ORGANIC NUTRIENT AND WEED MANAGEMENT WITH SWEET CORN ON SANDY SOIL

J.R. West, M.D. Ruark, A.J. Bussan, E.M. Silva, and J.B. Colquhoun
University of Wisconsin-Madison, Madison, Wisconsin

Abstract

The Central Sands region of Wisconsin is host to commercial-scale vegetable production, requiring intense nitrogen (N) fertilization. The limited nutrient holding capacity and minimal organic matter content of sandy soils in the Central Sands contributes to water nitrate contamination. Organic management may help to alleviate problems associated with leaching by increasing organic matter and nutrient retention in this soil. For organic agriculture to be feasible in this region, organic N inputs need to be demonstrated as suitable alternatives to inorganic N sources. Sweet corn was grown under organic management at the Hancock Agricultural Research Station in the 2011 and 2012 growing seasons with the objective to test common organic N inputs under these growing conditions and to test weed management interaction. Three early season manure systems were established: spring-seeded field pea as green manure (GrM), composted poultry manure (CPM), and no manure (NM, control). Weeds were managed moderately and intensely to create weed pressure differences, and plots were fertilized with feather meal at rates of 0, 100, 150, and 200 lb ac^{-1} of N (0N, 100N, 150N, 200N) and 250 lb ac^{-1} of N (250N, 2012 only). Soil samples (0-12 in) were collected at 5 time points throughout the growing season in 2012 to evaluate differences in plant-available soil nitrate-N concentrations (SNN) among early season manure systems and selected N rates (0N, 150N, 250N). Both years of data collection demonstrated positive yield response to nitrogen fertilization with 11-0-0 feather meal. Mean yields were highest in 200N treatment in both study years, averaged across manure system and weed treatments. In 2011, a mean yield of 8.3 ton ac^{-1} in the 200N treatment averaged higher than those of the 150N and 100N treatments. In 2012, there were no statistically significant differences in yields among treatments receiving N fertilizer. In 2012, GrM and CPM treatments had greater yields than NM treatment, and intense weed management yielded higher than moderate weed management. In 2012, SNN was generally higher in 250N treatment than 150N treatment, and higher in both 250N and 150N treatments as compared to 0N treatment. This trend is statistically significant at sampling time points (TP) following fertilizer split applications. Averaged across N rates and manure systems, SNN was highest at V4 (TP2) and lowest at harvest (TP5), indicating an increase of plant-available N between the time of emergence (TP1) and TP2, and utilization of SNN by TP5. SNN in GrM treatment was statistically significantly higher at TP1 than that of NM treatment (before N rate differentiation). This increase is likely due to the field pea amendment, and may contribute to the statistically significantly higher yield in GrM treatment as compared to NM treatment. Based on the yield results of this study, early season CPM and GrM application as a source of N did not appear to be well utilized by the sweet corn crop. The timing of nutrient mineralization and plant uptake is highly variable, causing asynchrony between N release from organic sources and sweet corn N uptake exacerbated by poor nutrient retention in sandy soil. The use of organic feather meal during the growing season was found to result in comparable yields to those of synthetic nitrogen fertilization in concurrent studies, suggesting feather meal has N release patterns similar to

inorganic forms of N.

Introduction

The Central Sands region of Wisconsin is host to intensive conventional processing vegetable production, causing significant water quality problems due to pesticide and synthetic fertilizer leaching and runoff. Organic management is appealing to many growers as a means to avoid the use of synthetic fertilizers and pesticides. Further, the organic industry in the United States grew 9.5% in 2011 to reach $31.5 billion in sales, of which over 90% is organic food and beverage (Organic Trade Association, 2012 Press Release) and organically managed land area worldwide grows about 8.9% per year (Paull, 2011). Wisconsin and other Midwestern states have demonstrated a strong presence in the organic market and would likely benefit financially and environmentally from increased adoption of organic management practices.

