CORN YIELD RESPONSE TO RESIDUAL FORAGE CROP ROTATION AND MANURE AMENDMENT EFFECT IN POTATO ROTATIONS

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Abstract

Accurate prediction of multiple-year N availability from organic sources is difficult and can complicate nitrogen management for producers using these sources. The objective of this study was to use corn yield and soil N monitoring to evaluate long-term nutrient availability from rotational systems on an irrigated Alfisol in central Michigan. Over a 5-year period, multiple crop sequences were grown with either annual liquid dairy manure at 12,260 L ha^{-1} or conventional mineral fertilizer application from 2002 to 2004. Crop rotations during this period included potatoes preceded by one-year crops of corn, alfalfa, and sudex and two-year stands of alfalfa and festulolium. Corn was planted across all treatments in 2005 and 2006 with no applied fertilizer or manure and grain yields were measured for response to residual N. Results in 2005 indicated significant crop rotation and manure amendment effects on corn grain yield. Cropping systems including forage rotation in 2004 and manure amendments increased grain yields by at least 4.5 Mg ha^{-1} compared with potato-corn rotations with no manure amendments. Normalized difference vegetative index (NDVI) measurements in mid-July of 2006 were greater for treatments with forage rotation in 2004 or manure amendment history. Soil samples collected in late June 2006 will be analyzed for soil NO_3-N to evaluate effects of previous forage rotation and manure amendment.

Introduction

The agronomic value of residual organic N from previous crop residues and manure applications can be difficult to estimate. Complexity in predicting N availability from these sources to subsequent crops complicates the determination of appropriate application rates of mineral fertilizers to match crop demand. Current management approaches used to estimate organic N availability have been called into question citing, among other concerns, wide variability in year to year mineralization.

Organic N from crop residues, amended animal manures, and residual fertilizer can contribute to the overall soil N pool, significantly impacting the N availability for future crops (Alexander, 1977; Campbell et al., 1991). Paul and Beauchamp (1993) found repeated annual manure applications increased soil N priming and mineralization. Long-term annual beef manure application to irrigated corn in Wisconsin increased corn uptake of N from manure treatments in the first three years following application, relative to mineral fertilizer treatments, reflecting an increased labile pool of organic N (Ferguson et al., 2005). Increased N mineralization has been observed in potato production systems following manure amendments compared with mineral fertilizer treatments (Webb et al., 1997). Long-term experiments including alfalfa in a corn-cereal rotation had greater available N and potential net N mineralization compared with corn-cereal rotations without alfalfa (Russell et al., 2006). Gil and Fick (2001) measured increased soil N mineralization in crop rotations including legumes such as alfalfa compared to rotations without legumes. Carpenter-Boggs et al., (2002) found the inclusion of alfalfa in a corn rotation increased soil N mineralization from 133 kg N ha^{-1} in continuous corn rotations to 189 kg N ha^{-1}.

Positive yield responses to manure amendment compared with mineral fertilizer additions have also been observed. Residual effects of manure amendment were shown to increase corn yields for at least one year following manure applications (Eghball et al., 2004). Poultry manure application to first-year potatoes increased second-year cereal grain yields compared with potato rotations amended with mineral fertilizers alone (Nicholson et al., 2003). Kaffka and Kanneganti (1996) were able to attribute increased orchardgrass forage yields to residual dairy manure N the second year following application. Orchardgrass yield responses to annual dairy manure were found to exceed 60% those of fertilizer treatments three years past the last manure application (Cherney et al., 2002).

While the effects of organic N sources have been widely noted, the prediction of N availability for crop utilization continues to present challenges. The pre-sidedress nitrate test (PSNT) described by Magdoff et al. (1984) for corn has proven to be the most reliable in-season measurement of available N for crop uptake. However, decreased test accuracy for corn recommendations following alfalfa or manure applications has been noted (Andraski and Bundy, 2002). Despite these challenges, positive correlations have been shown between PSNT NO_3-N concentrations and corn grain yields following forage rotation (Rasiah, 1999) and manure amendment (Zebarth et al., 2001). Russell et al. (2006) found correlations of 0.82 between available soil N and corn grain yields.

