DOES NITROGEN FERTILIZATION WITH MANURE INJECTION VERSUS SURFACE APPLICATION INFLUENCE CORN FOR SILAGE AND WINTER RYE YIELD, PHOSPHORUS BALANCE AND SOIL TEST PHOSPHORUS OVER THREE YEARS?

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ABSTRACT

Switching from nitrogen (N)-based to phosphorus (P)-based manure management can decrease P loss to the environment, allowing for sustainable P management in dairy farms. At high P soils, dairy farmers often surface apply the liquid manure to corn (*Zea mays* L.) for silage at the P-based rates and supplement the limited N to corn with N fertilizers to ensure optimum crop production. With high fertilizer prices, one solution to reducing the N requirement of corn could be to inject manure, conserve the ammonium-N fraction of the manure, and decrease the N need for corn. An experiment was conducted on a dairy farm located in Breese, IL from October 2019 to April 2022 with two main treatments including (i) surface application of manure at a P-based rate with 110 lbs ac^{-1} (to match 180 lbs N ac^{-1}) requirement for corn and (ii) injection manure at P-based rate plus 15 lbs N ac^{-1} to match 180 lbs N ac^{-1} requirement for corn. Our objectives were to evaluate whether injecting manure with lower N fertilizer need can produce similar corn silage yield and quality and if the manure application method influences the following winter rye (*Secale cereale* L.) as a forage crop in rotation. Our results indicated that injecting manure could produce a similar corn silage yield to surface application. This practice resulted in no quality loss but could save up to $150 of N fertilization. Winter rye in rotation also had similar biomass yield, nutrient accumulation, forage quality, and carbon input (shoots and roots) indicating that a shift from surface application to injection offers similar benefits, could reduce odor issues with surface application, and can save N fertilizer costs. Injecting manure effect on soil test P (STP) was similar to the surface application and did not increase STP over a three-year period. Future research should evaluate N- versus P-based manure management in intensified corn for silage with winter cereals in double cropping systems for eliminating N use, reducing the potential for P buildup in the soil, and increasing soil health.

INTRODUCTION

In Illinois, corn is a major cash crop, and corn grown for silage is particularly an important source of feed in the dairy farms. Dairy farmers often apply liquid dairy manure to meet the N requirement of a corn crop (N-based management) and also to enhance soil quality. However, the relatively high ratios of P to N in manure, when compared to the nutrient needs of a corn crop, can lead to an increase in soil test phosphorus (STP) levels over time (Sadeghpour et al., 2017). Elevated STP levels can result in greater phosphorus loss into surface and groundwater (Kleinman et al., 2002; Jahanzad et al., 2019).

Transitioning from an N-based approach to a P-based approach in managing manure for corn has been suggested to help regulate STP levels (Sadeghpour et al., 2017). However, such a shift necessitates a reduction in the manure application rate, which may impact the availability of N for the corn crop. Fertilization for N to supplement the N need for a corn crop has been proposed in soils that have high STP (Battaglia et al., 2021). In no-till systems, manure incorporation is not practiced, and thus, surface application of manure often results in loss of ammonium-N fraction through ammonia volatilization (Duncan et al., 2017). An effective approach that not only increases the N utilization of manure through reduction in ammonium-N loss but also addresses odor concerns linked to surface application is injection (Battaglia et al., 2021). Phosphorus-based manure management even with incorporation might result in a corn yield penalty (Sadeghpour et al., 2016), and adding fertilizer could eliminate that influence (Maguire et al., 2008). Literature is scant on evaluating P-based manure application methods (injection versus surface application) effects on both corn for silage and the following winter rye in rotation. Therefore, the primary objective of our research was to assess the consequences of switching from a surface application of P-based liquid dairy manure and supplementing it with N (110 lbs N ac^{-1}) to injection of manure at the P-based rate with low N requirement (15 lbs N ac^{-1}) on corn and winter rye performance in rotation. We hypothesized that a transition from P-based rate surface application to injection could produce similar corn yield at lower fertilizer N requirement and therefore, benefit the growers by saving N fertilizer and also by benefiting the environment through reduction in P runoff and odor concerns associated with the surface management practices.

