

Effect of Manure, Compost, and Potassium Application on Alfalfa Yield, Potassium Content and Soil Test Potassium in Aurora, NY

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Introduction

While K fertilizer cost has decreased from recent all-time highs of \$0.80/pound to currently \$0.40/pound, K remains an expensive macro-nutrient. Alfalfa removes large amounts of K (57 lbs K₂O per ton DM assuming 2.384% K for legume hay; DairyOne Forage Library, 2011) and with alfalfa forage production of 740,000 acres and average per acre yield of 3.2 tons reported for 2010 ([http://www.nass.usda.gov/Statistics by State/Ag Overview/AgOverview NY.pdf](http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_NY.pdf)), total alfalfa crop K removal in New York State is approximately 135.5 million pounds of K₂O. If this removal had to be completely replaced by fertilizer K, at \$0.40/pound, it would require about \$73 per acre of alfalfa cropland or more than \$54.2 million dollars annually. Potassium can be recycled through manure applications, replaced by fertilizer applications or resupplied by the soil. Soil K supplying capacity is large for clay soils and fairly low for sandy soils but all agricultural soils supply K to crops as clay minerals weather (break down) over time, and this process reduces the need for K supplementation from manure or fertilizer. Manure, when applied to meet N needs for corn in a corn-alfalfa rotation, supplies large amounts of K during the corn years, typically increasing soil test K levels and often providing excellent K levels for the first few years of a new alfalfa stand. However, as manure applications are often avoided early in the stand life, and as soil test K levels decline with heavy alfalfa utilization, producers and agricultural advisors are understandably reluctant to avoid K fertilizer use on older (3rd, 4th year) alfalfa stands out of concern for reduced yield and/or winter kill.

Producer questions addressed in this project are: (1) is the K applied with manure or compost in corn years sufficient to bridge alfalfa years in the rotation, and (2) what tools can be used to reliably identify if extra K is needed. In 2001, a large-scale long-term corn-alfalfa rotation study was initiated at the Musgrave Research Farm in central NY. Corn silage was grown for 5 years on calcareous soils under N-based (without incorporation) and P-removal based manure and/or compost management as well as 6 rates of N fertilizer plus banded P and K according to Land Grant guidelines. The field was then rotated to alfalfa. The questions related to K management were: (1) can manure or compost supply the K needed for the alfalfa years in the rotation, and (2) is extra K needed for the plots that did not have a manure or compost history?

Materials and Methods

The long term study at the Musgrave Research Farm was initiated to compare corn and alfalfa yield under different fertility management strategies. During the corn years (first 5 years), in four of the ten treatments manure or compost was applied at two rates (annual application of 20 and 34 tons/acre compost or 8,000 and 20,000 gallons/acre liquid manure). The manure and compost rates were set to meet corn N needs without incorporation (the higher N-based rates) or P crop removal (the lower rates; manure was incorporated in the P-based treatments to conserve N). Additional treatments during the corn years consisted of a no-N control and five fertilizer N rates

(50, 100, 150, 200 and 250 lbs N/acre). The entire trial was replicated five times (randomized complete block design). Alfalfa was established with 20 lbs P₂O₅ and 20 lbs of K₂O/acre in 2006 (after the five years of corn) and harvested in a 4-cut system with the exception of 2006, the seeding year with two cuts, and 2007, which was harvested in three cuts due to drought.

A K rate study was initiated in 2007 using plots that did not receive manure or compost as part of the original 10 treatments established in 2001. Upon initiation of the K rate study, the soil test K levels of these plots averaged 117 lbs K/acre, classified as high in soil test K according to the Cornell Morgan soil test K interpretations for alfalfa. The K trial consisted of five annual K application rates: 0, 83, 166, 252, and 335 lbs K₂O/acre applied at green-up. The 252 lbs/acre rate was the estimated crop removal rate for the site, assuming an average crop removal of about 57 lbs K₂O per ton of DM (2.384% K₂O) and an estimated annual yield average of about 4.4 tons DM for the Kendaia/Lima soil at the farm.

Results and Discussion

Compost versus Manure versus Commercial Fertilizer; Dry Matter Yield

Alfalfa dry matter yields ranged from an average annual yield (over 5 years including the establishment year and the 2007 drought year) of 4.0 tons/acre for plots that did not have a manure or compost history and did not receive additional K, to 5.3 tons/acre for plots with the higher compost and manure rates during the corn years. In years 4 and 5, the compost histories and the high manure N rate history out-yielded the lower manure rate and the yields of plots that had not received any manure or compost during the corn years (Figure 1).

