^{15}N-FERTILIZER RECOVERY EFFICIENCY BY CORN USING CONTROLLED RELEASE UREA

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ABSTRACT

Limited research has been conducted on the use of ^{15}N-labeled controlled release urea fertilizers under field conditions for corn production. The objectives of this study were to: 1) evaluate the fate of N derived from a blend of two enhanced efficiency N fertilizers in corn plants throughout the growing season; and 2) to determine the N recovery efficiency of the two N sources from a blended application. A field study was conducted during the 2015-2016 growing season at Iracemápolis, SP, Brazil. The experimental design was a complete randomized block design with four replications. Treatments consisted of six N rates (0, 53, 107, 160, 214 and 267 lb N acre^{-1}) incorporated before corn planting. The N source was a blend of polymer-sulphur coated urea (PSCU) and NBPT-treated urea (TU) in a 70:30 ratios, respectively. Only the NTU was ^{15}N-labeled at 1.6% atoms ^{15}N. The ^{15}N recovery efficiency values and N uptake from the non-fertilized plots were used to estimate the N recovery from the blend. Corn plant N derived from PSCU, TU and soil N varied throughout the season. At V4, most of the fertilizer-N in the plant was derived from TU, while at growth stages V12, R2 and R6, most of the fertilizer-N in the corn plant was derived from PSCU. This suggest that PSCU fertilizer plays a bigger role for N supply to the corn later in the season. Soil N was the main N source for N in the corn plants and this fraction decreased as N fertilizer rate increased. At harvest, an average of 58% of the total N uptake was derived from the soil, while 32% was derived from PSCU and 10% from TU. At harvest, N-fertilizer recovery efficiency was in average 61% for PSCU and 39% for TU.

INTRODUCTION

Nitrogen (N) is a key nutrient for corn production worldwide. However, cereal-grain NUE is generally low and estimated to be 33% worldwide (Raun and Jhonson, 1999). Better soil and crop management practices can help to improve NUE. Furthermore, correct fertilizer N management is essential to increase overall NUE. To use the right source, at the right rate, at the right place and at the right time are essential components for improved NUE (Roberts, 2007).

The use of slow and controlled release N fertilizers are proposed as an alternative to improve fertilizer nitrogen use efficiency (Trenkel, 2010). These fertilizers are intended for better synchronization of N supply and plant requirements during the growing season (Chalk et al., 2015). However, little or no research has been conducted at the field scale with the use of ^{15}N-labeled controlled release fertilizers to study the fate of N derived from fertilizers in plants (Chalk et al., 2015). Polymer-sulphur coated urea (PSCU) and NBPT treated urea (TU) are becoming two important N sources in the Brazilian fertilizer market. Furthermore, these two sources are commonly used as blends with or without conventional untreated urea.

The objective of this study was to: 1) determine the fate of N derived from a blend of two enhanced efficiency N fertilizers in corn during the growing season; and 2) to estimate the N-fertilizer recovery efficiency of each source from a blend application including the interaction with the soil N pool.

MATERIAL AND METHODS

A field study was conducted at Iracemápolis, São Paulo, Brazil during the 2015-2016 growing season, on a Typic Hapludox with the following soil characteristics in the top 8 inches: pH_{CaCl2} = 5.2; S.O.C. = 14.5 g dm^{-3}; P = 19 mg dm^{-3}; K = 3 $mmol_c$ dm^{-3}; Ca = 35 $mmol_c$ dm^{-3}; Mg = 18 $mmol_c$ dm^{-3}; H+Al = 34 $mmol_c$ dm^{-3}; CEC = 97; BS = 65%; clay content = 520 g kg^{-1}; silt content = 153 g kg^{-1}; and sand content = 327 g kg^{-1}.

The experiment was set up as complete randomized block design with four replications. Plots were 13.1ft wide by 39.4ft long, with eight rows of corn (20 in row spacing), at 28,340 plants $acre^{-1}$ plant density. Phosphorus fertilizer was band-applied at 107 lb P_2O_5 $acre^{-1}$ with the planter using triple superphosphate (TSP), while potassium fertilizer was surface-broadcast applied one day before corn planting at 107lb K_2O $acre^{-1}$, as potassium chloride (KCl).

