ORGANIC FARMING RESEARCH FOUNDATION

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Project Title:

Organic strategies for growing corn under low-nitrogen stress

FINAL PROJECT REPORT

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INTRODUCTION

Corn is a plant with high nitrogen requirements. Levels of soil nitrogen that are lower than what the plants need at specific times during growth can limit yield and feed quality characteristics. We set out to investigate the utility of several methods of addressing possible low soil N on corn grown in the organic farming system used in central New York State. These methods were inoculation with symbiotic fungi (T-22, *Trichoderma harzianum*), choice of variety, and planting density. We wanted to know how these treatments would effect yield and the feed quality of the grain when nitrogen stress was present.

METHODS

This experiment was carried out in a split-split plot design to reduce potential interference among adjacent plots. Three fields were chosen and three replicates of the experiment were planted on each. The certified organic field on the Christensen Farm (Yates County, New York) was planted in corn in 2001 and soybeans in 2000. This was our high nitrogen stress field since this was a corn-on-corn situation. Organic farmers do not normally plant corn-on-corn but we hoped to cover the range in available N levels from very low to just below normal. On transitional land rented by the Martens (Yates County) our low nitrogen stress field was planted after a plow down of sweet clover. This field had been in wheat in 2001 and in soybeans in 2000. Drought in 2001 severely limited the growth of the clover and lower than normal N levels were anticipated. The third field was located on Cornell University's Musgrave Farm and was our early season nitrogen stress field. This field had been in alfalfa and grass for the last three years and was managed organically this year for purposes of this experiment. We expected adequate N levels at this field though perhaps some N limitation early in the season. All three fields were on Honeoye Silt Loam and were plowed in May and disked twice before planting.

The main plots were treated or untreated with T-22 fungal inoculant. Main plots were laid out in a randomized complete block design with three replicates in each field. Gary Harmon at the Geneva Station coated the inoculated seeds for us prior to planting to reduce any chances of cross contamination of treated and untreated seed. A starch coating was used to remain in compliance with organic standards for seed treatment.

The main plots were split into eight subplots so that the responses of eight corn varieties could be studied. The four hybrid varieties were Pioneer Brand 35P12, Pioneer Brand 36B08, Master's Choice Brand MC530, and Master's Choice Brand MC540. Seeds of these varieties were provided by the seed companies. The open-pollinated (OP) varieties included "Nokomis Gold" from Don Adams, "Wapsie Valley" from Victor Kucyk, Golden Glow from the lead author, and "Iroquois White" from Jane Mount Pleasant.

The subplots were further split into three so that three planting densities could be assessed. These were 16,000 plants/acre that is recommended for most OP corn varieties and some Master's Choice Brand hybrids, 28,000 plants/acre that is recommended for most hybrids, and the intermediate 22,000 plants/acre. Each two-row sub-subplot was about 1/500th acre and four were planted in each variety subplot. The outermost rows were used as borders between varieties and the remaining six rows were randomly assigned as pairs to one of the three plant densities. Border rows were also thinned to the density of the adjacent, same variety rows.

The fields in Christensen and Martens fields were planted on 28 May 2002 and the Musgrave field was planted on 3 June. This was about two weeks later than normal due to heavy rains at that time. A two-row plot planter was used and each sub-subplot was planted at the high planting density in rows 30" apart. Usually four or more border rows were planted around each experimental field. On the north side of the Christensen field only one row was used so the experiment could fit into this very long, narrow field. This arrangement also allowed a five-row border on the south side of the field that was adjacent to a manured, corn field. Buffer areas at the ends of the experimental plantings were 20' or more in length and were planted to extra seed of several of the varieties used in the experiment.

Starter fertilizer was used at the Christensen and Martens fields. Fertrell 2-4-2 was planted with the seed at the rate of @ 8 lb N / acre, though the planter frequently became plugged and fertilization was uneven. A custom organic starter fertilizer (2-4-4) was planted with the seed in the Martens field (@ 4 lb N / acre) and no problems were experienced. No starter was used at the Musgrave field. An additional sidedress application was used at the Christensen field to bring the nitrogen level up to what was perceived as a more reasonable level. Fertrell 4-2-4 was applied with a lawn spreader at the rate of @ 12 lb N / acre on 13 June. It was incorporated with the next cultivation.

