ORGANIC FARMING RESEARCH FOUNDATION

P.O. Box 440
Santa Cruz, CA 95061

tel ~(831) 426-6606
fax ~ (831) 426-6670

email ~ research@ofrf.org
web ~ www.ofrf.org

Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

An on-farm trial of microbial seed treatments for organic field corn in the Finger Lakes, New York

FINAL PROJECT REPORT

Principal investigators:
Dr. Anu Rangarajan
Cornell University
Department of Horticulture
121 Plant Science Building
Ithaca, NY 14853
(607) 255-1780
ar47@cornell.edu

Steven Vanek, Cornell University Department of Horticulture
Brian Caldwell, Cornell University Department of Horticulture

Collaborating farmers:
John Myer, Myer Farm, Ovid, NY
Klaas Martens, Martens' Farm, Penn Yan, NY

Funding provided by OFRF: $5,429, awarded spring 2004

Project period: 2004 (one year)

Report submitted: April 2005

1. Project Summary

In an effort to promote more consistent and higher stand counts and crop vigor in organic field corn, we tested the effectiveness of four commercial microbial seed inoculants and one compost inoculant on stand, early vigor, and yield of corn crops on organic field crop farms in the Finger Lakes region of New York. A trial was conducted on four organically managed fields planted to field corn in 2004, in which four microbial inoculants (Kodiak, Yieldshield, T-22 Planter Box, and Mycostop Mix), and one sieved dairy manure compost were applied to corn seed prior to planting. No significant differences were found among treatments and a control treatment without any applied inoculant to seed, and stand and corn yield in all treatments were good. In 2004, soil temperatures at the time of planting the trial were adequate for rapid germination and growth of corn, so that the establishing corn crop may not have faced any limitation from soil pathogens that these biofungicidal treatments were intended to alleviate. In previous years when stand was poor in some organic corn fields, records of air temperature show that soil temperatures were likely lower, which would have favored seed and root rot pathogens relative to germinating corn seedlings. More challenging conditions to early corn growth may be required in future years of a trial to demonstrate the utility in an on-farm setting of microbial or compost inoculants for seed.

2. Introduction

We undertook these trials in response to problems of low stand count and early vigor in organic field corn that we observed during NEON (Northeast Organic Network) fieldwork in 2002 and 2003. At two NEON collaborating farms in the Finger Lakes region of New York, we noted field corn stand counts that averaged 80% of what farmers consider to be their target stand, with a range from 54% to 99% over 12 fields. The May planting period in both these years was cool and rainy, and it was felt that seed and root rot organisms such as *Pythium spp*. that attack germinating seeds under these conditions might be playing a role reducing stand. Low stand reduces yield of a corn crop because corn plants can only compensate for their missing neighbors to a limited extent. In addition, low stand in field corn makes weed management more difficult because the corn canopy allows more light through for interception by weeds. Even when emerging plants are not killed outright, damaged plants with reduced vigor may cause limitations for yield and weed management. Achieving good stand is thus an important objective of organic field crop farmers, who try to achieve stands of 22 to 25 thousand plants per acre (54,000 to 62,000 plants/ha) in the Finger Lakes of New York..

As possible solutions to these problems, a number of microbial inoculants are now approved for use in certified organic production that claim to increase the vigor of the plant by inhibiting disease-causing organisms in corn such as *Fusarium* fungi and the fungal relative (Oomycete) *Pythium*. In addition, there is evidence that composts also inhibit pathogens under certain conditions, so that the idea of duplicating the protective effect of a microbial inoculation with a lower-tech and less proprietary compost inoculation is one that may be of interest to farmers. As we sought to respond to problems of poor corn stand, we saw an obvious niche for a multi-year on-farm trial that would provide relevant data for organic producers on the utility of these products and practices for organic farming systems.

3. Objectives

- Trial a number of organic-certified, seed-applied beneficial microbial inoculants that claim to improve emergence and early vigor of crops, using established organic farms as trialing sites.
- As suggested by OFRF during the review of our project proposal, test a compost inoculation treatment as an alternative to a purchased microbial inoculant.
- Compare these treatments to controls provided by the farmers' typical practice.
- Document and share information on the efficacy of these products with both organic farmers and the research and extension community.
- Contribute these results to a set of fact sheets under development by the Northeast Organic Network, OMRI, and MOFGA.

4. Materials and Methods

We worked with two collaborating farms (Myer Farm and Martens' Farm) and planted two fields (replicates) of the trial on each farm. Although farmers were very generous with their time, establishing trials was difficult due to frequent rains in May (see Fig. 9) that severely restricted the number of days when planting could occur. Thus we planted two instead of three fields per farm as originally envisioned in the proposal. Planting each trial replicate added between 45 minutes and one hour to the time that a farmer would normally take to plant a field. The first field at the Myer farm was planted May 14 and the second after a long rainy spell, on June 4. At Martens' farm, the first field was planted June 5 and the second on June 6. The fields on the Martens' farm followed clover that had been frost seeded into small grains the previous spring. One of the fields at the Myer Farm followed clover frost seeded two years earlier and harvested for seed the previous year. The other field followed alfalfa hay that had been established for several years.