Treatments consisted of six N rates (0, 53, 107, 160, 214 and 267lb N $acre^{-1}$) as a blend of polymer-sulphur coated urea (PSCU) and NBPT-treated urea (TU) in a 70:30 ratio, respectively. The N fertilizer treatments were applied as subsurface band to avoid potential runoff or surface movement of the fertilizer. The PSCU is a fertilizer with 39% N and the TU 45% N. Nitrogen fertilizers were hand applied in hoe-opened furrows at 2in depth and 4in away from the corn rows and then covered with soil. Corn (DEKALB 390 VT PRO) was planted after N-fertilizers furrows were closed.

A micro-plot 4.92ft wide and 4.92ft long (three corn rows) to apply non-labeled PSCU + ^{15}N-labeled NTU (1.6 atom% ^{15}N) was installed inside each plot, using the same N rate of the commercial N fertilizer applied on the rest of the plot. Two plants from the micro-plots were sampled at V4, V12, R2 from the left and the right corn rows. At harvest (R6), two plants were sampled from the center corn row of the micro-plots. The samples were collected from the field, separated into leaves (leaves + tassel + husk leaves), stem, cob and grain, dried in a forced air oven at 65ºC for 5 days, then weighed and finely milled (2 mm screen) for determination of total N and ^{15}N abundance in a mass spectrometer (Barrie and Prosser, 1996).

In this study, total nitrogen uptake in the control treatments (no N added) was assumed to be the total N derived from the soil (NDFS). This value was used for other treatments with N application, and was assumed that N fertilization has no effect on plant uptake efficiency of the soil N pool. This approach (using the difference method as in Stevens et al., 2005b) may underestimate the N added interaction (NAI) value or the so-called “priming effect” (Stevens et al., 2005a). Nevertheless, we believe this approach has a potential to estimate the N uptake by corn plants from two different N sources in a blend and to give an approximate value of corn N uptake from the soil as well.

Fertilizer recovery efficiency for NTU (FRENTU) (%), N derived from NTU (NDFNTU) (% and lb N $acre^{-1}$) were measured at V4, V12, R2 and R6, and calculated using equations 1, 2 and 3.

$$FRETU\ (\%) = \left(\frac{\left(\frac{^{15}Np}{^{15}Nf}\right) \times\ NU}{NTU} \right) \times 100\ \times 2 \qquad (Eq. 1)$$

where ^{15}Np is the abundance of ^{15}N in excess at the different plant-components (%): leaves, stems, cobs and grains; ^{15}Nf is the abundance of ^{15}N in excess in the fertilizer applied (%); NU is the N uptake (lb N acre^{-1}) at the different plant-components; and NTU is the amount of N applied as TU fertilizer (lb N acre^{-1}). This equation was used for sampling at the V4, V12 and R2 growth stage (Jhonson and Kurtz, 1974). Was assumed that 50 % of the N from fertilizer in the plant was taken up from the labelled fertilizer and 50 % from the conventional fertilizer, making it necessary to use the multiplication factor 2 on equation 1 (Jhonson and Kurtz, 1974). However, for sampling at R6 corn growth stage the factor 2 on equation 1 was not used because the sampling was performed in the center row, so corn plants had ^{15}N available at both sides of the row.

$$NDFTU\ (\%) = \left(\frac{FRETU\ \times\ NTU}{NU} \right) \qquad (Eq. 2)$$

where FRECU is the fertilizer recovery efficiency for TU (%); NTU is the amount of N applied as TU fertilizer (lb N acre^{-1}); and NU is the N uptake (lb N acre^{-1}) in the different plant-components.

To express NDFTU as lb N acre^{-1}, equation 3 was used.

$$NDFTU\ (lb\ N\ acre^{-1}) = \left(\frac{NDFTU\ (\%) \times\ NU}{100} \right) \qquad (Eq. 3)$$

where NDFTU is the N derived from TU (%); and NU is the N uptake (lb N acre^{-1}) in the different plant-components.