Soil samples were taken at planting and in mid-July to assess the levels of available nutrients. Eighteen samples were taken with a spade in a regular pattern across the entire experimental area. These were mixed together in a bucket to form a composite from which a subsample was taken. This subsample was provided to the Cornell Soil Nutrient Laboratory for standard analyses of major and minor minerals, organic matter, and pH.

Weeds were controlled with 1) a second disking immediately before planting, 2) tine weeding, and 3) cultivation with mounted cultivators. The Martens field was tine weeded once about a week after planting while the other fields were tine weeded twice, once before emergence and again after the plants reached approximately the 3-5 leaf stage. The Christensen and Martens fields were cultivated once only but the Musgrave field was cultivated twice. Initial cultivation occurred on the 25th and 26th of June. On the 25th the Christensen and Martens fields were cultivated with a front mounted shovel cultivator for close cultivation to the rows. On the 26th all three fields were cultivated with a rear mounted Danish tine cultivator for between row weed control. Ten days later the Musgrave field received an additional pass with the Danish tine cultivator because the corn there was still short enough to do so. Weed control was excellent at the Christensen and Musgrave farms but not to acceptable levels at the Martens field. This was apparently due to only one tine weeding and a late first cultivation.

The Martens and Musgrave fields were thinned using asparagus knives to appropriate plant densities in late June and early July. The Christensen field was not thinned because with the uneven starter fertilizer application the variety subplots could not be split for the density treatments. Instead rows that appeared to have been appropriately fertilized (given early growth and color) were recorded for later harvest as high-density plots.

In mid-October observations of lodging and plant condition were made at all three fields. The Martens and Christensen fields were harvested on 17 and 18 October and the Musgrave field was harvested on 25 and 26 October. Because of a wider than expected range in maturity, the plots were hand harvested. This allowed for the harvest of very dry ears and still wet, heavy ears at the same time. To speed up hand harvest only one row of the sub-subplots was harvested in most cases (one row, about 1/1000th acre) though to obtain a 1/2-1 pound sample of grain full plots were harvested in some cases. The harvested ears were weighed, subsampled, reweighed, dried for two days at 40 degrees C, reweighed, shelled, and then the dried grain was weighed again. Samples of the dry grain were sent to the Dairy One Laboratory in Ithaca, NY for near infrared (NIR) spectral analysis of nutrient density. Standard methods were used throughout.

After the data were compiled they were analyzed for differences among means using ANOVA in the SAS program. To properly predict F values in a split plot and a split-split plot special SAS code must be entered to identify the proper error terms for each treatment. The high-density data were analyzed across all three sites in order to best examine differences among fields and between untreated and Trichoderma inoculated seeds. This was a split plot design. Density could only be examined using the two sites where all three densities were used; for that analysis a split-split plot design was employed. Varietal differences were considered in both analyses.

RESULTS

Growing Conditions

The growing season of 2002 began very wet and cool but by June had become slightly warmer than normal and very dry. All the corn in our experiment underwent a significant drought stress by the time of cultivation and this lasted until well into grain filling. This provided us with very low yields relative to expectations and fairly scattered yield estimates. Coefficients of variation for yield data were very high, 30.63 for the split plot analysis and 26.09 for the split-split plot analysis. This suggests the need for more data or a better experimental design to better test hypotheses. One very dry season is not enough to make broad conclusions.

Soil Fertility

The three fields we used had reasonable levels of organic matter, all around 3%, and medium levels of phosphorus (Table 1). The Christensen field and the Musgrave field both had high pH levels and calcium contents as well as medium levels of potassium. The Martens field had slightly low pH, about half of the calcium content, and high potassium levels.

We set out to investigate low nitrogen stress, but really did not find any (Table 1). Cornell University recommends to sidedress if nitrate levels fall below 40 pounds per acre. While all three of our fields were below this level early in the season, by midseason the nitrate levels well exceeded this. Plowing down alfalfa on Honeoye soils appears to provide more than enough nitrogen for a season of growing corn. Better than expected spring growth of the clover plowdown on the Martens field also provided more than enough nitrogen. What was most surprising was that even corn on corn with minimal starter and sidedress fertilizer had adequate levels of nitrogen. However there was clearly some early season nitrogen stress in the Christensen field as properly fertilized rows were greener and bigger than rows that were accidentally skipped because of plugging in the planter. Also, the protein content of the corn in the Christensen field was lower, suggesting some N limitation. Still, the Honeoye soil provided enough cushion even under these conditions so that no nitrogen stress could be found later on in plant appearance or yield. All the fields suffered from severe drought stress and the Martens field had the added stress of severe weed pressure.