Four microbial inoculants, one compost treatment, and one control treatment (no inoculant applied to seed) were planted in each field (see Fig. 1 and treatment descriptions below). Each treatment area was a strip of two planter passes (twelve rows) running the length of a field, which was accomplished by loading pre-treated seed, driving the planter down and back with a tractor, emptying that treatment's seed, and reloading with the next batch of seed. Although little residue was left in the hoppers after shaking these out, we tried to address the issue of residue in the actual planter unit by sampling well into the rows so that any treatment dust would already have left the planter. In one narrow field, we planted only six rows per treatment, which necessitated carrying seed on the tractor to the far end of the field.

Figure 1. Example plot plan, representing one of two fields per farm:

	Buffer at edge of field	
buffer	Mycostop *(each strip 6 or 12 rows)*	buffer
	Compost	
	Yieldshield	
	Control	
	T-22	
	Kodiak	
	Remainder of field	

Treatments:
The four commercially available and OMRI-approved seed treatments are described below. We followed the application rates and methods given by the manufacturer. Where a range of rates was specified, we tended to apply at the higher end of the range, reasoning that this would be more likely to reveal any treatment effect. In the course of planning the trial, we realized that one of the microbial inoculants, T-22, is not described by the manufacturer as having suppressive effects on seed rots and early root disease in cool soil. Although T-22 therefore did not address the main research question, we decided to keep it in the trial because information about all available inoculants that claim to improve plant health and yield would be helpful to organic field crop growers. We gratefully acknowledge the supplying of inoculants and compost by Gustafson, AgBio inc., BioWorks, and Fessendens dairy, and participation of farmers' seed, equipment and donation of time and expertise.

Kodiak (*Bacillus subtilis* GB03) (Gustafson, Plano, TX): This is a strain of *Bacillus subtilis* which is intended to "colonize the developing root system, suppressing disease organisms such as *Fusarium*, *Rhizoctonia, Alternaria,* and *Aspergillus*" and can result in "more uniform stands and higher yields" (Gustafson data sheet). It is labeled on corn to suppress root diseases caused by *Fusarium* and *Pythium*. Kodiak comes as a very small amount of concentrate powder (bacterial spores) that was mixed into water at a rate of 3.12 g suspended in 190 ml water and applied to one unit of seed (80 thousand seeds or about 49 lbs or 22 kg). We mixed it with the seed the night before planting, using a large plastic pan (about 48"x 18" – see Fig. 10) to treat 5-lb batches of the seed (with gloves) which were then all mixed together before planting. Gustafson recommends using a concrete mixer for small batches, but there was some doubt on our part that this would insure even coating given the very small amount of liquid to be added. Using a pan allowed us to visually ensure that all the seed had been wet by the bacterial suspension. In actual use by farmers, Kodiak is frequently applied using a misting system that mists seeds as they pass through a planter. The effort we expended in applying this treatment and the Yieldshield inoculant prompted one collaborating farmer to recommend that all such treatments needed to have an easier planter box formulation (a powder mixed with the seed), such as the T-22 and Mycostop.

YieldShield (*Bacillus pumilis* GB34) (Gustafson, Plano, TX): Similar to Kodiak, Yieldshield comes as a concentrate which contains hardy spores of bacteria that are intended to colonize the root system of the plant early in growth. The data sheet describes "a mode of action in which the plants' own host resistance is activated" as a feature of Yieldshield's function. We applied it in the exact same manner as Kodiak.

Mycostop Mix (*Streptomyces griseoviridis* K61) (Verdera, Finland; AgBio Inc., Westminster, CO): Mycostop Mix is a naturally occurring bacterium that has been isolated from *Sphagnum* peat. Like the other biofungicides, it is intended to colonize plant roots and also secretes antifungal compounds. It is most active between 59˚F and 77˚F, but remains active at temperatures down to 41˚F, and according to the manufacturer can "stimulate plant growth even in healthy crops". Verdera has only recently introduced this powdered planter box formulation of Mycostop which allows its use on field crops. OMRI only approved it as of June 1, 2004, so we were unable to use it in the first trial planted May. In the trials planted in early June, we applied it to seed in a large, clean plastic storage bin prior to filling planting boxes at the field, at a rate of 50g per unit of seed (80 thousand seed or about 49 lbs or 22 kg).