Fertilizer recovery efficiency for PSCU (FREPSCU) (%) and N derived from PSCU (NDFPSCU) (% and lb N acre^{-1}) were estimated at V4, V12, R2 and R6, and calculated using equations 4, 5 and 6.

$$FREPSCU\ (\%) = \left(\frac{(NU -\ NDFTU) - NDFS}{NPSCU} \right) \times\ 100 \qquad (Eq. 4)$$

where NU is the N uptake (lb N acre^{-1}) at the different plant-components; NDFTU is the nitrogen derived from TU (lb N acre^{-1}) at the different plant-components; NDFS is the N derived (lb N acre^{-1}) from the soil at the different plant-components; and NPSCU is the amount of N applied as PSCU fertilizer (lb N acre^{-1}).

$$NDFPSCU\ (lb\ N\ acre^{-1}) = NU - NDFS - NDFTU \qquad (Eq. 5)$$

where NU is the N uptake (lb N acre^{-1}) at the different plant-components; NDFS is the N derived from the soil (lb N acre^{-1}) at the different plant-components; and NDFTU is the N derived from TU (lb N acre^{-1}) at the different plant-components.

To express NDFPSCU as %, equation 6 was used.

$$NDFPSCU\ (\%) = \frac{NDFPSCU}{NU} \times 100 \qquad (Eq. 6)$$

where NU is N uptake (lb N acre^{-1}) at the different plant-components.

RESULTS AND DISCUSSION

Results from the study show a significant N uptake by leaves between the V4 -V12 growth stage (Figure 1). Bender et al. (2013) estimates a requirement of 7.9lb N per day between V10 and V14. Between V12 and R2, the amount of N uptake was lower. Leaves N content by R6 was decreased by half compared to N content at R2, suggesting a significant N redistribution to the grain. Stem N uptake was consistent between V12 and R6. According to Bender et al., (2013) the peak of N uptake is observed at R2. Cob N uptake decreased between R2 and R6, suggesting N remobilization. Grain N uptake increased dramatically between R2 and R6, likely from the redistribution process as well as from the soil (indigenous soil N + fertilizer N) by continuous and active uptake.

At V4, an average of 74% of the plant N was derived from the soil, 20% from TU and 6% from PSCU (Figures 1 and 2). This suggest a relatively slow corn root development at the stage and perhaps limited access to the N fertilizer bands. A higher N uptake at V4 from TU suggest a faster release of N compared to PSCU. This release pattern agrees with previous studies (Trenkel, 2010). For later sampling in the season, the NDFTU treatment went from 20 to 15, 9 and 10% of the total N uptake (V4, V12, R2 and R6). This suggests an increase on the N uptake from PSCU, as NDFS decreased, from 74 at V4 to 53% at V12. These results show the complex dynamic of N in the soil-plant system and the potential contribution of slow release N fertilizers. As N rate increased, more N in the plant was derived from fertilizers. Nevertheless, the main N source for corn plants was the soil N (average of 58% at harvest), highlighting the importance of the soil N mineralization processes for appropriate plant N nutrition. At harvest, the N from TU and PSCU components were a total of 42% of the total N uptake (Figure 2).

The recovery of TU was several times higher than PSCU at the V4 sampling, with lower FRE for the higher N rates (Fig 3). At V12 and R2, FRE for TU increased linearly with N rates, while for PSCU it was the opposite. At R6, the two N fertilizers showed higher FRE at lower N rates. From V12 to R6, PSCU showed consistently higher FRE than TU.

These findings show the importance of blending a slow release N source with a more rapidly available N source. This approach can secure a source of N for the early growth stages as well as good N supply later in the season (Payne et al., 2015). Fertilizer recovery efficiency is a key factor in modern agriculture. Applying less fertilizer than crop requirements can lead to decrease in yields and soil nutrient depletion, while over application of fertilizers can lead to severe environmental impacts and economic losses (Roberts, 2007). Approaches like the one used in this study can be adopted as a tool to estimate the fate of N fertilizer under various cropping systems utilizing slow release N fertilizers as an alternative to improve NUE.

