Crop Yield Response and Recovery of Nutrients Applied as Thin Stillage in a Black Chernozem

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Abstract

Rapid increase in ethanol production from cereal grain to substitute fossil fuel has resulted also in different types of byproduct associated with its production. One of these byproducts is thin stillage. Thin stillage is found to contain all essential plant nutrients which can promote its use as soil amendment/organic fertilizer. Consequently, The aim of this study was to examine the effect of thin stillage versus urea application on crop yield and nutrients recovery in Black chernozem soil. The experimental treatments included: 3 rates of thin stillage (16800; low rate, 33600; medium rate and 67200 L ha^{-1}; high rate) using two methods of application: injected or broadcasted) and 3 rates of urea-N (50, 100 or 200 kg N ha^{-1}). An unamended control was included. Treatments were applied for 2 consecutive years. In both years and per unit of N added, the thin stillage produced equivalent or higher yields than urea. This is explained by other nutrients in thin stillage, including phosphorus, that would contribute to plant nutrition and yield. Significant impact of method of thin stillage application on nutrients recovery was evident in both years, especially with the low rate of application. This study demonstrated that thin stillage byproduct can be effective amendments to provide nutrients to plants and enhance the production.

Introduction

Thin stillage is another major coproduct associated with ethanol production. It can be defined as the aqueous byproduct generated from the distillation of ethanol following fermentation of starch or sugar crops (carbohydrates) (Mustafa et al., 2000). The whole stillage, which contains solids from the grain along with added yeast and liquid from the water added during the process, is generated from fermentation and distillation processes. The whole stillage is then centrifuged to separate the liquid components (thin stillage) and the solid components (wet distillers grain). The thin stillage is then further processed by evaporation to produce syrup which can be blended with wet distillers grain resulting in wet distillers grain with solubles (WDDS) (Bonnardeaux, 2007). However, the evaporation process is costly and adds more expense to the cost of producing ethanol. Currently, one of the potential uses of thin stillage is that it can be used as a partial or complete drinking water replacement for cattle (Mustafa et al., 2000). Approximately 6 liters of thin stillage is produced from one liter of ethanol produced; a 190-million-liter ethanol plant can produce about 1-3 million liters of thin stillage per day (AURI, 2008). It was also previously reported that up to 20 liters of thin stillage may be generated for each liter of ethanol produced (van Haandel, 1994). There is growing interest in finding alternative uses for thin stillage, including digestion to produce methane (biogas) which can be used to power the ethanol plant, replacing natural gas, and recovering phosphate, ammonia and magnesium contained in thin stillage to produce struvite pellets as a slow release 5-21-1 fertilizer (AURI, 2008). More research is required to investigate alternative methods to utilize this significant byproduct stream associated with biofuel production. As thin stillage contains all essential plant nutrients which can promote crop production, and soluble organic matter that can stimulate soil biological activity, its direct application to agricultural soil might be a practical alternative. Therefore, the objective of this study was to investigate the effect of direct application of thin stillage in the fall in comparison with the conventional fertilizer of urea on crop yield and nutrients recovery in subsequent growing season for 2 consecutive years.

Materials and Methods

A 2-year field experiment was established in the fall of 2008 to address the study objectives. The experimental site is located in east-central Saskatchewan, Canada, near the town of Dixon. The predominant soil at the site is classified as Black Chernozems (Cudworth Association) with clay texture with an average particle-size distribution for the 0-60 cm depth of 24% sand, 24% silt and 52% clay as determined using particle-size analysis with pipette method (Gee and Bauder, 1986). The field of study has nearly level topography. The area of where Dixon site is located represents productive agricultural land in Saskatchewan (Stumborg et al., 2007). The average of long-term annual precipitation and temperature for this area is 373 mm and 0.7 °C respectively (Stumborg et al., 2007).

The field experiment was designed to include 11 treatments: three rates of thin stillage injected or broadcasted and three rates of urea. Disturbed and undisturbed checks were also included as a control. As detailed, the 11 experimental treatments were: thin stillage was applied at three rates, 16800, 33600 or 67200 L/ha using two methods of application (injection or broadcast) for each rate and mineral fertilizer was applied at three urea-N rates, 50, 100 or 200 kg N/ha; disturbed or undisturbed control. The three rates of thin stillage of 16800, 33600 or 67200 L/ha will provide approximately 50, 100 or 200 kg N/ha respectively, assuming that about 60% of thin stillage-total N will be available, and this will be appropriately comparable to the three rates of totally available urea-N (50, 100 or 200 kg N/ha). The experimental design was a randomized complete block with four replicates. The plots dimensions were 3 m width × 9 m length.