Organic agricultural systems integrate ecologically-based fertility management practices, such as manure cycling and cover cropping, which maintain or increase soil organic matter and soil organic carbon thus extending long-term soil fertility (Diacono and Montemurro, 2010). For this reason, organic practices may offer a solution to dependence on synthetic petroleum-based fertilizers and resulting water nitrate pollution and soil degradation. However, organic sources of nutrients are not readily plant-available and thus asynchrony of N mineralization and plant uptake is a challenge that may result in leaching, insufficient fertility, and inaccurate nutrient crediting (Gaskell and Smith, 2007; Diacono and Montemurro, 2010). Some studies, however, have shown that leguminous crops grown as green manure in a temperate climate can satisfy sweet corn N requirements (Griffin et al., 2000; Cline and Silvernail, 2002). The objectives of this study were to evaluate early season N management, intensity of weed management, and rate of N fertilizer on sweet corn yields and in-season soil nitrate concentrations.

Materials and Methods

Field studies were conducted in the 2011 and 2012 sweet corn growing seasons at the University of Wisconsin Hancock Agricultural Research Station on overhead irrigated Plainfield loamy sand soil (mixed, mesic Typic Udipsamment). The study was a randomized complete block strip-split plot design with 4 replications. The whole plot factor was pre-planting manure system, which included a plant-based green manure (GrM), an animal-based composted poultry manure (CPM), and a control (no manure amendment, NM). In the GrM system, field pea (*Pisum sativum*) was planted in April of the study year at a rate of approximately 100,000 stems ac^{-1} and the stand was incorporated 9 weeks later, prior to planting sweet corn seed. In the CPM system, pelleted composted poultry manure (advertised Nitrogen: Potassium: Phosphorus (N-P-K): 4-5-3 from Cashton Farm Supply, Ltd., Cashton, WI), was broadcast applied at a rate of 54 lb ac^{-1} of N, and incorporated by moldboard plow two weeks prior to planting (at the time of field pea incorporation for GrM treatments). The strip-plot factor was intensity of weed management. Weed were managed intensely (minimum weed pressure) and moderately (moderate weed pressure) through use of mechanical cultivation with a rotary hoe once within one week of planting (all treatments) and with weekly hand weeding starting four weeks from planting and ending at canopy closure, approximately seven weeks from planting (intensely managed treatments only). The strip-split plot factor was N fertilization rate. The nitrogen fertilizer source was Organic Materials Review Institute (OMRI)-approved feather meal (advertised N-P-K: 11-0-

0 from Renaissance Fertilizers, Rowley, MA) broadcast applied at rates of 0, 100, 150, and 200 lb ac^{-1} of N, and 250 lb ac^{-1} of N (2012 only) in two equal split sidedress applications at approximately the 4-leaf (V4) and 8-leaf (V8) growth stages. Treatments are detailed in Table 1.

Table 1. Organic nutrient and weed management treatments in sweet corn, 2011 and 2012.

Treatment abbreviation	Treatment description
NM	No manure system/Control
CPM	Composted Poultry Manure system
GrM	Field pea Green Manure system
MOD	Moderate weed management
INT	Intense weed management
0N	0 lb ac^{-1} of nitrogen (N)
100N	100 lb ac^{-1} of N, broadcast applied in 2 equal split applications at V4,V8
150N	150 lb ac^{-1} of N, broadcast applied in 2 equal split applications at V4,V8
200N	200 lb ac^{-1} of N, broadcast applied in 2 equal split applications at V4,V8
250N *(2012 only)*	250 lb ac^{-1} of N, broadcast applied in 2 equal split applications at V4,V8

As appropriate, treatment abbreviations may be combined. Example: NM-MOD-250 designates control manure system, moderate weed management, 250 lb ac^{-1} of N.

Individual plots measured 300 ft^2 (2011) or 200 ft^2 (2012) containing six or four rows, respectively, 15 ft long at 30 in spacing between rows. Addition of a 250N treatment in 2012 and field dimensions dictated the reduction in number of edge rows per plot in 2012; sampling rows were consistent between years. Untreated sweet corn seed (Hybrid yellow, Del Monte variety DMC 21-84) was planted to ~24,000 plants ac^{-1}. Starter fertilizer was applied at planting using OMRI-approved composted poultry manure crumbles (advertised N-P-K: 5-3-2, Midwestern Bio Ag, Blue Mounds, WI) at a rate of 20 lb ac^{-1} of N. In 2012, plots were thinned by hand following inadvertent overplanting.