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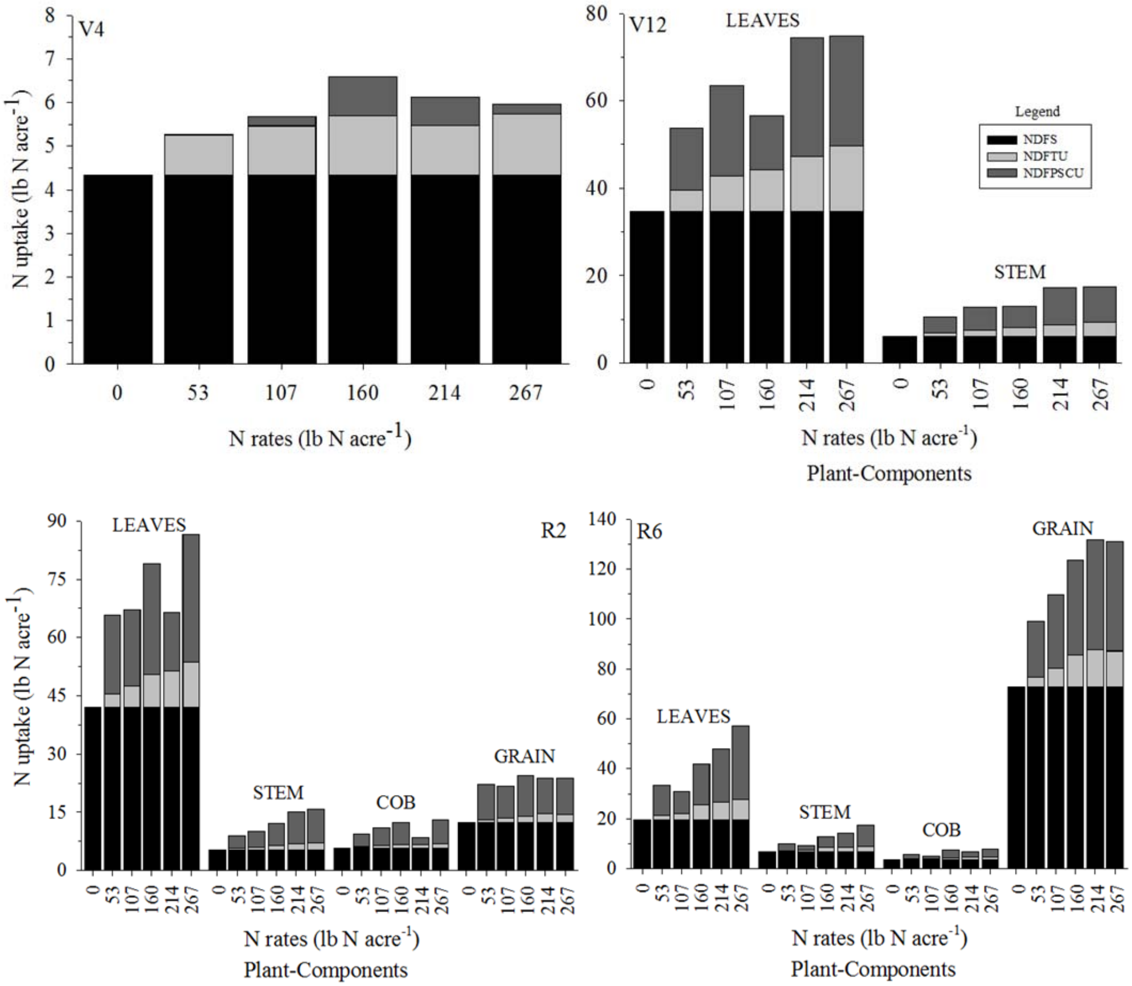

Figure 1. Nitrogen uptake and N derived from the soil (NDFS), from polymer-sulphur coated urea (NDFPSCU) and from NBPT-treated urea (NDFTU), and N allocation in plant-components (leaves, stem, cob and grain) evaluated at various N rates (0, 53, 107, 160, 214 and 267 lb N acre^{-1}), at four corn growth stages (V4, V12, R2 and R6), at Iracemápolis, São Paulo, Brazil, during the 2015-2016 growing season.