Thin stillage was obtained from Pound-Maker Agventures ethanol plant located at Langigan, Saskatchewan. It was applied to the filed in early fall each year by Prairie Agricultural Machinery Institute (PAMI). A homogenized sample of thin stillage was collected prior to application and analyzed for chemical composition by ALS Laboratory Group, Saskatoon, SK.

The field was seeded to wheat in the first year and canola in the second year. Plants were harvested when physiological maturity was reached. Two 1-m^2 plant samples per plot were cut manually above the surface. The samples were dried by forced air at 45 °C, total biomass weighed, and mechanically threshed using a stationary thresher. Then, grain and straw yield were determined. Straw samples were ground to < 2 mm in a Wiley mill and grain samples were finely ground with a Cyclone mill. Total N and P were measured by digesting the ground grain and straw samples in sulfuric acid-peroxide (H_2SO_4-H_2O_2 using a temperature-controlled digestion block (Thomas et al., 1967), followed by colorimetry for P and the NH_4-N in the digest was determined using a Technicon Autoanalyzer II (Technicon Industrial Systems, 1973). Total N and P uptake were then calculated from plant N and P concentrations and total dry matter yield, and this allowed for calculating N and P recoveries as the difference in nutrient uptake between treated and untreated plot divided by the rate of nutrient application.

Results and Discussion

Effect on wheat grain yield – Year 1

All treatments significantly increased the yield, compared to the unfertilized control (Fig. 1). Injected thin stillage resulted in higher grain yields than broadcast thin stillage at low and medium rates. This may be from greater nutrient losses when TS is surface applied. Per unit of N added, the thin stillage produced equivalent or higher yields than urea. This is explained by other nutrients in thin stillage that contribute to plant nutrition. Injection of thin stillage appears to be an effective strategy for supplying nutrients to crops.

Effect on N and P recovery – Year 1

N recovery was significantly affected by thin stillage and urea application rate (Fig. 2). However, the greatest effect on N recovery was observed with the low rate of urea treatments (Fig. 2). The N recovery decreased with increasing the rate of urea and injected thin stillage. Injecting thin stillage showed a better N recovery compared to the broadcast method of application. Injection method of thin stillage may have reduced the loss of N by volatilization process as this is expected where NH_4-N represents approximately 20% of total N in thin stillage. Effect of thin stillage broadcasting method on N recovery was relatively similar among all thee three rates of application (Fig.3). The notable differences between thin stillage and treatments is probably due to the soluble P contained in thin stillage amendment.

P recovery was better with injected thin stillage, especially at the low rate (Fig. 3). This can be related to the placement of P closer to roots by injection. P recovery in broadcasted thin stillage treatments followed a similar patter as N recovery, with no differences among the rates.

Effect on canola seed yield – Year 2

The environmental conditions in the growing season of 2010 were different to that of 2009 where the region experienced excessive moisture. However, the treatment effects on canola seed yield were similar to wheat in 2009 (Fig.4). The significant impact of thin stillage application on canola seed production can be attributed to the rapid turnover of thin stillage organic matter and thereby release nutrients for plant uptake.

Effect on N and P recovery – Year 2

N recovery was higher with low and medium rates of injected thin stillage and urea (Fig. 5). It followed a similar pattern to that of 2009. P recovery in the year of 2010 showed also a similar behavior to that of 2009 (Fig. 6).

Conclusion

Thin stillage has potential as soil amendment/fertilizer to increase soil fertility and crop production. No adverse effect/phytotoxicity was observed at the rates applied. Injecting thin stillage appeared to be a better method of application, as it improved recovery of both N and P compared to broadcasting.