Remote optical sensing has recently received renewed interest with the emergence of increasingly accurate and affordable technological capabilities. Optical sensing instrumentation can be used to calculate vegetative indices, which reflect a plant's photosynthetic potential and living cell mass. This type of instrumentation has been shown to be a reliable estimator of N use efficiency, growing season N requirement, and yield potential for crops including corn, sorghum, and wheat in the US Central Great Plains and some areas of the Midwest (Martin et al., 2005, Lukina et al., 2001, Raun et al., 2001). Mid-season NDVI measurements in grain sorghum found correlations exceeding r^2=0.60 with yield over three separate sampling dates (Yang et al., 2000). Satellite and aerial sensing has shown positive correlations with Minolta SPAD (Konica Minolta, Hong Kong) chlorophyll meters in corn, demonstrating potential usefulness of this technology for detecting N deficiencies (Han et al., 2002). Initial work using NDVI as a predictor of yield has been primarily focuses on wheat production. However, NDVI has been used on a small scale to accurately predict corn yield over a four-plant area at the V8 growth stage (Martin et al., 2005).

The objective of this study was to examine the residual effects of forage crop rotation and manure amendment in potato production. Difficulties in predicting N mineralization and seasonal availability of organic N sources continues to prevent wide-spread adoption of more integrated dairy and potato cropping systems. Through the measurement of corn grain yields, PSNT soil sampling, and mid-season NDVI, treatment effects from three years of forage crop rotation and dairy manure application are examined in order to better understand organic N dynamics.

Background

A study was initiated in Michigan in 2002 to examine the effects of dairy production integration with potato cropping systems. The experiment was located at the Michigan State University Montcalm Potato Research Farm (43°21' N, 85°10' W) on a McBride sandy loam (coarse-loamy, mixed, frigid Alfic Fragiothods). Forage crop rotations of one-year stands of alfalfa and sorghum-sudeangrass (sudex) and two-year stands of alfalfa and festulolium in rotation with potatoes were compared to regionally-common corn-potato rotations (Table 1). Alfalfa and festulolium rotations were managed as production forage systems, with all biomass removed from the plot with each cutting. Sudex was managed as a green manure crop, with all biomass chopped and returned to the soil surface. Irrigation was applied as needed throughout the season via an overhead traveling system.

Each rotation was amended with liquid dairy manure at 12,260 L ha^{-1} in combination with mineral fertilizer, or mineral fertilizer alone. Manure samples were submitted to A&L Great Lakes Laboratories Inc. (Fort Wayne, IN) for analysis. First year available N was calculated from combined total ammonium and 30% first-year available organic N (Livestock Waste Facilities Handbook, MWPS-18). Manure treatments were supplemented with variable mineral fertilizer rates to balance nutrient applications between manure and mineral fertilizer treatments. Manure and mineral fertilizer treatments received equal amounts of calculated first-year available N from 2002 to 2004. An extensive description of research methods prior to 2005 is reported by Boring, 2005.

Corn grain yield measured in 2003 and 2004 following potatoes in rotation were not different regardless of fertilizer treatment (data not shown). This lack of response was similar to that observed in long-term Michigan State University trials investigating manure and fertilizer impacts on corn grain yields under irrigated conditions (Vitosh et al., 1994). However, these results indicate in-season responses, not longer-term, multiple-year effects that might be expected to occur as a result of manure applications.

In 2005 and 2006, corn was planted across all treatments to measure residual crop rotation and manure amendment effects though grain yield. No fertilizer or manure was applied to the plots in 2005 or 2006.

Table 1. Crop rotation for 2002-2006.