T-22 Planter Box (*Trichoderma harzianum* Rifai strain KRL-AG2) (Bioworks, Geneva, NY). In contrast to the other three microbial inoculants, T-22 is a fungus and not a bacterium. However it is similar in that it also colonizes the root system and is intended to thus protect the growing crop plant from fungal disease. The data sheet from Bioworks is quite clear in stating that T-22 is not likely to help with seed and root rots at and just after germination, especially in cold soil, as the fungus is inactive below 50˚F. Although it was therefore not likely to address the original research need, we retained it in the trial because it was an opportunity to test a by now reputable biofungicide in a well-established organic farm system. Similar to Mycostop, T-22 planter box was applied at a rate of 225 g (8 oz) per 100 lbs seed. This was near the top of the recommended application range of four to ten ounces per 100 lbs of seed.

Compost Treatment (Fessenden dairy, King Ferry, NY): It would seem that there are as many types of compost as people who make compost, so selecting one particular compost as a possible suppressive seed treatment was challenging. We decided to use an OMRI-approved, aerobic windrow compost made from separated dairy manure solids (Tender Loving Compost) that is locally available in the Finger Lakes region. Although an entire trial could be devoted to inoculative applications of composts to seed, we made our choice based on two factors. First, mature aerobic dairy composts have shown some promise in suppressing soil disease (Jean Bonhotal, Cornell Waste Management Institute, personal communication). Second, locally available, commercially certified compost at least made it possible that others might replicate or deepen our results, and that farmers wishing to use compost for an inoculative purpose could easily locate one as a starting point for their own attempts.

In applying the compost to seed we wished to maximize the chances of observing a beneficial effect while using methods that would be in principle accessible to anyone. Starting with a bag of compost as supplied by Fessenden's Dairy, we made a liquid suspension by mixing 600 g of compost with 1200 ml of distilled water in a large jar (see Fig. 11) and shaking for one hour. In addition, we sieved compost through a 2-mm sieve until we had 300 g of compost for each unit (49 lb) of corn seed. We then applied this amount of sieved compost to one unit of seed using 200 ml of the shaken suspension to mix and stick compost particles to the seeds. We knew from previously applying Kodiak and Yieldshield that this ratio of liquid to seed was sufficient to coat all the seed but woul still allow the seed to flow through the planting equipment. Sieving the <2mm fraction was intended to isolate the finest and biologically most active fraction of the compost and avoid problems with clogging the planter with clumps of compost. A liquid suspension in distilled water was designed to extract microbes and possibly give them a burst of biological activity as they were mixed with the seed. When done, the seed had a slightly darker color and was flecked with compost material. Considering the relatively low nutrient content of the compost and the tiny amount used per unit of seed, there was probably no “fertilizer” effect of this treatment and we felt that any response we did observe would be the result of microbial inoculation or possibly organic compounds in the compost.

Control Treatment: This was designed to be in all ways similar to the other treatments and to the farm’s practice, except without any added seed treatment. Both farms used a John Deere six-row planter of similar or identical model. One farm used graphite as a seed additive to lubricate the planter mechanism and seed as well as a banded organic starter fertilizer (Fertrell gold SS 2-4-2 at 300 lbs/acre). John Myer planted a Pioneer hybrid variety (38P05, maturity 93) at a rate of 31,000 seeds per acre in the fields at his farm, while Klaas Martens planted a Chemgro hybrid (5500, maturity 95) at 26 thousand seeds per acre with a target stand of 22 thousand per acre or above. Both of these farmers like to see stands between of 22 thousand per acre (54,000/ ha) or above.

Sampling and Evaluations:

We took samples and evaluated crop growth at the V6 (sixth leaf of vegetative growth) stage, when corn plants are entering the exponential growth phase, and at season end before harvest. By doing this we were attempting to separate out any effects that might occur early in growth when stand and early vigor differences are most evident, as well as capture any eventual yield differences that are obviously important to farmers.

All sampling used the same set of flagging that was established at the V6 stage when walking and measuring plots in the crop was easier. To stay out of the way of cultivating equipment, we placed all of our flags in the rows. Using a measuring tape and 24” colored flags (red, blue, and bright orange worked well), we established four hundred-foot areas down the length of each treatment using the two rows in the middle (rows three and four of six) of the downward pass of the two planting passes used for each treatment. We then used these two middle rows for the initial V6 sampling, and the two rows just to the outside of this (rows two and five of six) for the final yield sampling. Setting up four separate areas in each treatment allowed us to gauge variability within the field, although these four replicates were all averaged together and the field-wide average for each treatment was used in statistics.

At both V6 and harvest, we counted all plants in each flagged area and divided by the area (500 ft^2) to measure stand count. At V6, we measured biomass of the growing plants by cutting one plant every 15 feet in each sample area, drying the combined sample in a drying oven at 65˚ C, and weighing. We used the weight of this dried sample along with the stand count measurement to calculate the dry aboveground biomass of corn plants at this stage. The V6 stage is defined as the point when 50% of the plants in the field have a sixth leaf with a well developed “collar” against the stem. In practice, the growth of plants varied a great deal both within and between fields. We sometimes made the choice to sample a field at what appeared close to the V6 stage when it was expedient rather than ensuring that the crop was precisely at the V6 stage. This, plus the different growing conditions in each field, caused the V6 biomass to vary between fields more greatly than between treatments. However, our statistical design of blocking is able to filter out field to field variation and focus on how treatments compared to each other, so that this does not obscure our results.