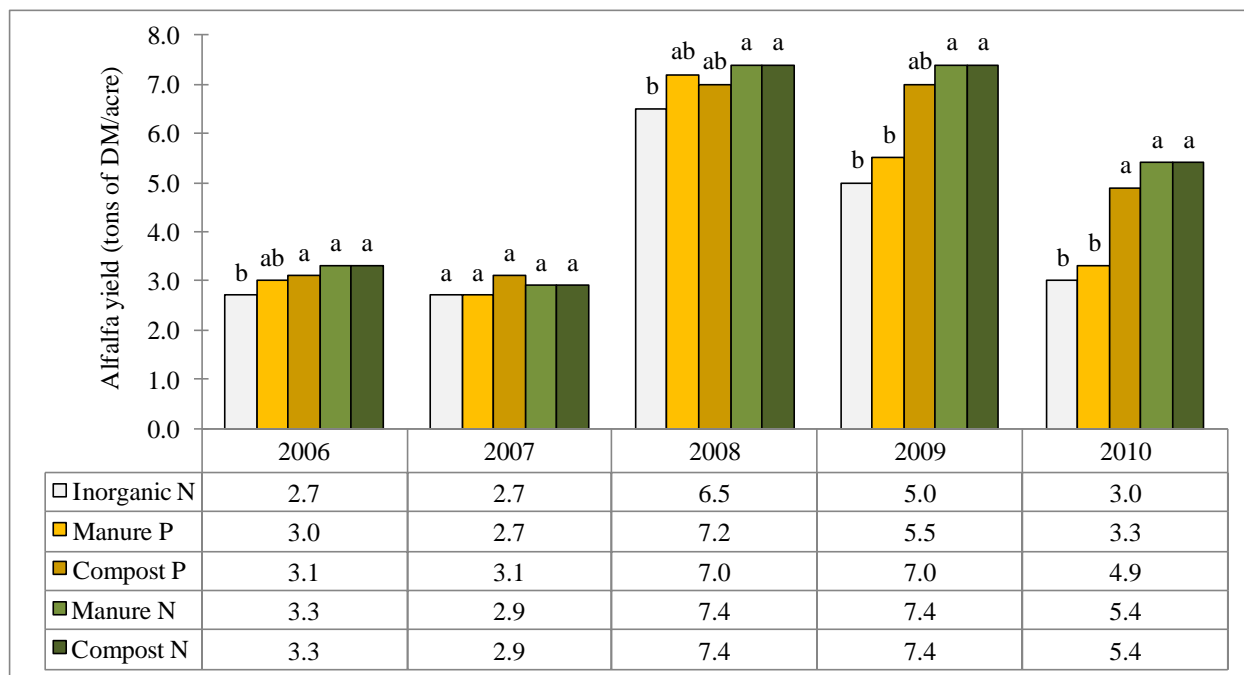


Figure 1: Annual dry matter yields (5 year average including the seeding year) for alfalfa grown after corn that was fertilized with compost, manure, or inorganic N fertilizer. Fields were fertilized with N or P based compost or manure rates or inorganic N fertilizer during the five years of corn production, prior to seeding of the alfalfa in 2006. No K was added during the alfalfa years. The year 2007 was a drought year at the Musgrave Research Farm.

Compost versus Manure versus Commercial Fertilizer; Soil Test Trends

The five annual additions of manure or compost under the corn years increased soil test K levels over time, as represented by the spring 2006 difference between 138 lbs K/acre soil test K (no compost or manure) and 262 and 278 lbs K/acre soil test K under the N-based compost and manure treatments, respectively (Figure 2). These values suggest an annual increase of 25-28 lbs K/acre soil test K for the N-based rates, versus 10-12 lbs/acre annual increase for P-based rates.

Soil test K levels declined over time under the alfalfa years for all manure and compost amended plots (Figure 2). In the last alfalfa year, only the N-based manure rate showed soil test K levels that remained higher than in the plots that did not have a manure or compost history. At the end of the 5th year, soil test K levels for all compost or manure treatments were still classified as high in K, suggesting the rotation can be managed without the need for K fertilizer addition.