	2002	2003	2004	2005	2006
Corn rotation (PCP)†	Potato	Corn	Potato	Corn	Corn
Corn rotation (CPC)	Corn	Potato	Corn	Corn	Corn
2-year forage (APA)	Alfalfa	Potato	Alfalfa	Corn	Corn
2-year forage (SPS)	Sudex	Potato	Sudex	Corn	Corn
3-year forage (AAP)	Alfalfa	Alfalfa	Potato	Corn	Corn
3-year forage (FFP)	Festulolium	Festulolium	Potato	Corn	Corn

† Three-year crop rotation sequence from 2002-2004.

Materials and Methods

Corn was planted across the entire experiment in the spring of 2005 and 2006 at a population of 74,300 seed ha^{-1} with an in-row seed spacing of 28 cm and 76 cm row spacing. Corn yields were determined with a plot combine by harvesting the center two rows of each four row plot. Grain yields were adjusted to 155 g kg^{-1} moisture content.

Pre-sidedress NO_3-N soil tests (PSNT) were obtained at corn V5 growth stage (vegetative leaf stage is defined according to the number of leaves having a visible leaf collar, including the first rounded-tip leaf). Fifteen cores per plot were collected from a depth of 0-30 cm. Soil was air dried and ground to pass a 2 mm sieve. Nitrate-N was extracted using 50 ml 1N KCl solution per 5 g of soil. Nitrate-N was determined from the extractant using a modified Griess-Ilosvay cadmium reduction (Keeney and Nelson, 1982)

NDVI measurements using a GreenSeeker (NTech Industries Inc., Ukiah, CA) remote optical sensor were obtained at the V14 growth stage. Approximately 12 m of the center two rows of each plot were measured independently at 0.6 m above the crop canopy.

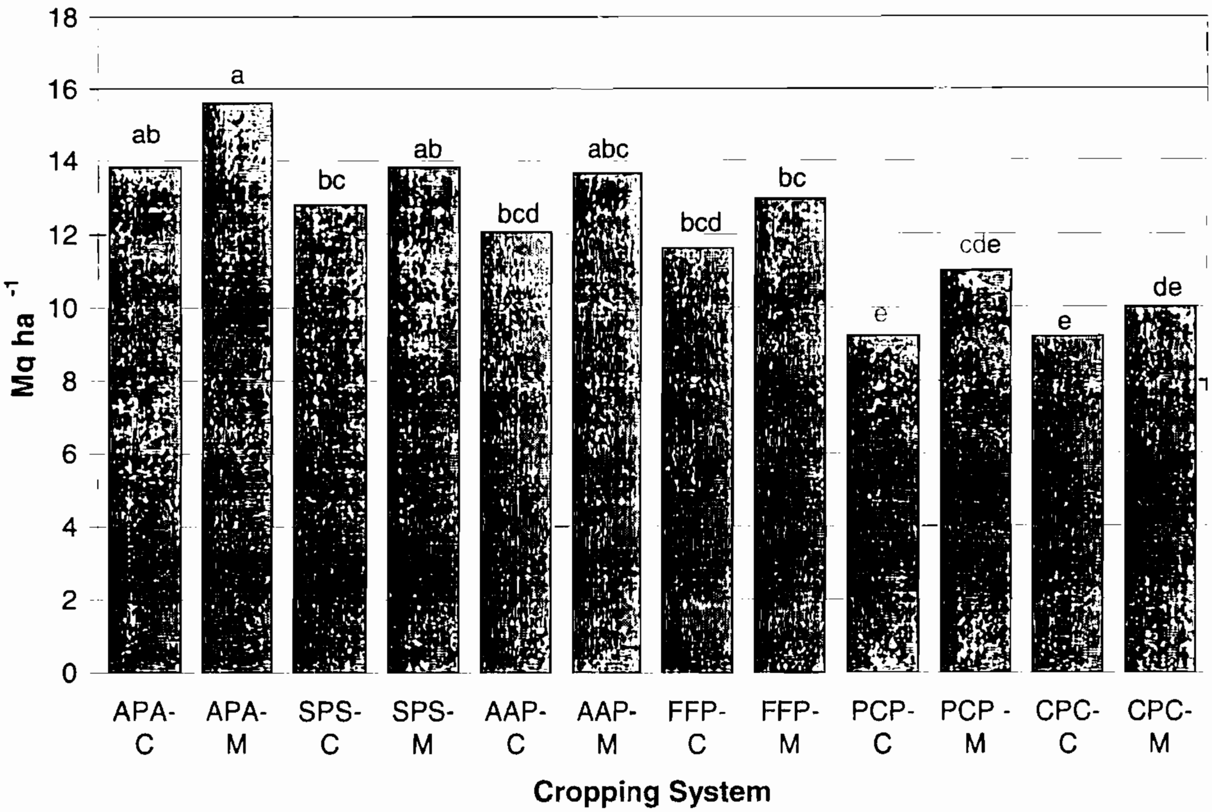
Analysis of variance (ANOVA) was performed on yields with Proc GLM (SAS Institute, 2004) using the Kenward-Roger method for determining degrees of freedom. When significant effects of treatment occurred, means were compared using Fischer's Least Significant Difference. Differences are considered significant at an alpha level of 0.05.