Split plot analysis

Because of the unevenness of the initial fertilization at the Christensen field, the variety subplots there were not split into density subsubplots. Only high-density plots were assigned and harvested in that field so that the effects of T-22 inoculation and variety could be assessed across all three fields at high density. This would be the most stressful condition and of greatest interest in determining the utility of this inoculant. The roughly 10% increase in yield observed with inoculation was not statistically significant, probably due to the high level of noise in the data (coefficient of variation = 30.63) and the fact that inoculation was only on main plots. Inoculation also had no significant effect on % fat, % starch or % ash, but the small difference between inoculated and uninoculated seed for % crude protein was statistically significant ($F=6.2$, $p=0.0376$). In this case inoculation slightly reduced crude protein content (Table 2). There were no significant interactions of inoculation with the other factors.

Average yields across the three fields were quite low and significantly different ($F=8.07$, $p=0.012$). The Christensen Farm and the Musgrave farm fields had average yields of 71.7 and 73.0 bu/A respectively. The Martens field was significantly lower than these at 56.1 bu/A. For % crude protein, % fat, and % ash, differences among the fields were significant in all cases, with no differences between the Martens field and the Musgrave farm, but with lower values at the Christensen farm. The single biggest difference was in crude protein, which averaged 10.2% and 10.5% at the Martens and Musgrave locations but only 9.4% for the Christensen farm. This trend does not follow the yield differences but does follow nitrate availability. With additional sites, a regression could be carried out to clarify these relationships. Differences for the other parameters were small enough to question the importance of statistical significance.

The effect of variety was highly significant for most other parameters. Hybrid varieties tended to yield more than the open-pollinated varieties, though the Pioneer Brand hybrids clearly yielded the most of all (Table 3). Nokomis Gold, an OP variety from Wisconsin, had yields that were essentially the same as the Master's Choice Brand Hybrids in this evaluation. Variety also had a strong effect on major feed quality parameters ($p<0.0001$). OP varieties tended to have significantly higher protein, higher fat, lower starch (not shown), and higher mineral ash contents (Table 3). Differences between varieties within a brand of hybrids were small across all of the parameters examined. None of the interactions among the treatments achieved statistical significance.

Table 1. Soil characteristics of three organically managed fields in central New York. Mineral parameters are reported as lb/acre.

Field	Time	% Organic Matter	pH	Nitrate	Phosphorus	Potassium	Calcium
Christensen	Planting	3.2	7.6	12	9	85	5120
	mid July	2.7	7.6	47	7	80	4550
Martens	Planting	3.0	6.3	9	9	225	2850
	mid July	2.5	6.1	60	9	185	2750
Musgrave	Planting + 1 week	3.0	8.0	39	7	80	7710
	mid July	3.0	8.0	79	10	85	7750

Table 2. Means for T-22 treatments across fields and varieties at the high density planting. Means with different superscript letters are significantly different at the <0.05 level.

Inoculation	Yield (bu/acre)	% Crude Protein	% Fat	% Starch	% Ash
No	63.1^{a}	10.2^{b}	4.6^{a}	71.9^{a}	1.6^{a}
Yes	70.8^{a}	9.9^{a}	4.6^{a}	72.1^{a}	1.6^{a}

Table 3. Means of corn varieties across T-22 inoculation and field in the split plot analysis across three organically managed fields.

Variety	Yield (bu/acre)	% Crude Protein	% Fat	% Ash
OP				
Golden Glow	35.7^{d}	11.2^{a}	$4.9^{b\,c}$	1.6^{c}
Iroquois White	22.4^{d}	11.4^{a}	5.8^{a}	2.1^{a}
Nokomis Gold	69.8^{b}	10.5^{b}	5.0^{b}	1.6^{c}
Wapsie Valley	53.2^{c}	10.6^{b}	4.7^{c}	1.7^{b}
Hybrid				
Pioneer Brand 35P12	102.3^{a}	9.5^{c}	3.9^{e}	1.5^{d}
Pioneer Brand 36B08	107.1^{a}	$9.2^{c\,d}$	4.0^{e}	$1.5^{d\,e}$
Master’s Choice Brand MC530	74.6^{b}	8.9^{d}	4.5^{d}	1.4^{e}
Master’s Choice Brand MC540	70.5^{b}	$9.1^{c\,d}$	3.9^{e}	1.4^{e}

Table 4. Means of density treatments across field, inoculation and variety treatments in two organically managed fields. Means with different superscript letters are significantly different ($p<0.05$).