MATERIALS AND METHODS

In 2019, a field experiment was initiated in Breese, IL (36º69'51" N, 89º53'61" W). According to the IL Agronomy Handbook, both STP and soil test K (STK) concentrations in 2019 were classified as very high and high, respectively. An experiment was conducted employing a randomized complete block design replicated four times. The two main treatments of this study were (i) surface application of manure at a P-based rate (12,900 gal ac^{-1}) with 110 lbs N ac^{-1} (to match 180 lbs N ac^{-1}) requirement for corn and (ii) injection manure at P-based rate (12,900 gal ac^{-1}) plus 15 lbs N ac^{-1} fertilizer to match 180 lbs N ac^{-1} requirement for corn.

Corn was planted on 30-inch row space using a no-till drill at 32000 ac^{-1} population. Winter rye was planted on 7.5-inch row spacing at 90 lbs ac^{-1} seeding rate. Corn planting dates were early-mid May and winter rye harvesting dates were late April to early May. Corn was machine-harvested from the middle rows of each plot after removing the edge effects. After weighing the harvested area, a subsample was collected and weighed again and then placed in an air-forced oven until it reach constant weight to measure dry matter yield for silage corn. Biomass sub-samples were then ground until they could pass through a 1 mm sieve, facilitating silage quality and nutrient analysis. The analysis was done by Ward Laboratories according to their analysis guideline (https://www.wardlab.com/services/feed-nirs-analysis/).

Winter rye's aboveground biomass was collected using grass shears (GS model 700; Black and Decker Inc., Towson, MD) during the late-April or early-May period. The harvesting area was 7.25 ft^2, which was done by avoiding edge effects. Subsequently, all biomass samples underwent a 72-hour oven-drying process at 118 f to determine their dry matter (DM) yield. Biomass sub-samples were then ground until they could pass through a 1 mm sieve, facilitating forage quality analysis. Forage quality indices evaluated in this study included CP, ADF, NDF, NDFD, ash, and lignin which were measured using near-infrared reflectance spectroscopy (NIRS). Guidelines for sample analysis and methodology can be found on the Ward Laboratory website (https://www.wardlab.com/services/feed-nirs-analysis/). Phosphorus balance was calculated as P applied – P removed by crops. Soil test P was analyzed using Bray-1 P extraction and ranges of P in the soil were determined based on Illinois Agronomy Handbook Guidelines (http://extension.cropsciences.illinois.edu/handbook/pdfs/chapter08.pdf). Data were evaluated for normality of the residuals and then analyzed with SAS statistical software at $p<0.05$, considered significant.

RESULTS AND DISUCSSIONS

Corn Silage Yield, Winter Rye Yield, and Total Yield

Corn silage yield was affected by year but not treatment (manure application method) or the interaction of year by treatment. Corn silage yield was higher in 2019 (14,730 lbs DM ac^{-1}) and 2021 (16,336 lbs DM ac^{-1}) than 2020 (8,616 lbs DM ac^{-1}) reflecting weather conditions and weed management issues in 2020 (Fig. 1).

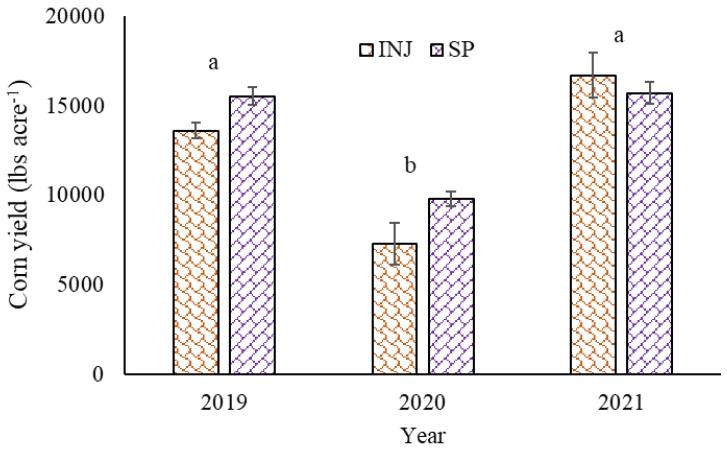

Fig 1. Effect of manure application method on corn silage yield in different years. The bars indicated standard error. INJ: inject manure, SP: spread manure. Year comparison means with the same letter are not significantly different (Tukey ≤ 0.05).

Corn silage yield (averaged over years) was 13,733 lbs DM ac^{-1} for surface application and 13,104 lbs DM ac^{-1} for manure injection. Rye forage yield (aboveground biomass) was similar between INJ and SP in all years. Rye forage yield ranged from 1732 lbs DM ac^{-1} in 2022 to 2854 lbs DM ac^{-1} in 2021 mainly reflecting harvesting time (Fig. 2).