Results and Discussion

Grain yields in 2005 were greater with the inclusion of forage production in the recent rotation history, ranging from 15.6 to 13.7 Mg ha^{-1} (Fig. 1). Yield from rotations with no history of forage rotations ranged from 11.0 to 9.2 Mg ha^{-1}. Rotations with no forage history or manure amendment had significantly lower yields than rotations with forage crop history. Rotation effects ($P<0.0001$) and manure effects ($P<0.0045$) were both found to be highly significant.

Corn yield responses to forage rotations have been previously observed in production systems. Ferguson et al. (2005) found corn silage yields increased with the application of manure compared to mineral fertilizers by 1-2 Mg ha^{-1} in six out of a ten years. Rasiah (1999) followed six years of conventionally fertilized alfalfa, bromegrass or continuous corn production with non-fertilized corn to examine effect on grain yield. Corn yields with alfalfa or bromegrass as a previous crop were 7.1 and 6.1 Mg ha^{-1}, respectively, and were significantly greater than the 4.4 Mg ha^{-1} yield reported for corn following corn.

Figure 1. 2005 corn grain yield response to cropping system rotations and manure (M) versus inorganic fertilizer (C) treatments. Bars with the same letter designation are not different at α=0.05.

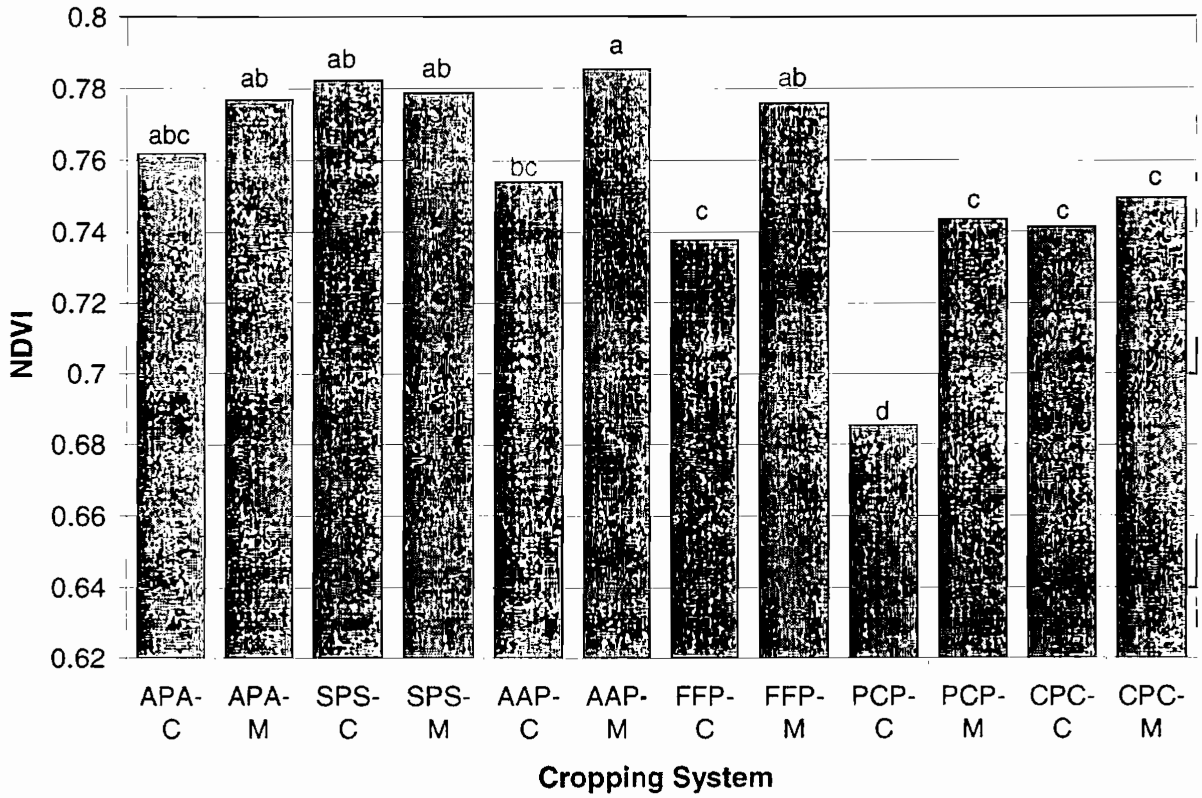


Average NDVI measurements at V14 were greatest in rotations with the most recent forage rotations, ranging from 0.769 to 0.782 for rotations with alfalfa and sudex crops in 2004; and for two-year forage stands with manure amendments with values of 0.785 for two-year alfalfa and 0.776 for two-year festulolium (Fig. 2). Rotations with no forage rotation history had significantly lower NDVI readings, ranging from 0.686 to 0.744. Both crop rotation and manure amendment effects were found to be highly significant (P<0.0001).