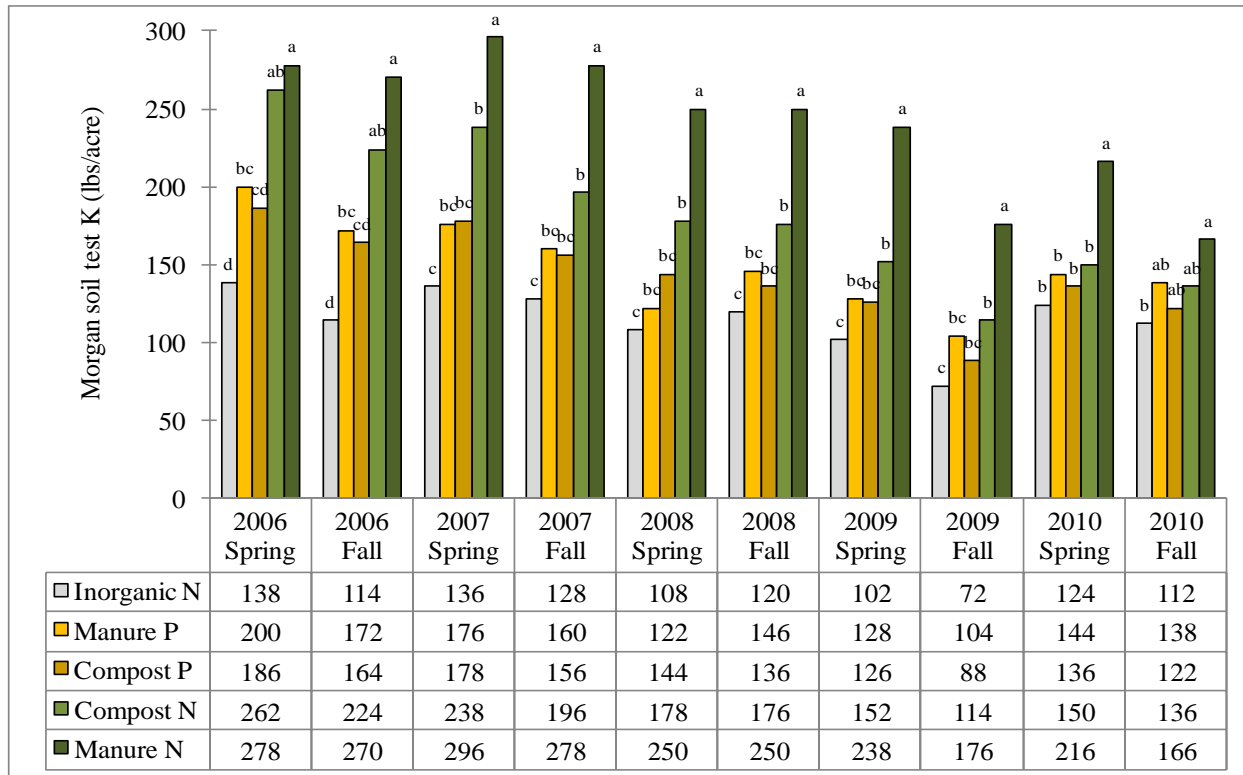


Figure 2: Trends in soil test K during the alfalfa years of the rotation (calcareous Kendaia/Lima soil management group 2 soil). Fields were fertilized with N or P based compost or manure rates or inorganic N fertilizer during the five years of corn production, prior to seeding of the alfalfa in 2006. No K was added during the alfalfa years.

Potassium Addition; Dry Matter Yield

The addition of K to plots without a manure or compost history increased yields only in 2008, an exceptionally good growing season with average yields of 6-7 tons/acre dry matter, considerably above the average yield potential for the soil type (Table 3). That year, a K addition of 252 or 355 lbs K₂O/acre delivered a significantly higher yield (0.4-0.7 tons/acre) than the no-K control. For each of the other three years (2007, 2009 and 2010), K addition did not impact yield. Averaged over the five years of alfalfa, annual yield was 3.7 to 4.0 tons/acre, consistent with the yield potential for the soil type, *with no net gain in yield with K addition*. Thus, the optimum K rate across all five years was 0 lbs K₂O/acre, less than the 20 lbs K₂O/acre Cornell recommendation for a Kendaia/Lima soil with an initial Morgan soil test K of 117 lbs K/acre.