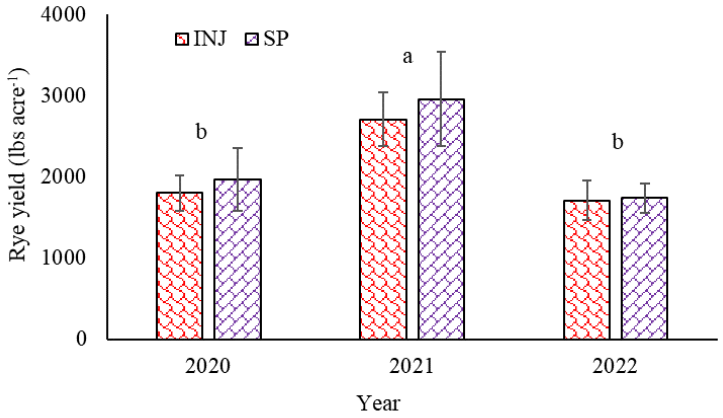

Fig. 2. Effect of manure application method on winter rye yield in different years. The bars indicated as standard error. INJ: inject manure, SP: spread manure. Year comparison means with the same letter are not significantly different (Tukey ≤ 0.05).

Total forage yield (corn DM yield plus winter rye DM yield) was only influenced by year. It was similar between the two manure application methods. Total forage yield was higher in 2020 (16,587 lbs DM ac^{-1}) and 2022 (18,077 lbs DM ac^{-1}) than in 2021 (11, 085 lbs DM ac^{-1}) mainly due to low yields in corn in 2021 (Fig. 3).

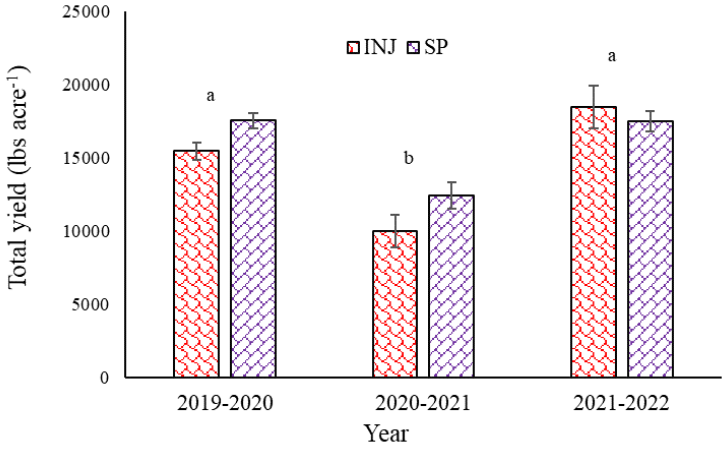

Fig. 3. Effect of manure application method on total forage yield (corn for silage plus winter rye) in different years. The bars indicated as standard error. INJ: inject manure, SP: spread manure. Year comparison means with the same letter are not significantly different (Tukey ≤ 0.05).

Phosphorus Removal, Balance, and Soil Test Phosphorus

Corn P removal was only influenced by year, and both INJ and SP had similar P removal within each year. Corn P removal was higher in 2019 (36.11 lbs ac^{-1}) and 2021 (44.80 lbs ac^{-1}) than in 2020 (23.46 lbs ac^{-1}) (data not shown). Phosphorus removal was influenced by year but not treatment or year-by-treatment interaction. Phosphorus removal was higher in 2021 (7.22 lbs ac^{-1}) than in 2020 (4.25 lbs ac^{-1}) and 2022 (4.42 lbs ac^{-1}) (data not shown). Total P removal was similar between the two application methods within each year. However, total P removal was lowest in INJ in the 2020-2021 season (26.03 lbs ac^{-1}) and highest in INJ and SP in 2021-2022 (49.23 lbs ac^{-1}) (data not shown). Phosphorus balance was negative in two of the three years and was highest in INJ in 2020-2021 (12.65 lbs ac^{-1}). Bray-1 STP concentrations were 78.5 mg kg^{-1} for INJ and 76.7 mg kg^{-1} for SP in spring 2019. After three years of P-based rate manure management, in spring 2022, STP levels remained unchanged, and INJ had an STP level of 79.0 mg kg^{-1} while SP had an STP level of 78.5 mg kg^{-1} (data not shown).

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