At harvest, we determined yield by harvesting every 25th ear in each 100 foot section. Harvesting according to plants counted made it easy to combine harvest and stand count operations. Harvested ears were dried at 65˚C, shelled, and the corn grain weighed. We used the harvest stand count to calculate a per acre yield from the grain weight, and adjusted this figure to 15.5% moisture as is standard for corn yields.

We used the general linear model ANOVA in the Minitab 14 statistical package to analyze for differences in stand count, V6 biomass, and yield between treatments. We used the four fields as blocks in a randomized complete block design, with one missing value because of the lack of Mycostop mix in the first trial field.

In addition to these plant measurements, we installed temperature data loggers at each field to measure both soil and air temperature. Soil temperature was measured two inches deep (about the corn planting depth). These temperatures are especially important just after planting when cool soil can slow corn germination and growth and favor the growth of seed and root rot organisms like *Pythium*.

5. Results and Discussion.

Stand Counts and Early Biomass

We found no significant differences between treatments in any of the assessments we made of stand, early plant dry biomass, or yield (Figures 2 through 5). Stand counts early in the season and at harvest were roughly the same (Figures 2 and 4). These counts also varied little among the four fields; field averages ranged from 22,600 to 25,100 plants per acre and so were satisfactory from the collaborating farmers' perspective. Qualitatively, the earliest planted field (planted May 14) was more uneven in plant size, with patches of poor growth that were not seen as frequently in the other fields. This was probably due to heavy rains in the second half of May (see Fig. 9) that led to crusting and waterlogged soils. It is interesting that even under these poor conditions when seed treatments might have been particularly effective in preventing root and seed rots, this first field did not show any clear treatment differences between microbial treatments. However, high patch to patch variability in the fields may have been a factor that obscured treatment effects.

Regardless of within-field variability and wet soils early in the season, our lack of treatment differences may also have been due to fairly warm soil temperatures early in the season. The temperatures we measured throughout May and early June were adequate to good for corn to germinate and grow quickly (Fig. 7). Thus although 2004 was a wet year, it was also warm in the early season which may have alleviated any disease pressure from *Pythium* or other seed and root rots. The comparison in spring temperatures with 2002 and 2003 is interesting. Although we do not have soil temperatures for the early season in these previous years, we do have the average air temperature which along with insolation is likely to be a main driver of the shallow soil temperature. Figure 8 clearly shows that 2004 was had the warmest daily average air temperatures during the corn planting period of these three years. This provides additional explanation as to why stand and early vigor showed no treatment differences in our trial, since corn growth was not limited by temperature at any time after planting, and why stand and vigor may have been a problem in the two previous years.

Additionally, it may also be the case that soils on these two organically managed farms already are somewhat suppressive to pathogens due to higher organic matter content and greater microbial diversity. However, to distinguish between the effect of weather, soil suppressiveness, and compost or microbial treatments, a more stressful environment for early corn growth will likely be needed than that present in 2004 in our trials. At the least, this trial indicates that in years when growing conditions are good, farmers growing organic corn may be unlikely to perceive any utility of microbial or compost seed inoculation. One of the collaborating farmers observed that in his previous experience with the T-22 inoculant, it only seemed to improve crop growth when conditions were stressful; our other farmer collaborator had seen no results from T-22 when he had tried it.

Yield

Summer 2004 was average in temperature (see Fig. 6), but qualitatively quite cloudy. Low sunlight and the late planting date for the 95-day varieties we used led to late maturity (the later planted fields were still at dough stage in late September). Other than these factors, growing conditions were good (see photo of corn crop, Figure 12), and the yields we measured on these fields matched the good stands. Yields across the four fields varied significantly, with field averages ranging from 75 to 139 bushels/acre, better than many of the yields observed in the two difficult corn years of the NEON project. One of the farmer collaborators commented that yields would have been even higher if wet spots in the fields had not yielded poorly due to low fertility, probably from denitrification or leaching. As with stand and early biomass, there were again no significant treatment differences of microbial or compost inoculation. As indicated above, the fact that the early season in 2004 was fairly good for corn growth may explain the lack of impact of inoculants that are intended to protect corn plants only when conditions allow pathogen attack. More years of data would be required to conclude whether microbial or compost inoculants are a worthwhile investment for farmers who have been managing soil organically.

Figure 2. Early season stand for five experimental seed treatments and control. Error bars are one standard error of the mean. There were no significant differences between treatments.