Table 3: Alfalfa yield (tons/acre) as impacted by potassium rate. Alfalfa was established in 2006. First K applications took place in spring 2007. The soil is a calcareous Kendaia/Lima soil (SMG 2). The 252 lbs/acre application rate is the crop-removal based application rate for this site.

Year	Potassium (K ₂ O) applied in spring (lbs/acre)										
	0		83		166		252		335		<i>P value</i>
Alfalfa yield in tons DM/acre											
2006	2.5	a	2.6	a	2.6	a	2.7	a	2.6	a	0.8517
2007	2.8	a	2.6	a	2.6	a	2.6	a	2.6	a	0.8016
2008	6.3	b	5.9	b	6.5	ab	6.7	a	7.0	a	0.0013
2009	5.3	a	4.8	a	5.1	a	4.3	a	4.8	a	0.5254
2010	3.0	a	2.5	a	3.0	a	2.5	a	2.9	a	0.3945
Total	20.0	a	18.4	a	19.8	a	18.8	a	19.9	a	0.5819
Annual	4.0	a	3.7	a	4.0	a	3.8	a	4.0	a	0.1309

Potassium Addition; Soil Trends

The K addition did not increase alfalfa yield but elevated soil test K levels over time (Figure 3) where application rates exceeded 2/3rd of crop removal (166 lbs K₂O/acre). The average soil test K at seeding in the spring of 2006 was 117 lbs K/acre (classified as high). Without K addition, spring soil test K levels ranged from 82 lbs K/acre in 2008 and 2009 to 110 lbs K/acre in 2010, taking into consideration some expected variability in soil test K, these results primarily reflect the soils ability to resupply K after significant amounts of crop removal and suggest that this soil can supply needed K at the harvest/removal levels experienced over the five year period.