Acknowledgement

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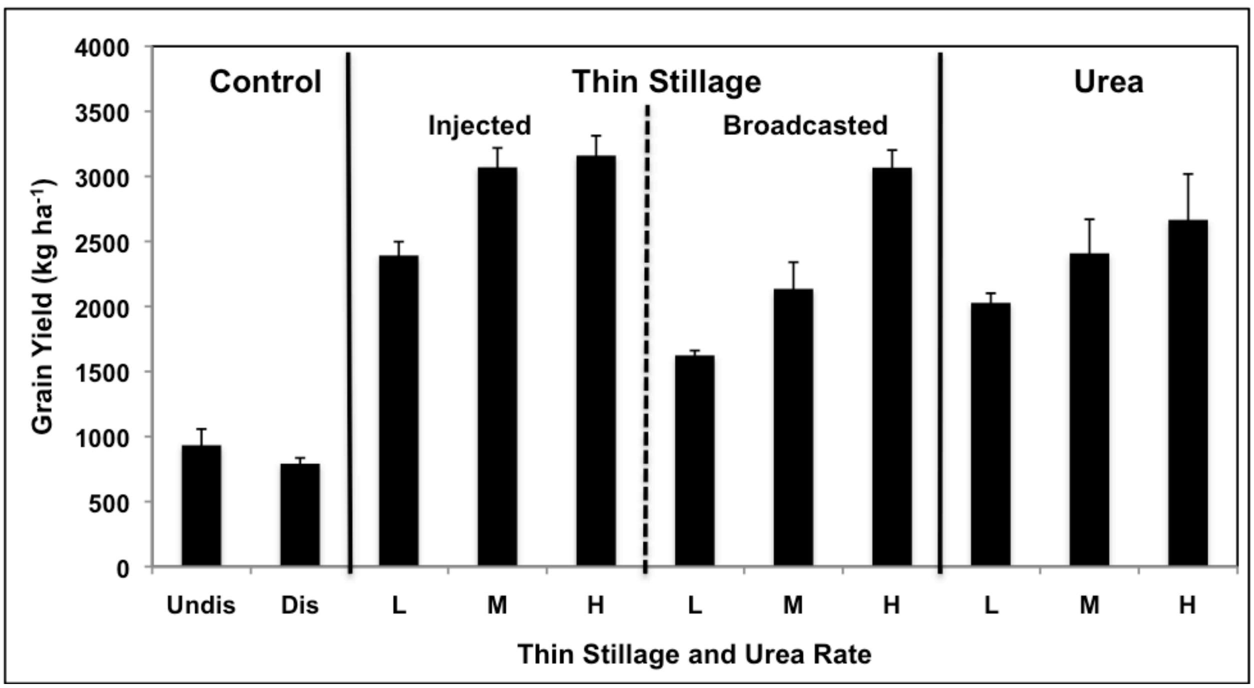

Fig. 1. Effect of thin stillage and urea application in the fall on wheat grain yield in the growing season of 2009. Amendments application rates were: low (L), medium (M) and high (H).