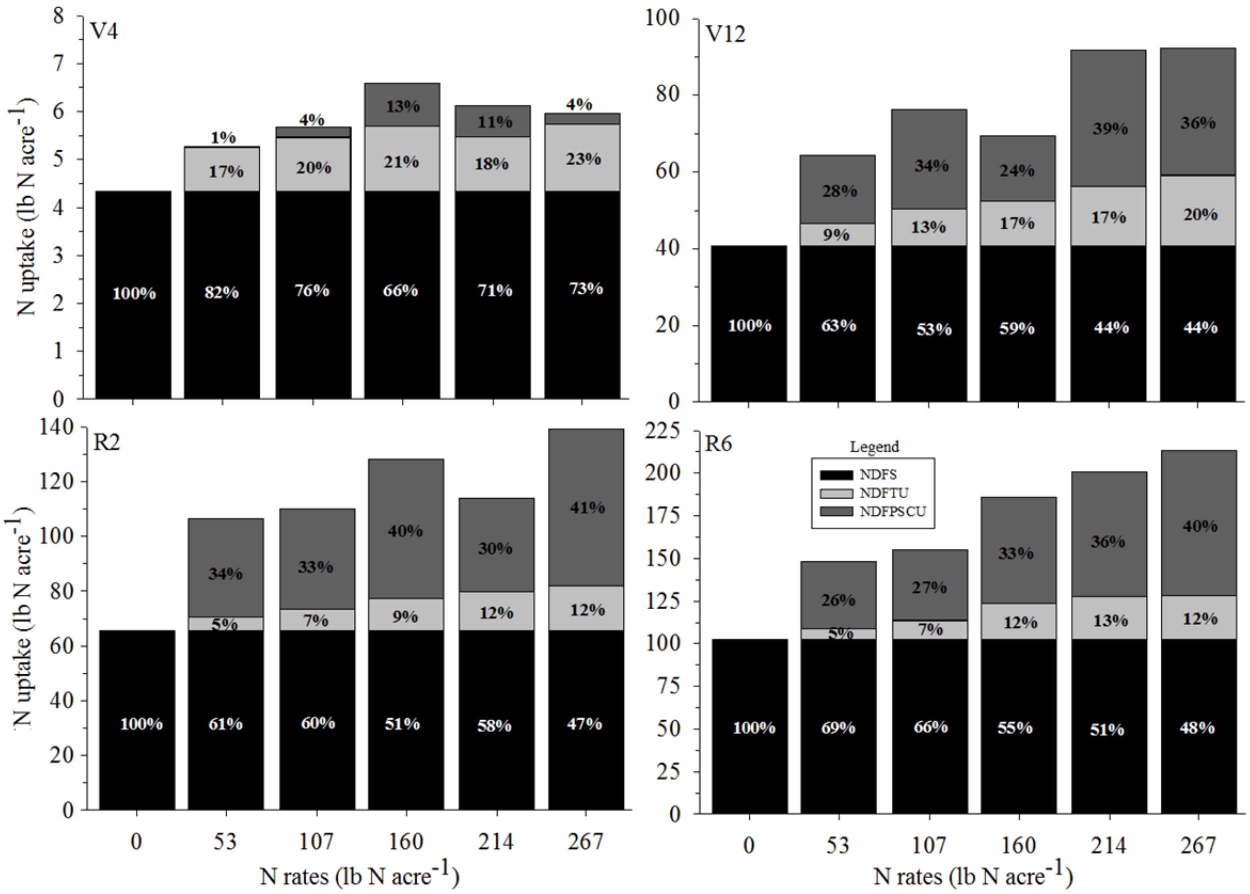

Figure 2. Total nitrogen (N) uptake by corn plants (sum of plant-components: leaves, stems, cobs and grain) and nitrogen derived from the soil (NDFS), polymer-sulphur coated urea (NDFPSCU) and NBPT-treated urea (NDFTU), and their proportional participation of the corn total N uptake, at various N rates (0, 53, 107, 160, 214 and 267 lb N acre^{-1}), at four corn growth stages (V4, V12, R2 and R6) at Iracemápolis, São Paulo, Brazil, during the 2015-2016 growing season.