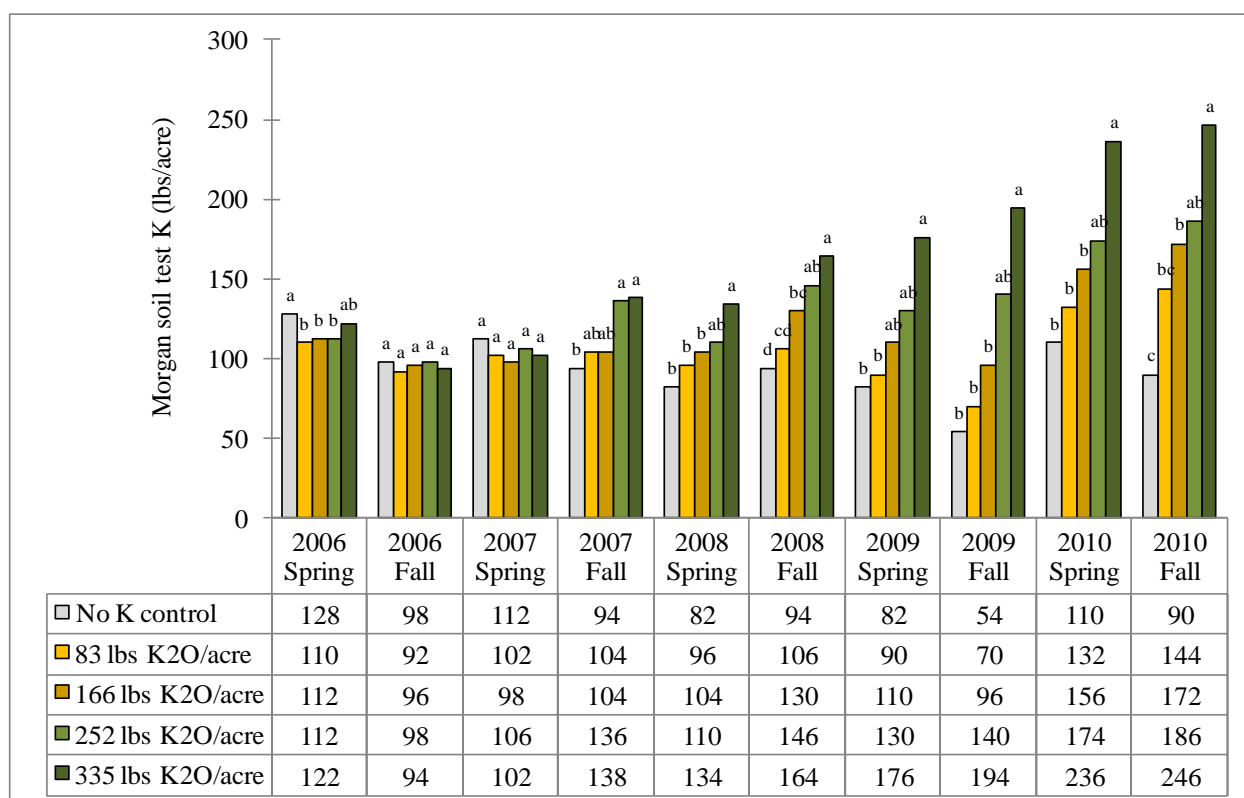


Figure 3: Trends in Cornell Morgan soil test K with addition of K fertilizer. The K addition did not impact total yield. Soil tests are classified as high when the Cornell Morgan soil test K value is between 100 and 164 lbs K/acre and very high if it exceeds 164 lbs K/acre (the soil is a calcareous Kendaia/Lima soil management group 2 soil).

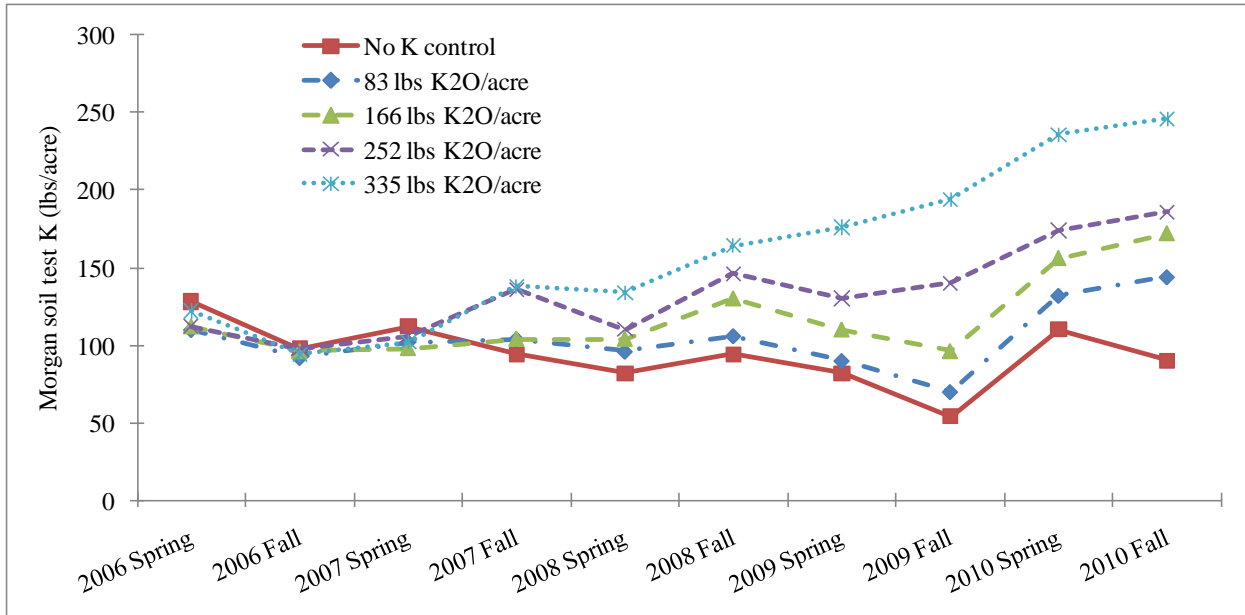


Figure 4: Soil test K levels increased with K addition of 166 lbs K₂O/acre or more.

Potassium Addition; Tissue Trends

In addition to increasing soil test K levels, K addition at 166 lbs/acre or more also increased whole plant K content sampled at 3rd cutting in 2010 (Figure 5). In comparison, whole plant K levels for the plots with the manure and compost histories amounted to 1.5% for the fields with a compost history versus 1.6 and 1.9% for fields with P-based and N-based manure applications, respectively, further suggesting that K availability was not yield limiting in the inorganically fertilized plots. These results call into question the 2% critical value that is commonly reported for alfalfa, indicating further research is needed to evaluate the critical plant K levels for alfalfa.