Sweet corn yield was quantified by hand-harvesting ears from the two center rows of each plot (rows 3 and 4 in 2011, rows 2 and 3 in 2012) with full kernel development and minimal apparent pest damage. Field weights were recorded immediately and scaled up to ton ac^{-1}. Soil samples were collected from all treatments immediately after harvest (TP5) to measure plant-available nitrate-N remaining in soil in both study years. In addition to harvest soil sampling, in 2012 soil samples were collected from NM-INT, CPM-INT, and GrM-INT 0N, 150N and 250N treatments at emergence (TP1), V4 (TP2), V8 (TP3), and tassel (TP4) to quantify N dynamics over the growing season. Soil samples (0-12 in) were collected and combined from 4 random locations within each plot with a 0.7 in diameter core. Soil samples were oven dried, mechanically ground and passed through a 2 mm mesh screen. Approximately 1.500 g of soil from each sample was combined with 15 mL of 2M potassium chloride for soil nitrate extraction. Following mechanical oscillation, the solution was filtered and the soil extract was analyzed for nitrate using the Vanadium reduction of nitrate method as described in Doane and Horwáth (2003).

Results and Discussion

Yield

Mean yield by N rate (averaged across manure system and weed management treatments), as quantified by field weight of ears, ranged from 6.4 to 8.3 ton ac^{-1} (2011) and from 9.6 to 10.2 ton ac^{-1} (2012). In 2011, there was a statistically significant increase in yield as N rate increased, but in 2012 there was no statistically significant difference in mean yield in the non-zero N rate treatments as averaged across other study factors (Fig. 1). The lack of N-rate treatment effect in 2012 was likely due to the drought-induced dependence on irrigation water, which has high nitrate levels in this region, thus contributing large amounts of N to the crop and lowering optimum N rates. There were no statistically significant interaction effects in either study year.

In 2011, yield across manure system and weed treatments in the 200N treatment averaged 8.3 ton ac^{-1}, which was statistically significantly higher than those of the 150N or 100N treatments (7.1 and 6.4 ton ac^{-1}, respectively). Mean yield from the 150N treatment was higher than that of the 100N treatment, though not statistically significant. Averaged across N rate and manure system treatments, the INT weed treatment yielded 6.0 ton ac^{-1}, as compared to 5.7 ton ac^{-1} in the MOD weed treatment; this difference was not statistically significant. Averaged across N rate and weed management treatments, the CPM manure system treatment averaged highest yields with 6.1 ton ac^{-1}, followed by the control (5.8 ton ac^{-1}) and GrM (5.5 ton ac^{-1}), though none of these differences in mean yield were statistically significant.

In 2012, mean yield averaged across other study factors in both GrM and CPM systems (9.5 and 9.2 ton ac^{-1}, respectively) was higher than that of control (8.8 ton ac^{-1}), statistically significant in GrM. The INT weed treatment was statistically significantly higher in yield than that of the MOD weed treatment, with mean yields of 9.4 and 8.9 ton ac^{-1}, respectively, averaged across other treatment factors. Though there are some yield increases associated with CPM and GrM treatments, these increases do not reflect the full 54 lb ac^{-1} of N from CPM and estimated 30 lb ac^{-1} of N (2011) and 89 lb ac^{-1} of N (2012) from GrM incorporated into the soil prior to corn seed planting. This disparity highlights asynchrony between N release from these organic sources and sweet corn N uptake.

Soil Nitrate

By N rate averaged over manure systems and TPs, SNN was statistically significantly higher in 150N and 250N treatments than that of 0N treatment, and SNN in 250N treatment was statistically significantly higher than that of 150N treatment (Fig. 2). Averaged over manure system, SNN at TP3 (following 1st fertilizer split application) and TP4 (following 2nd fertilizer split application) was statistically significantly greater in 150N and 250N treatments than those of 0N treatment at respective TPs. At TP4, SNN in 250N treatment was also greater than that of 150N treatment. At TP5, SNN in the 250N treatment was greater than that of 150N and 0N treatments (Fig. 2). Averaged over time point, SNN was greater in 150N and 250N treatments compared to that of 0N treatment in each of the NM and CPM treatments. SNN averaged across TP was greater in GrM treatment than that of NM treatment at 250N.

Table 2. Soil sampling time points and summary of results by N rate, averaged over manure system, 2012.