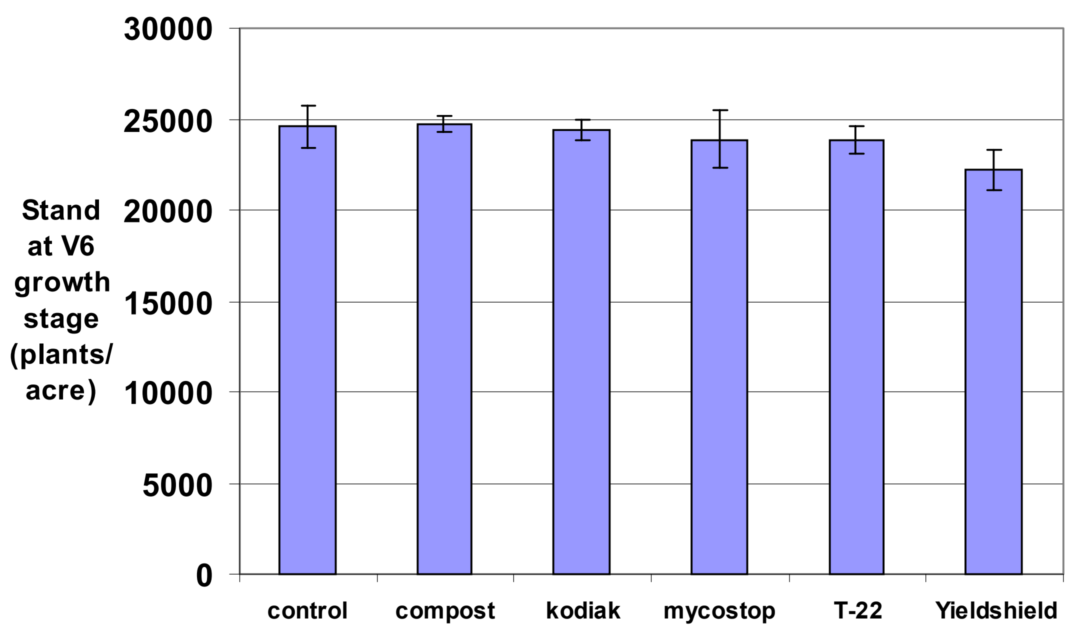


Figure 3. Early-season dry above-ground biomass for corn crops in five experimental seed treatments and control, taken at the sixth collar (V6) stage. Error bars are one standard error of the mean. There were no significant differences between treatments.

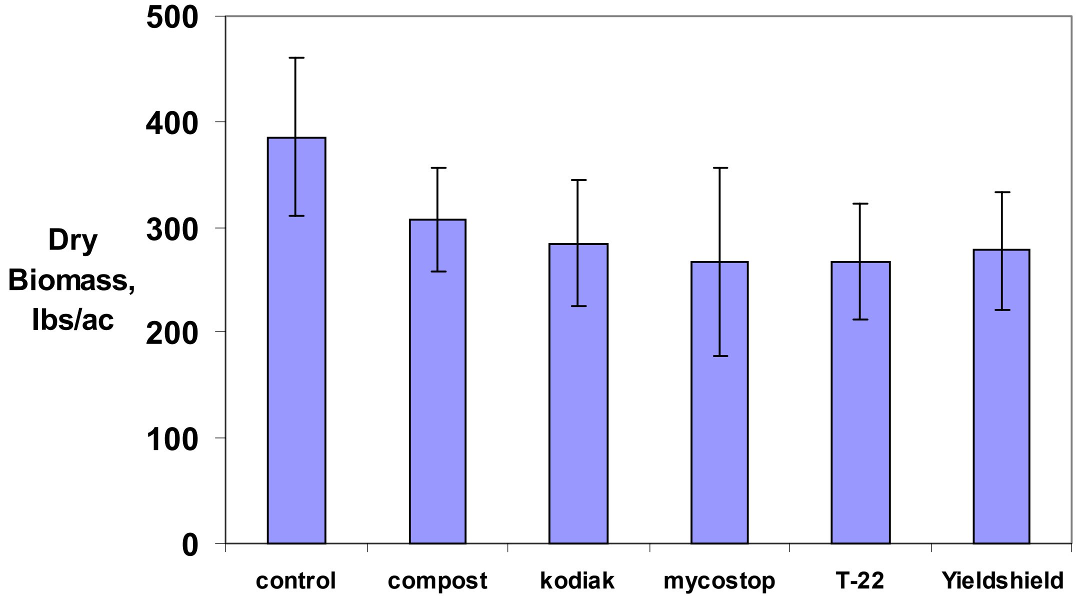


Figure 4. Stand at harvest for five experimental seed treatments and control. Error bars are one standard error of the mean. There were no significant differences between treatments.