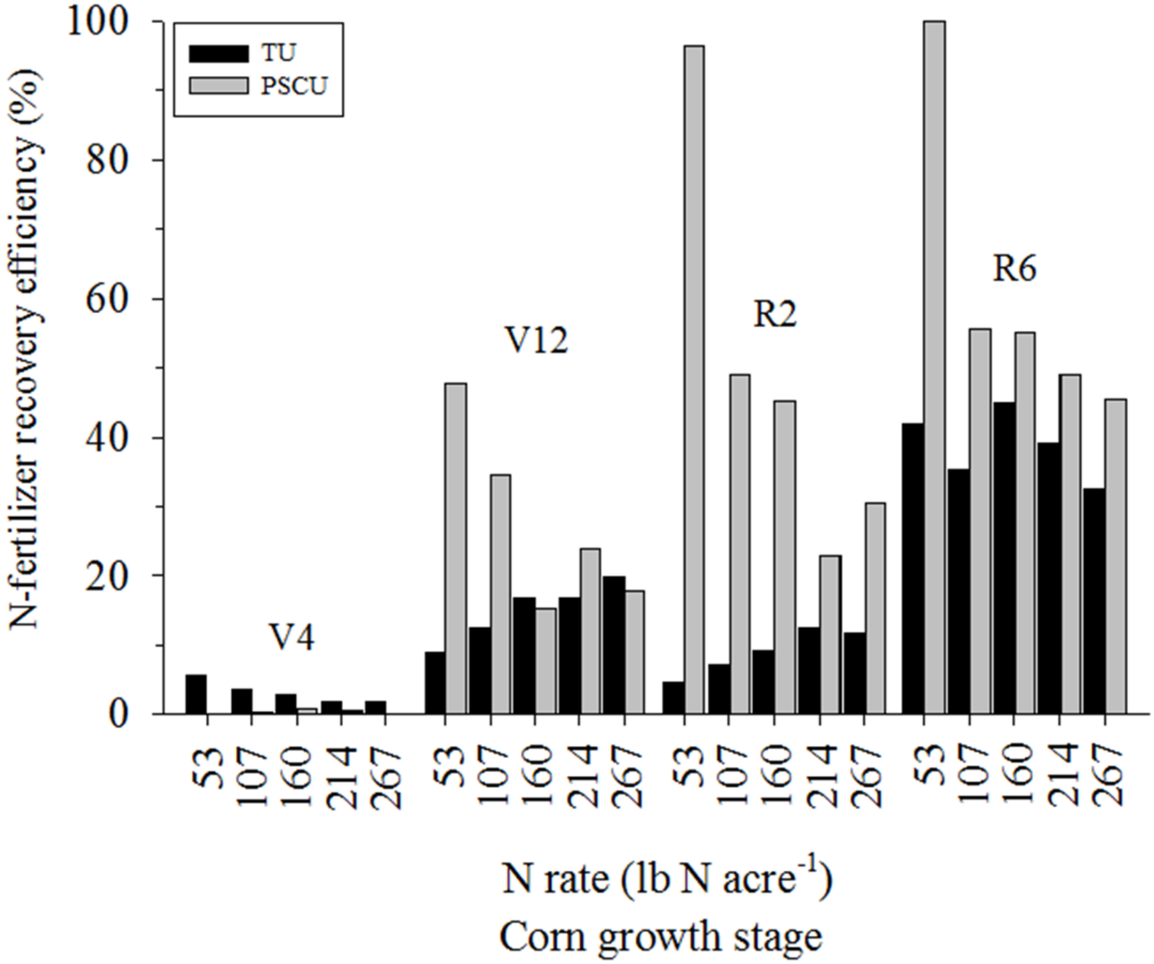

Figure 3. Nitrogen fertilizer recovery efficiency for polymer-sulphur coated urea (PSCU) and NBPT-treated urea (TU) at various N rates (0, 53, 107, 160, 214 and 267 lb N acre^{-1}), at four corn growth stages (V4, V12, R2 and R6) at Iracemápolis, São Paulo, Brazil, during the 2015-2016 growing season.

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