Corn grain yield prediction by in-season NDVI has shown promise. Martin et al. (2005) used NDVI measurements on four-plant sets to predict corn yields. Other researchers have been able to forecast corn yields using NDVI as a component of other yield-predicting equations. Net primary productivity estimated using photosynthetic active radiation and NDVI accounted for 89% of variability in irrigated Mexico corn yields (Báez-González et al., 2002). Staggenborg and Taylor (2000) used Green Normalized Difference Vegetative Index (GNDVI) to predict 40% of yield variability in Kansas corn production. The successful use of NDVI, or variations thereof, suggest that positive correlations are possible between 2006 corn NDVI readings and grain yield.

Pre-sidedress NO_3-N samples are expected to correlate positively with 2006 corn grain yield. Correlations between soil N and corn grain yields have been reported (r^2=0.82) when corn was preceded by alfalfa, corn, or soybeans (Russell et al., 2006). Accurate prediction of organic N amendment contributions in corn systems using the PSNT may allow for mid-season management of N systems that have proven difficult to predict.

Figure 2. Normalized difference vegetative indices (NDVI) recorded at the V14 corn growth stage (2006) using a GreenSeeker hand-held sensor. Bars with the same letter designation are not different at α=0.05.



Summary

Grain yields in 2005 were increased with the presence of a forage rotation crop in the production history, with alfalfa in the year preceding corn resulting in the greatest yield increases. A trend was observed throughout all cropping systems indicating increased corn grain yields in rotations with manure amendment history compared with rotations with no previous manure application. Mid-season NDVI measurements in 2006 showed that forage rotations in 2004 or two-year forage stands combined with manure amendments had greater biomass than systems with no forage rotation or manure amendments. These readings are anticipated to be indicative of 2006 grain yields, reflecting similar responses to those observed for the 2005 growing season. The observed residual treatment effects from forage crop rotation and manure application demonstrate organic N carry-over through multiple year crop production. This information can increase knowledge of multiple year organic N effects and help producers more accurately design fertilizer regimes to account for available soil N.

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