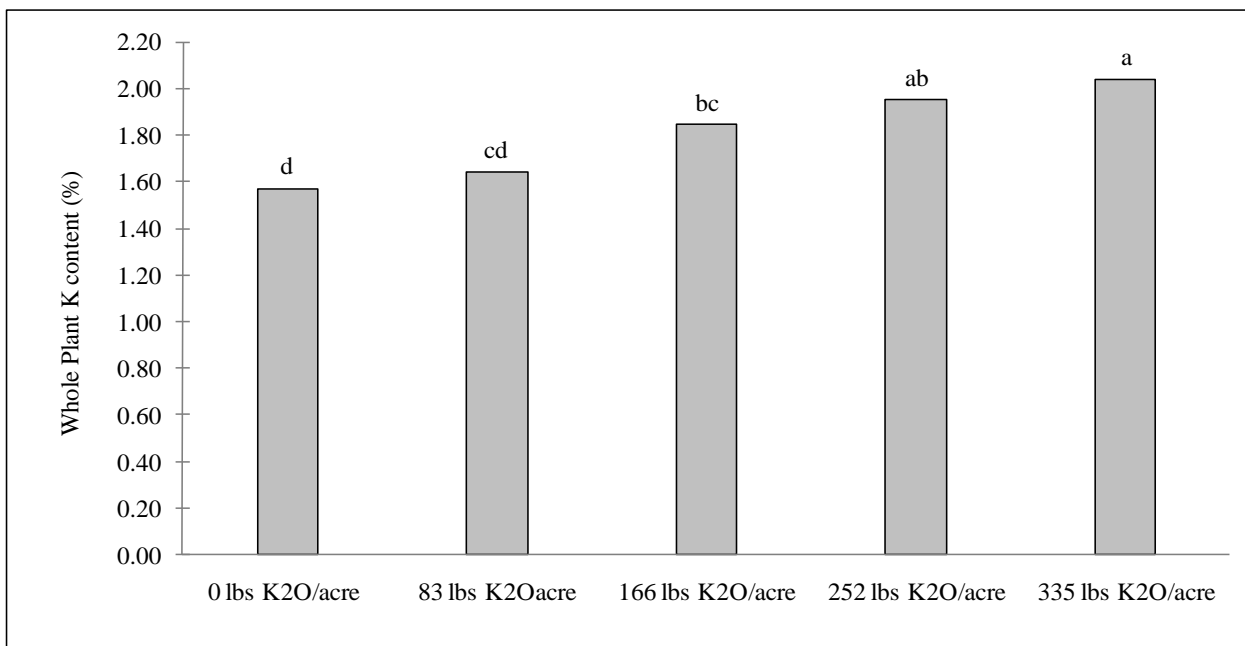


Figure 5: Impact of K addition on tissue K at 3rd cutting after four years of K addition (2010). The fertilizer addition (annual additions at green-up) did not increase yields.

Summary and Conclusions

The questions posed in this study related to K management were: (1) can manure or compost supply the K needed for the alfalfa years in the rotation, and (2) is extra K needed for the plots that did not have a manure or compost history? The data indicate that the annual manure and compost additions at both N and P-based rates during corn silage production years provided sufficient K to meet crop needs for the following five alfalfa years. When N-based rates of manure were applied during the corn years, soil test K levels were elevated at the start of the alfalfa portion of the rotation and remained elevated over all other treatments for the five years of alfalfa. Soil test K levels were back to 2006 baseline levels for the other three organic amended treatments. These results indicate that corn alfalfa rotations can be managed without K addition during the alfalfa years in a manure or compost context. For plots without a compost or manure history, soil test K levels were maintained over the years without K fertilizer addition and despite plant K levels below 2% the alfalfa did not show a yield increase with K fertilizer addition suggesting the soil's annual K supply was sufficient to sustain a 4 tons/acre per year yield at this location. Regular soil testing is the best way to monitor fields for responsive conditions to avoid yield losses or unnecessary expenses and unnecessarily high forage K levels that can lead to other problems. The yield increase in the plots with the manure or compost histories over plots that were managed with fertilizer only suggest benefits of manure and compost beyond their N, P and K additions. Similar studies are needed at different locations and with different soil types to evaluate if the results of this study can be repeated elsewhere.

Acknowledgments

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