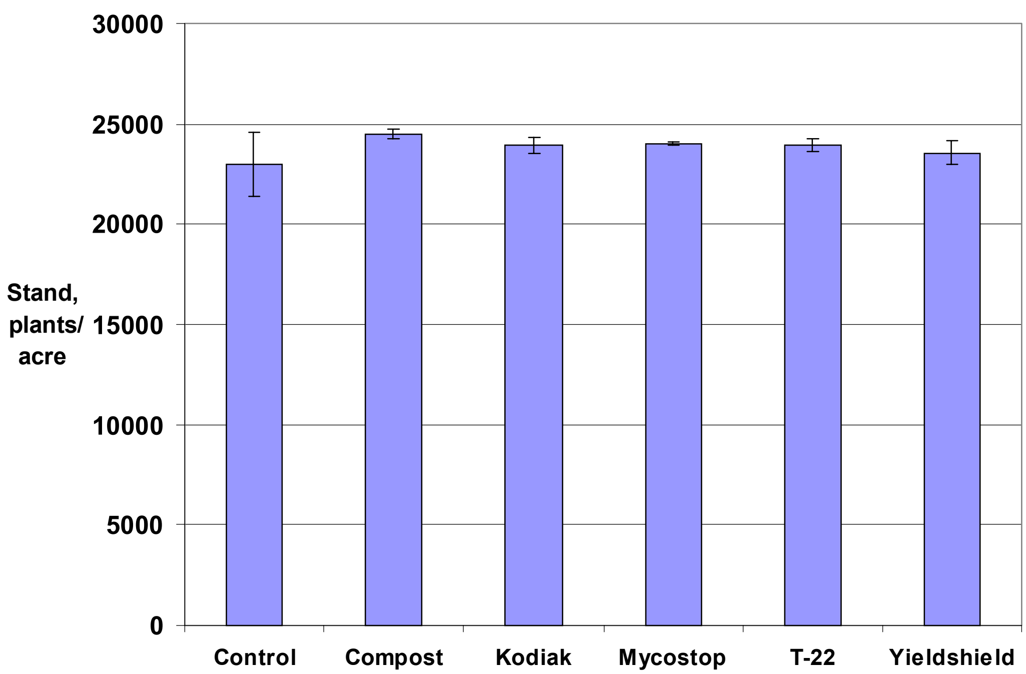


Figure 5. Corn yield for five experimental seed treatments and control. One bushel/acre = 56 lbs/acre. Error bars are one standard error of the mean. There were no significant differences between treatments. All corn dry weights were adjusted to 15.5% standard moisture.

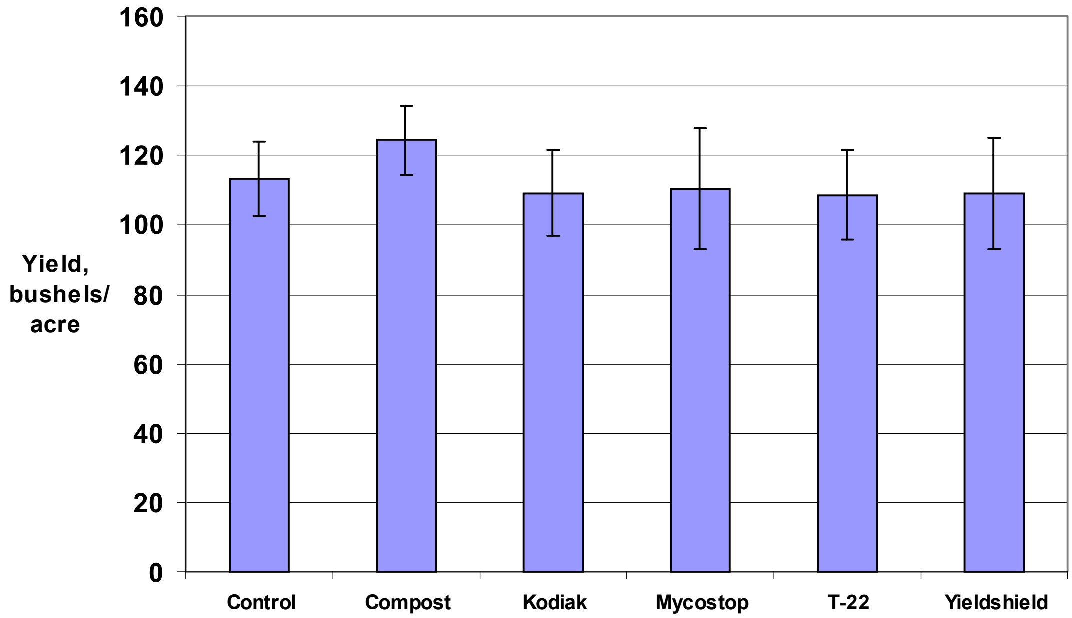


Figure 6. Average daily air temperature for the 2004 growing season, averaged over the four sites. Error bars across the four sites indicate low variability among sites. Blue curve is the 20-year regional average daily temperature through the summer. 2004 was largely an average year with a warm period in late August and early September.

