Journal 45: 213-218.

Wagger, M.G., 1989. Time of desiccation effects on plant composition and subsequent nitrogen release from several winter annual cover crops. Agron. J. 81, 236-241.

Wall, R. E. 1984. Effects of recently incorporated organic amendments on damping –off of conifer seedlings. Plant Disease 68: 59-60.

Wander, M. M., S. J. Traina, B. R. Stinner, and S. E. Peters. 1994. The effects of organic and conventional management on biologically-active soil organic matter pools. Soil Science Society of America Journal 58:1130-1139.

Weston, L. A. 1996. Utilization of allelopathy for weed management in agroecosystems. Agronomy Journal 88: 860-866.

Wright, S. F. & Upadhyaya, A. (1999). Quantification of arbuscular mycorrhizal fungi activity by the glomalin concentration on hyphal traps. *Mycorrhiza* **8**, 283-285.

Yenish, J., A. D. Worsham and W. S. Chilton. 1995. Disappearance of DIBOA-glucoside, DIBOA, and BOA from rye (*Secale cereale* L.) cover crop residue. Weed Science 43: 18-20.

Zibilske L. M. 1994. Carbon mineralization. In S. H. B. Mickelson, J.M. (Ed.), *Methods of Soil Analysis, Part 2, Microbiological and Biochemical Properties.* (pp. 835 -). Soil Science Society of America, Madison, WI.

APPENDICES TO THE PROJECT DESCRIPTION

Appendix 1: details of insect pest sampling procedures

Sweet Corn: European corn borer, *Ostrinia nubilalis,* Corn earworm, *Helicoverpa zea,* and Fall Armyworm, *Spodoptera frugiperda,* will be monitored weekly using the sequential sampling plans described in http://www.nysipm.cornell.edu/scouting/scoutproc/fmsc99.html. Special attention will be given to gathering data on European corn borer egg masses.

Potato: Colorado potato beetle, *Leptinotarsa decemlineata*, eggs, small larvae, and adults will be monitored weekly from emergence through harvest using the sequential sampling plan and thresholds from http://www.nysaes.cornell.edu/recommends/24frameset.html. Plots will be intensively monitored at two to four day intervals during the period of initial egg hatching when the daily high temperature is above 70°F for two or more days. Potato leafhopper, *Empoasca fabae,* will be monitored from early June through August. Adults will be counted on yellow sticky cards as described below in methods for beneficial insects. Nymphs will be counted on the undersides of the 5 leaves on the lower half of 4 plants per plot.

Cabbage: Percentage of plants infested by Cabbage root maggot, *Delia radicum,* will be monitored from planting through July by looking for brown tunnels in stems and roots on five plants per plot. Adult Flea beetles, *Phyllotreta striolata* and *P. cruciferae*, will be counted at cotyledon, seedling, and mature head stages, on five leaves of five plants per plot. Percentage of plants infested with Diamondback moth, *Plutella xylostella*, imported cabbageworm, and cabbage looper will be sampled simultaneously from June through harvest on five plants per plot.

Lettuce: Tarnished plant bug, *Lygus lineolaris,* Aster leafhopper, *Macrosteles quadrilineatus,* Aphids, *Myzus spp.,* and Slugs (early in season), will be monitored weekly on 5 leaves of 4 plants per plot.

Field Corn: Fall Armyworm, *Spodoptera frugiperda,* will be monitored at seedling emergence and at the 8-12 leaf stage by visually counting 4 sections of 10 row feet for larvae or damage. European corn borer, *Ostrinia nubilalis* will be monitored at 8-12 leaf stage and silking, by visually searching every tenth plant for fifty plants per plot for egg masses and larval entry holes.

Soybean: Since seed corn maggot, *Delia platura,* can be numerous in fields with high organic matter content, stand counts for 4 sections of 10 row feet at seedling emergence will be taken. Potato leafhopper, *Empoasca fabae,* will be monitored from early June through August. Adults will be counted on yellow sticky cards as described below in methods for beneficial insects. Nymphs will be counted on the undersides of the 5 leaves on the lower half of 4 plants per plot.

Spelt: Cereal leaf beetle, *Oulema melanopus*, armyworm, and cutworm will be monitored by visual counts on 50 plants per plot in April and May.

KEY PERSONNEL

Project Director and Co-PDs

Charles Mohler will be responsible for overall coordination of project activities and supervision of staff. He will hire and oversee employees (with assistance from Co PD's), ensure timeliness of field operations and data collection, oversee or conduct data analyses, including the economic analyses, prepare annual reports, speak at meetings, and prepare some extension and scientific publications, particularly those dealing with weed management.

Brian Caldwell has been particularly instrumental in design of the cropping systems experiments. He will continue to advise on conduct of the experiments. His primary role, however, will be to coordinate and conduct much of the extension activities of the project. Including setting up field days, speaking at meetings of farmer organizations, writing articles for farmer-read publications and designing the "living laboratory course".

George Abawi and his staff will conduct the soil pathogen bioassays in his laboratory, and work with Mohler on determining the role of pathogenic fungi in controlling weeds between the time of cover crop incorporation and crop planting. He will prepare scientific papers on the soil health aspects of the cropping system study.

Leslie Allee will train field staff in use of insect trapping equipment (pitfall traps and sticky cards) and insect identification. She will conduct analyses of the insect data and prepare scientific publications on the results of the insect studies.

Anusuya Rangnarajan, along with Eric Nordell, Laurie Drinkwater and Antonio DiTommaso, obtained the Hatch seed grant that initiated the vegetable experiment. She will advise on crop yield and crop quality evaluations in the vegetable experiment. She will contribute to analysis and publication of vegetable yield and quality data. She will work with Caldwell on development of the extension program.

Janice Thies and her staff will conduct the soil biology analyses, and prepare scientific publications on the results.

Researcher Collaborators

Thomas Bjorkman will be in charge of the nutrient satellite experiment at the Marten's farm. He will analyze and publish nutrient and yield data from that study.

Antonio DiTommaso and **Daniel Brainard** will assist Mohler in conduct and publication of the weed studies associated with the project.

Harold Van Es and his staff will conduct and interpret the soil physical analyses. With other CoPD's he will prepare scientific publications on the effects of soil physical conditions on crop production and the effectiveness of cultivation.

Quirine Ketterings and **Laurie Drinkwater** and their staffs will conduct N-mineralization and other nutrient studies in the grain and vegetable experiments, respectively. They will interpret nutrient analyses and contribute to publications on soil nutrition and its relation to crop yield, weeds, insects and soil pathology.

James Frisch will build a "Marten" style row-crop cultivator and ridge cleaning attachments for the planter that will be used in the grain experiment.

All of the researchers will contribute to the "living laboratory courses" by speaking at field days. Rotation of field day presentations among project personnel will help keep field days from becoming repetitive and increase the learning of course participants. Many of the researchers will also contribute learning modules for the courses.

Farmer Collaborators

Klaas Marten has been intimately involved in design of the grain experiment from the outset and initiated the satellite nutrient study at his farm. He will continue to obtain in-kind support for the nutrient experiment (compost) and contribute his equipment and labor to the conduct of that experiment. He will act as an advisor on the conduct of all experiments, but especially the grain and nutrient study. He and his wife, Mary Howell Marten, will speak at field days as part of the "living laboratory course" and at meetings of farmer organizations.

Eric Nordell has led the design of the vegetable experiment from the outset and has contributed to the design of the grin experiment as well. He will continue to advise on conduct of all experiments, but especially the vegetable experiment. He and his wife, Anne Nordell, will speak at field days as part of the "living laboratory course" and at meetings of farmer organizations.