Time point #	Date, description	Mean soil nitrate-N concentration (SNN, mg kg^{-1}) *(standard error)* 0N	150N	250N
TP1	22Jun, Corn emergence	2.9 *(0.35)*	3.4 *(0.44)*	4.0 *(0.50)*
TP2	3Jul, 4-leaf stage (V4)	4.0 *(0.43)*	4.7 *(0.41)*	4.5 *(0.44)*
TP3	18Jul, 8-leaf stage (V8)	2.0 *(0.23)*	4.0 *(0.41)*	4.2 *(0.48)*
TP4	1Aug, Tassel	1.1 *(0.27)*	3.0 *(0.32)*	5.3 *(0.71)*
TP5	5Sep, Harvest	1.1 *(0.34)*	1.5 *(0.22)*	3.2 *(0.36)*

Corn emerged ~7 days post-planting, 23 days after CPM and GrM incorporation. 11-0-0 feather meal was split-applied at V4 and V8, directly following TP2 and TP3 soil sampling.

By time point averaged over N rates and manure systems, SNN was statistically significantly higher at TP2 than at all other TPs, and SNN was statistically significantly lower at TP5 than at all other TPs. In 0N and 150N treatments, SNN was highest at TP2 (Fig. 2). This indicates an increase in plant-available N between the time of emergence and the first fertilizer application, and lines up with a critical biological need for N by the crop (Gaskell and Smith, 2007). In 0N treatment, SNN at TP4 and TP5 was at its lowest concentration, statistically significant compared to those of TP1 and TP2. In the 150N treatments, SNN at TP5 was statistically significantly lower than that of all other TPs, similar to dynamics in 0N treatment. SNN in the 250N treatment was highest at TP4 following the second fertilizer split application, a concentration that comes down somewhat by TP5 (statistically significant) but not completely to the TP5 SNN levels of 0N and 150N treatments (Fig. 2). There were no other statistically significant findings by TP in the 250N treatment, perhaps due to high initial concentration of SNN at TP1 in 250N plots prior to N rate differentiation (Fig. 2).

By manure system, SNN averaged across N rates and time points was statistically significantly higher in the CPM treatment as compared to that of the NM treatment. SNN in GrM treatment was statistically significantly higher at TP1 than that of NM treatment (before N rate differentiation) (Fig. 3). This increase is likely due to the field pea amendment, and may contribute to the statistically significantly higher yield in GrM treatment as compared to NM treatment (averaged across N rate and weed management treatments, discussed above). SNN at TP5, averaged across all N rate treatments, was statistically significantly lower than those of TP1 and TP2 in CPM and GrM treatments, also lower in NM treatment though not statistically significant (Fig. 3).

Conclusions

Based on the yield results of this study, early season GrM and CPM application as a source of N did not appear to be well utilized by the sweet corn crop. The timing of nutrient mineralization and plant uptake is highly variable, and asynchrony between N release from organic sources and sweet corn N uptake is exacerbated by poor nutrient retention in sandy soil. The use of organic feather meal during the growing season was found to result in comparable yields to those of synthetic nitrogen fertilization in concurrent studies, suggesting feather meal has N release patterns similar to inorganic forms of N.