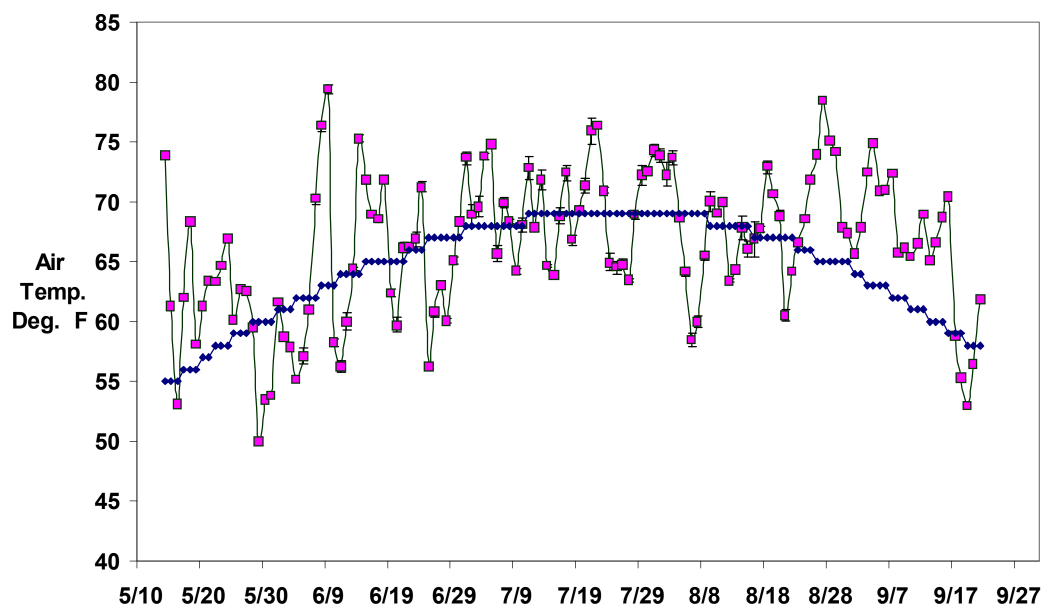


Figure 7. Soil temperatures at 2-inch depth averaged over four sites. Error bars (one std. error) across the four sites are shown for the daily average soil temperature, indicating the low variability among sites. Period shown is from planting of the first trial to tassel initiation at most sites. Daily variation between minimum and maximum readings is damped as the season progresses and soil is covered more and more by the corn canopy.

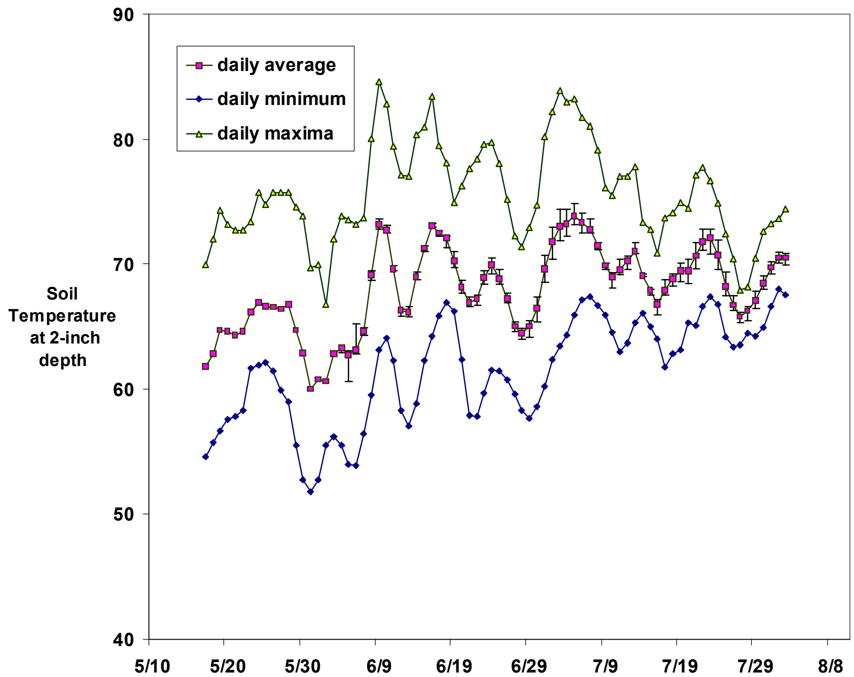


Figure 8. Average air temperatures before and during the planting window for field corn in three previous years in the Finger Lakes region. Graph shows that soil temperatures were likely to have been warmer in 2004 than either of the two previous years, leading to better conditions for corn germination and rapid early growth. Three-day running average of temperature is plotted to make trends easier to see.