Density	Yield (bu/acre)	% Crude Protein	% Fat	% Ash
Low (@ 16k/acre)	71.0 [a]	10.5 [a]	4.7 [a]	1.7 [a]
Medium (@ 22k/acre)	69.9 [a]	10.4 [a]	4.7 [a]	1.7 [a]
High (@ 28k/acre)	64.6 [b]	10.1 [a]	4.6 [a]	1.6 [a]

Split-split plot analysis

Variety still had very large effects on yield and feed quality parameters, giving results similar to those from the larger analysis (results not shown). However, density showed a significant effect on yield only, which tended to decrease as plant density went up (Table 4). No significant interactions among treatments were observed in this analysis either. That said, there were some interesting trends within each variety across density treatments that would be interesting to more fully investigate. For instance, both Golden Glow and Iroquois White yielded best at the lowest density (52.4 and 28.5 bu/A). Golden Glow yields fell continuously with increasing density while Iroquois White had its poorest yields at both medium and high density (@22 bu/A). Nokomis Gold had yields that held pretty evenly across density (68.5-65.0 bu/A) and Wapsie Valley gave its best yield at the medium density but fell right off at high density (63.1 and 51.7 bu/A). The hybrids appeared to differ in their responses to density also. Pioneer Brand 35P12 yielded best at medium density and the same at high or low densities (114.6 vs 95.3 bu/A for both low and high) whereas Pioneer Brand 36B08 yielded about the same across densities (105.5, 106.7 and 102.9 bu/A). Master's Choice Brand hybrid MC530 yielded best at low density (84.6 vs 72.0 or less bu/A) and Master's Choice Brand hybrid MC540 yielded about the same across densities (74.5, 73.3 and 69.4 bu/A).

DISCUSSION

We probably did not actually assess the ways in which management might affect nitrogen stress in organically grown corn so much as instead assessing how management would affect drought stress response. It was that sort of year. The drought was an unfortunate surprise, but field histories in two of the fields strongly suggested that nitrogen stress would be present. Perhaps the organic matter levels and vigor of soil biota was such that in these soils variations in recent nitrogen additions will be buffered.

From this single season of evaluation, it appears that T-22 inoculation does not clearly increase yield in organically grown corn during a significant drought event. These data are however noisy and limited, so continued research is called for to further assess the use of *Trichoderma* in organically grown corn. With more replications perhaps the trend of increasing yield via T-22 inoculation will become clearer. Similarly, with more replication we may have been able to assess how T-22 inoculation affects individual varieties, conclusions we are not comfortable making from these limited data.

Reducing the planting density appeared to offer some advantage in yield during stress. However, the greatest differences in yield and feed quality parameters were among varieties. Variety specific management decisions may be required to achieve specific yield or nutrient density goals in organically grown corn under these conditions. Clearly the highest yields came with the two best performing hybrids, one of which did well under any planting density (Pioneer Brand 36B08). If one knew that a drought was coming perhaps backing off on planting density would be worthwhile. It seems like it might be for Pioneer Brand 35P12, especially as it had the highest yield of all at medium density. For those growing OP corn, lower density appeared to be a good recommendation generally. However, since droughts are not always easily predicted, it would be good to know how a farmer's variety of choice performed across a range of moisture conditions. Then a planting density that was likely to best balance the chance to make use of better rainfall conditions and to best reduce losses during a drought could be implemented.

These data provide a possible reason for the frequent reports of better animal performance when animals are fed OP corn. Given our limited data set, it appears that when fed on a pound for pound basis, some OP corn is higher in nutrients and energy than the hybrids we examined and would provide a more concentrated feed source. However, the yields would have been much lower than with the better performing hybrids and these data are limited. Our results have been provided to a cooperating agricultural economist (Mike Duffy, Iowa State) who will be helping to determine the economic impact of higher protein in corn grain and the economic viability of OP corn varieties. The ability of higher feed quality to compensate for the value lost due to low yield will be addressed, as will seed price differentials between hybrid and OP varieties. Those analyses are ongoing.