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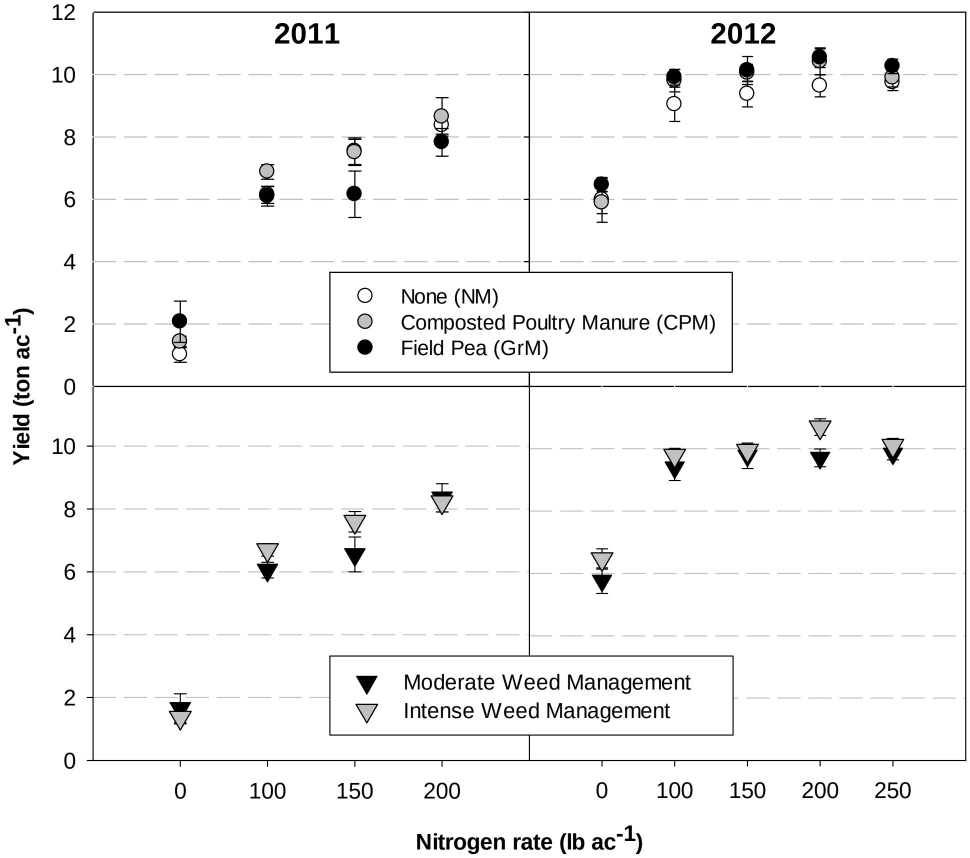

Figure 1. Mean fresh corn yield (ton ac^{-1}) vs. N rate (lb ac^{-1}) in 2011 and 2012, by manure system (top) and weed management (bottom). Error bars represent standard error.

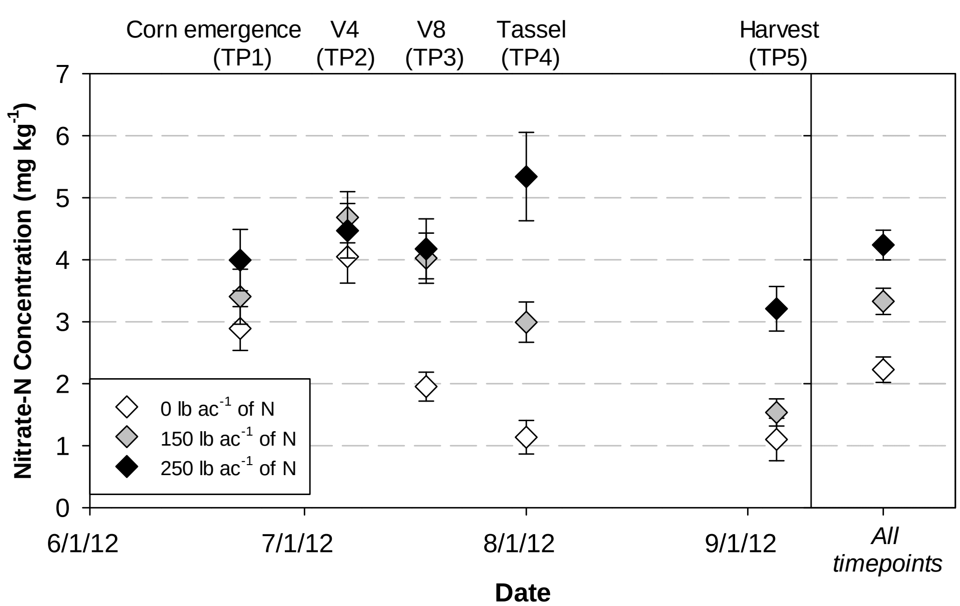

Figure 2. Nitrate-N concentration (mg kg^{-1}) in soil over time, by nitrogen rate averaged across manure system. Samples were taken at corn emergence (22 June, 23 days after CPM and GrM incorporation and 9 days post-planting), 4-leaf stage (V4, 3 July, just prior to first fertilizer split application), 8-leaf stage (V8, 18 July, just prior to second fertilizer split application, tassel (1 Aug.), and harvest (5 Sep.). Error bars represent standard error.