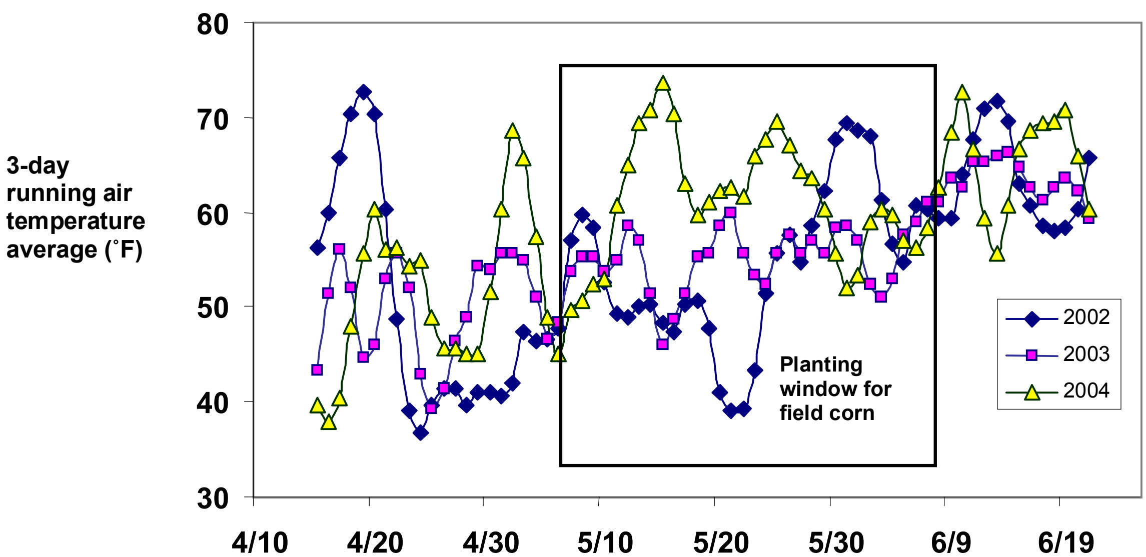
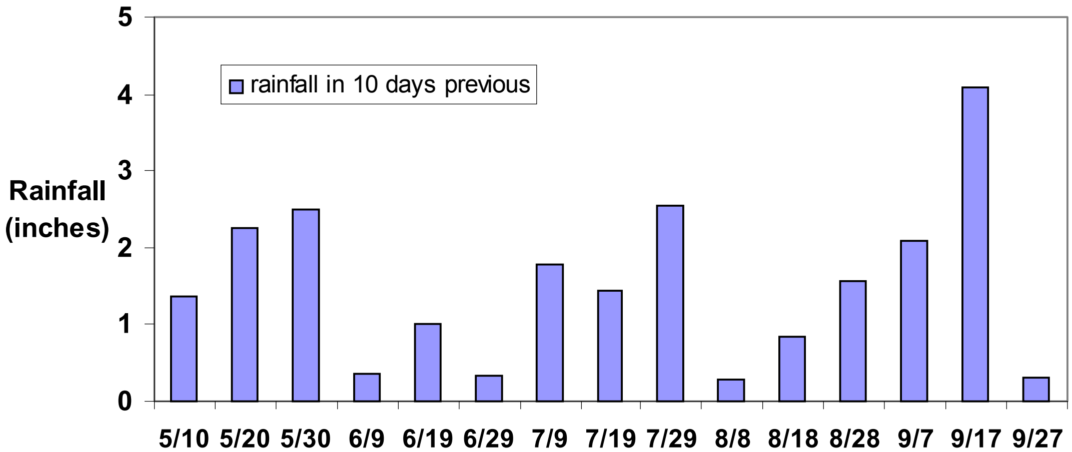


Figure 9. Rainfall for ten-day intervals at one of the farm sites. The rainfall pattern at the other site was similar. The majority of the season was wet with a dry spell in June.



6. Outreach:

We plan to share these preliminary results in the following ways:

- Presentation at a New York Certified Organic (NYCO) meeting, February 2004. NYCO is the main organic field crop growers association in the Finger Lakes.
- Writing a short report for the NYCO newsletter and for other State and regional publications.
- Referencing this report as a web resource. If OFRF is to post this report we will merely link to the OFRF website.

7. Conclusions and Recommendations:

- Further testing of microbial and compost inoculation under more stressful conditions for corn emergence is needed to demonstrate whether these practices are beneficial to yield and cost-effective.
- In years with good early season conditions for corn growth (adequate water and warm temperatures in late spring), it may be unlikely to see benefits from inoculation with these practices, either on corn emergence, early vigor, and growth later in the season leading to higher yields.
- Future work should strive to find farm sites that minimize variation within each farm site, possibly through smaller plots and by paying close attention to in-field variability in topography. However, it is also important to remember that the higher variability of actual farm fields is the reality with which farmers actually contend, so that full field, on-farm trials are likely more relevant to farmers' situation.
- For this type of trial where treatments are administered at planting, it would be better to have four or more collaborators so that the additional time contributed by any one farmer during the often hectic planting period is reduced.

8. Addenda: Photos from the trial.

Figure 10. Photo of large plastic pan used for applying Kodiak and Yieldshield seed treatments.

Figure 11. Compost extract after shaking in a 2-quart canning jar. Beaker at left is liquid that has been poured off for mixing with sieved compost and seed.

Figure 12. Corn crop at one of the fields in mid-August, at tassel stage.