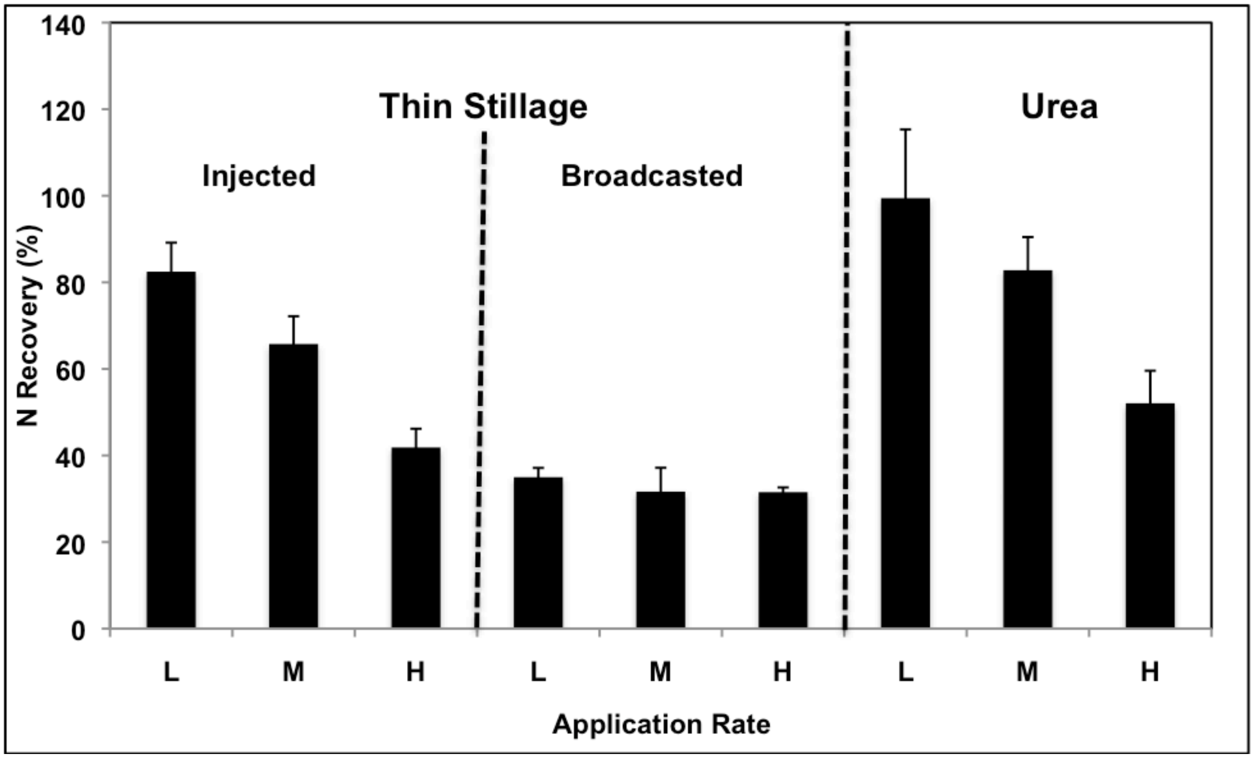

Fig. 2. Effect of thin stillage and urea application in the fall on N recovery in the growing season of 2009. Amendments application rates were: low (L), medium (M) and high (H).

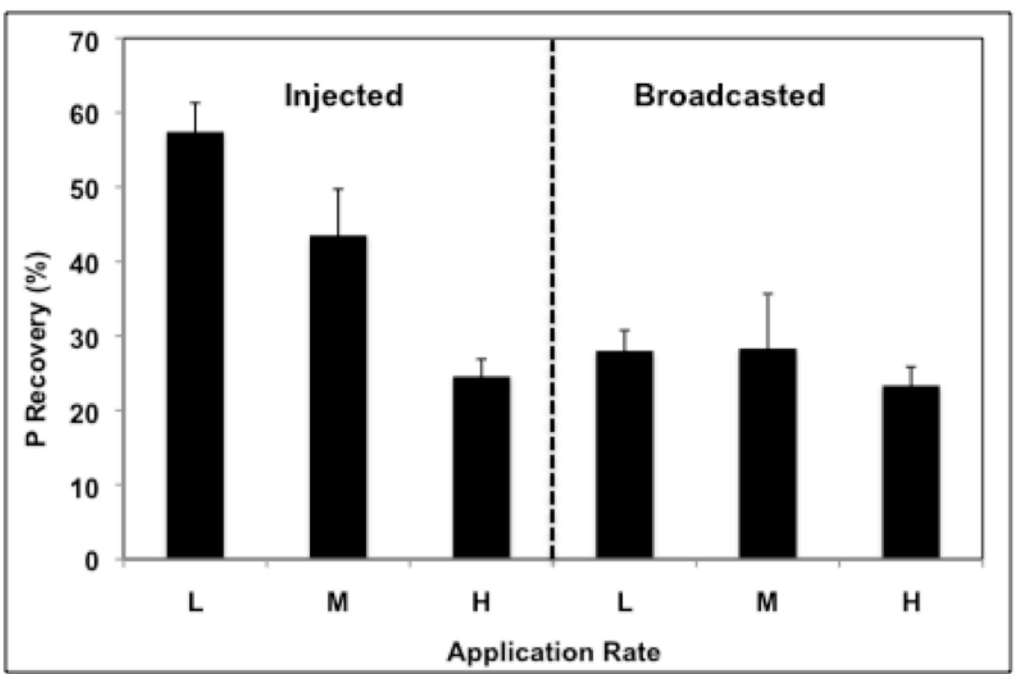

Fig. 3. Effect of thin stillage and urea application in the fall on P recovery in the growing season of 2009. Amendments application rates were: low (L), medium (M) and high (H).