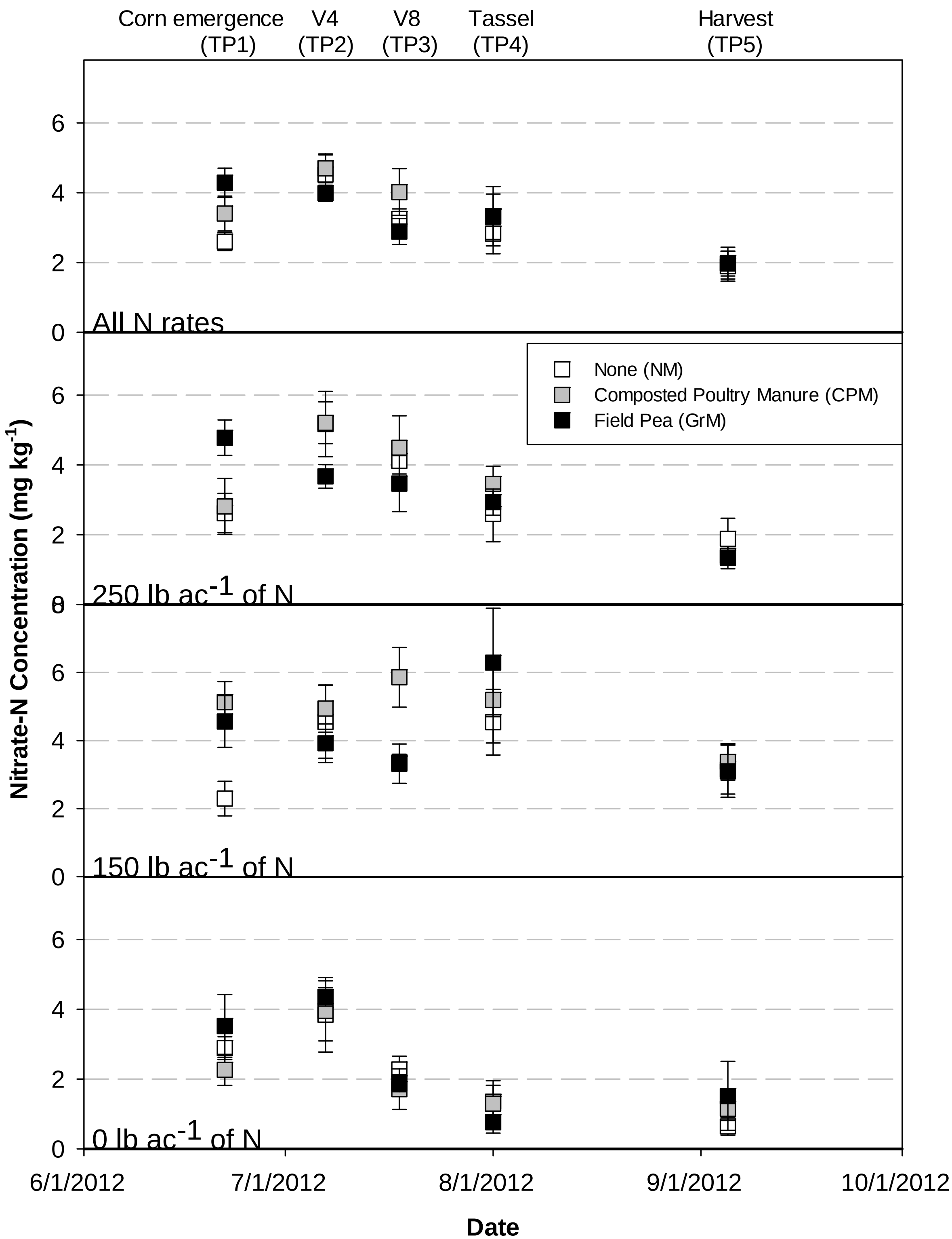

Figure 3. Nitrate-N concentration (mg kg^{-1}) in soil over time, by manure system at three nitrogen rates and averaged over N rate. Samples were taken at corn emergence (22 June, 23 days after CPM and GrM incorporation and 9 days post-planting), 4-leaf stage (V4, 3 July, just prior to first fertilizer split application), 8-leaf stage (V8, 18 July, just prior to second fertilizer split application, tassel (1 Aug.), and harvest (5 Sep.). Error bars represent standard error.

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Program Chair:

David Franzen
North Dakota State University
Fargo, ND 58108
(701) 231-8884
David.Franzen@ndsu.edu

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International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
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