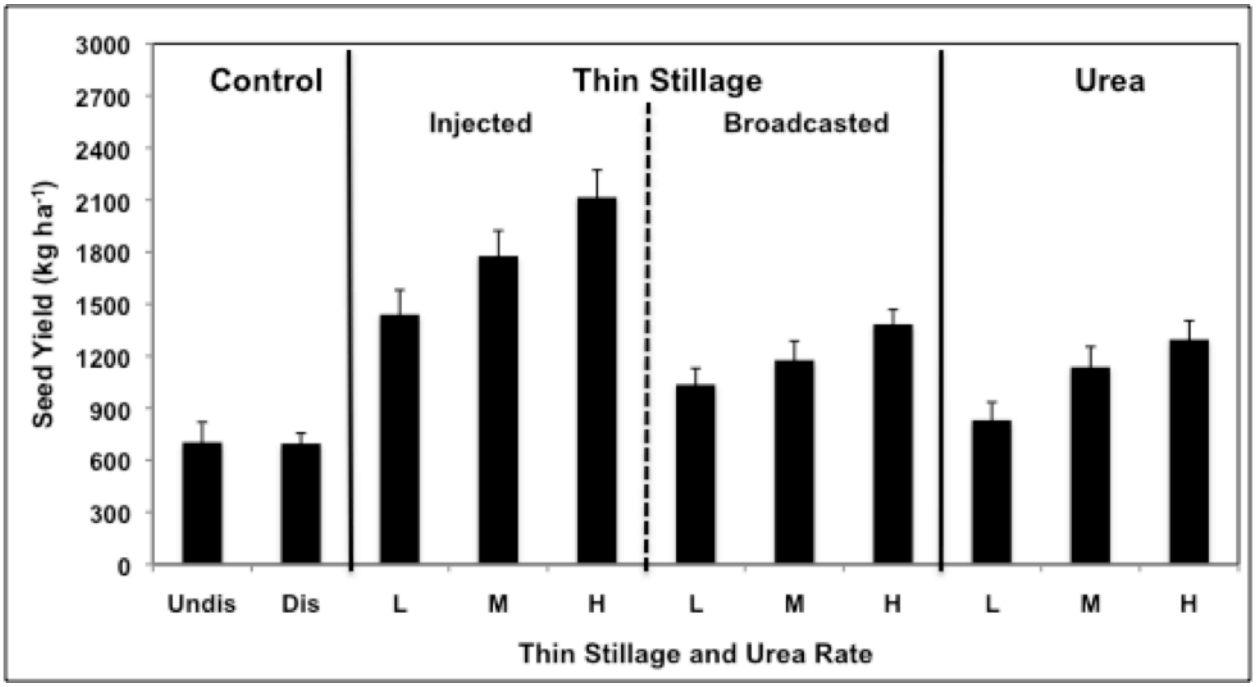

Fig. 4. Effect of thin stillage and urea application in the fall on canola seed yield in the growing season of 2010. Amendments application rates were: low (L), medium (M) and high (H).

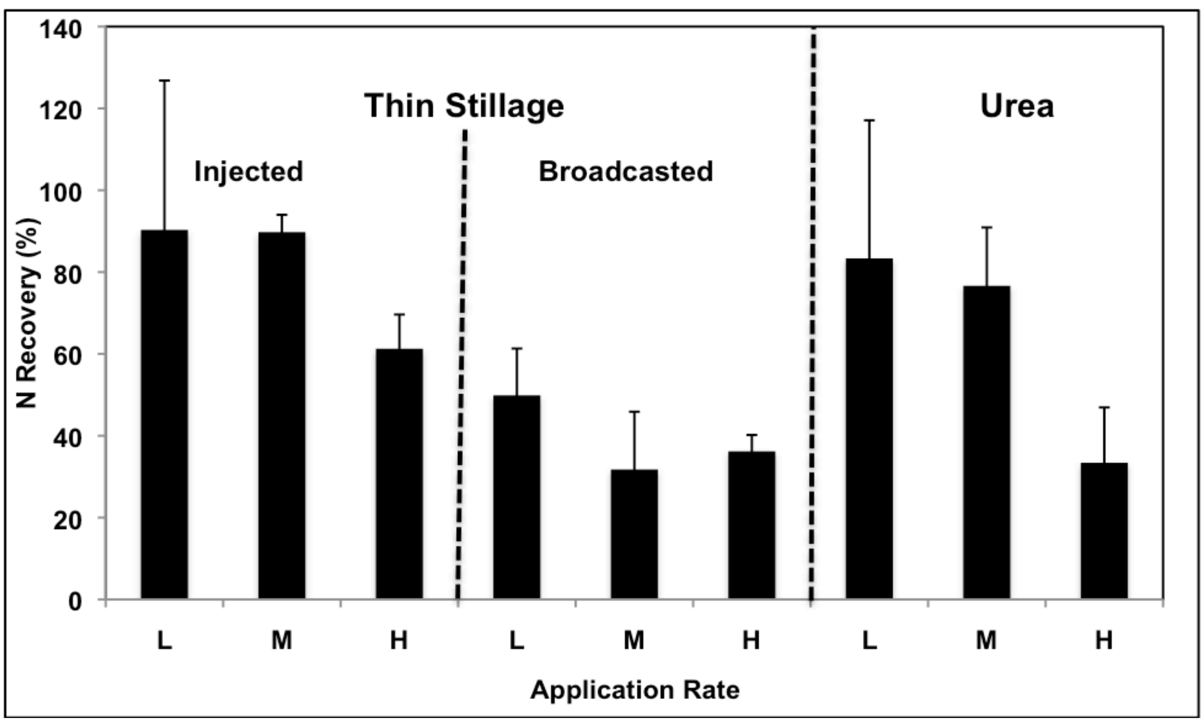

Fig. 5. Effect of thin stillage and urea application in the fall on N recovery in the growing season of 2010. Amendments application rates were: low (L), medium (M)

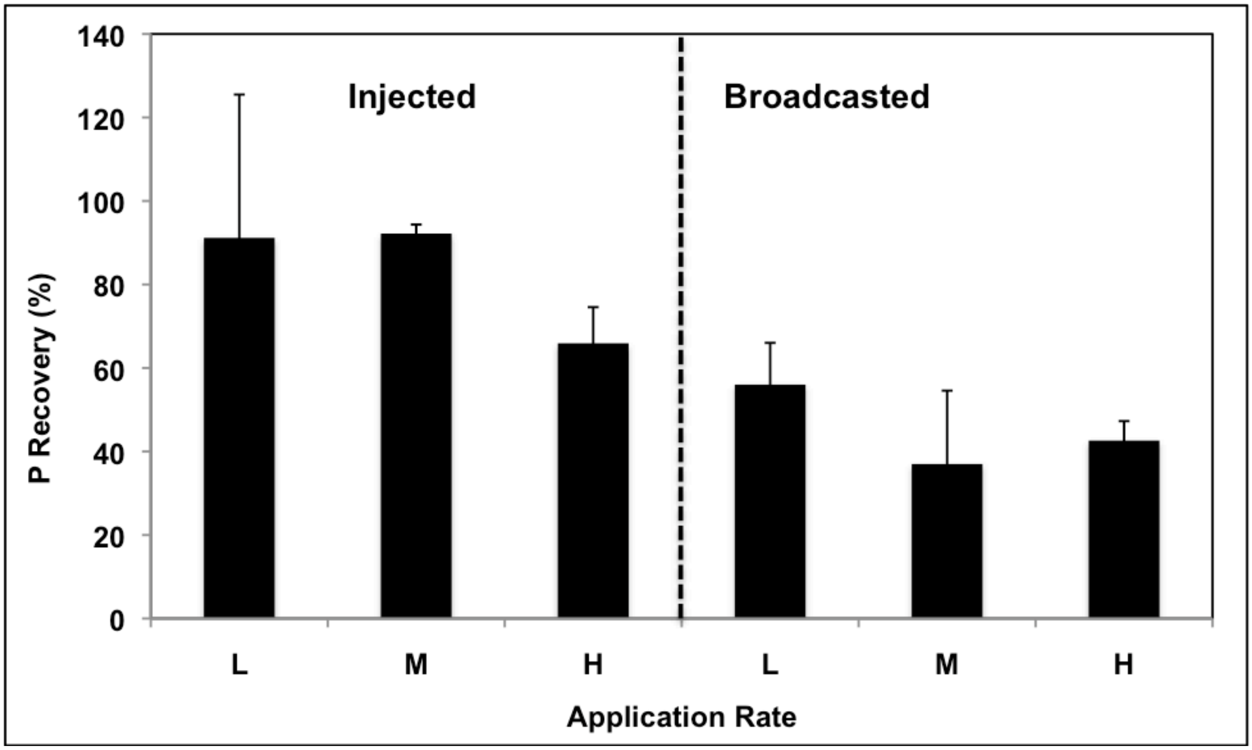

Fig. 6. Effect of thin stillage and urea application in the fall on P recovery in the growing season of 2010. Amendments application rates were: low (L), medium (M) and high (H).

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