Journal of Plant Nutrition

ISSN: 0190-4167 (Print) 1532-4087 (Online) Journal homepage: http://www.tandfonline.com/loi/lpla20

Fertilizer Placement to Maximize Nitrogen Use by Fescue

Charles W. Raczkowski, David E. Kissel, Merle F. Vigil & Miguel L. Cabrera

To cite this article: Charles W. Raczkowski, David E. Kissel, Merle F. Vigil & Miguel L. Cabrera (2016): Fertilizer Placement to Maximize Nitrogen Use by Fescue, Journal of Plant Nutrition, DOI: 10.1080/01904167.2016.1143491

To link to this article: http://dx.doi.org/10.1080/01904167.2016.1143491

Accepted author version posted online: 01 Feb 2016.

Fertilizer Placement to Maximize Nitrogen Use by Fescue

Charles W. Raczkowski[1,*], David E. Kissel[2], Merle F. Vigil[3], Miguel L. Cabrera[4]

[1]North Carolina A&T State University1601 East Market Street, Greensboro, NC 27411

[2]Crop & Soil Sciences Department, The University of Georgia

[3]USDA-ARS, Central Plains Resources Management Research

[4]Crop & Soil Sciences Department, The University of Georgia

[*]Address Correspondence to Charles W. Rackowski: raczkowc@ncat.edu

ABSTRACT

The method of fertilizer nitrogen (N) application can affect N uptake in tall fescue and therefore its yield and quality. Subsurface-banding (knife) of fertilizer maximizes fescue N uptake in the poorly-drained clay-pan soils of southeastern Kansas. This study was conducted to determine if knifed N results in greater N uptake than the conventional top-dress application method in a deep, well-drained soil of east-central Kansas. The experiment, conducted in a Smolan silty clay loam soil, was a split-plot with fertilizer nitrogen rates 0, 140 and 280 kg N ha^{-1} applied as urea-ammonium nitrate (UAN, 28% N), knifed or top-dressed. Soil inorganic N (ammonium (NH_4)- and nitrate (NO_3–N)) and N in roots and plant tops were measured at various times during the growing season. At final harvest, most of the knifed N (99.7%) was accounted for in plant tissue (roots and tops) and soil, with more than half of the knifed N remaining as soil inorganic N. With the top-dressed method, 27% was unaccounted for and presumed lost in gaseous form. Knifing fertilizer N in fescue fields of east-central Kansas will maximize the availability of N, reduce potential N losses, and increase forage quality.

Keywords

fertilizer application method, fertilizer nitrogen recovery, nitrogen uptake, forage yield

 ACCEPTED MANUSCRIPT

INTRODUCTION

A major factor affecting fescue nitrogen (N) uptake, yield, and quality is the fertilizer application method used. Although not as effective as other placement methods, top-dressing of N is a common practice with cool season grasses in Kansas. Studies conducted in the 1980's and 1990's showed greater fescue N uptake and forage yield when subsurface-banding (knifed) than when surface broadcast (top-dressed) (Lamond and Moyer, 1983; Lamond et al., 1984; Moyer et al., 1985; Sweeney and Moyer, 1987; Moyer and Sweeney, 1995). Surface-banded (dribble) N also produced greater fescue yield and improved forage quality relative to top-dressed N (Lamond et al., 1984; Moyer et al., 1985). Using N^{15} tagged urea-N, Raczkowski and Kissel (1989) found that 23 % of the N could not be accounted for (presumed denitrified and/or lost as ammonia) when urea was top-dressed, but no losses of N occurred when the urea was knifed.

The above referenced studies were conducted on Parsons silty clay loam (fine, mixed, active, thermic Mollic Albaqualfs) soil, a poorly-drained clay-pan soil in southeastern Kansas. Our experiment was conducted on a deep, well structure soil in east-central Kansas to determine if the responses to fertilizer N placement in this well-drained soil differ from those obtained in southeastern Kansas. Although the study was conducted in 1983, we believe that documenting results will impact current fertilizer management decisions made by pasture growers in all regions of the state. The study objective was to evaluate fescue growth, N uptake, and soil inorganic N levels as affected by fertilizer N rate and placement method.

MATERIALS AND METHODS

The experiment was conducted at the Kansas State University farm, Manhattan, KS, in a Smolan silty clay loam (fine smectitic, mesic, Pachic Argiustolls) soil. Soil properties of the upper 15 cm were: 12 μg g^{-1} phosphorus by Bray 1, 322 μg g^{-1} potassium, 3.2% organic matter, cation exchange capacity 220 mmol kg^{-1}, and pH 7.4.

The experimental design was a split-plot with 3 replications, nitrogen fertilizer treatments assigned to main plots, and main plots divided into 5 subplots, each subplot used for a different sampling date. Main plots were 10 by 2.5 m. The six main plot treatments were a factorial combination of fertilizer placement methods top-dress and knife, and nitrogen rates 0, 140 and 280 kg N ha^{-1}. Urea-ammonium nitrate (UAN, 28% N) solutions were metered through a John Blue positive displacement pump (John Blue, Huntsville, AL), driven by the ground-speed power take-off of the tractor. Top-dressing was done using a spray boom with flat-fan-spray nozzles, attached to the three-point hitch of a Massey Ferguson tractor (Massey Ferguson, Des Moine, IA). Knifing consisted of injecting the UAN solution 15 cm deep with ammonia applicator shanks spaced 50 cm apart. Triple superphosphate was surface broadcast on all plots at the 35 kg P ha^{-1} rate before applying treatments, which were imposed on while the fescue was dormant on March 18, 1983.

Table 1 shows soil and plant sampling dates. A schematic diagram of the soil and plant sampling in knifed N subplots is shown in Figure 1. Plants were hand harvested at a cutting height of 2.5 cm from an area 50 x 150 cm. In knifed N subplots the harvested area included the three central bands. Plant samples were dried at 65°C, weighed, ground in a Wiley mill, and stored for total N analysis. In top-dressed N subplots, ten soil core samples (2.5 cm diam.) were collected from the harvested area and sectioned into soil depth segments 0 to 10, 10 to 20, 20 to 30, 30 to 60 and 60 to 90 cm. In knifed N subplots, 50 x 25 cm pits were dug centered over the three bands on the harvested area (Figure 1B). Soil was removed in the same depth increments as in the top-dressed

N subplots. All soil samples were immediately air-dried, ground to pass a 2-mm sieve, extracted, and analyzed for inorganic N. Roots were sampled from unfertilized and 280 kg top-dressed N ha^{-1} subplots by core sampling (10-cm diam. core) of the upper 30 cm of soil and sectioning the cores into depths 0 to 10, 10 to 20, and 20 to 30 cm. Roots were washed, dried at 65^{o}C, weighed, and ground for analysis. All plants were analyzed for total N concentration following digestion using a modified salicylic acid-thiosulfate procedure described by Bremner and Mulvaney (1983). Total N in plant digests and ammonium (NH_4-) and nitrate (NO_3-N) were determined with colorimetric procedures using a dual-channel Technicon Autoanalyzer (Technicon Industrial Systems, 1977a, 1977b).

RESULTS AND DISCUSSION

Application of fertilizer N increased fescue dry matter significantly for both methods of application (Figure 2). At the low N rate, slight differences in dry matter were found between methods prior to the final June 17th measurement. The average final dry matter produced by both methods was 7,484 kg ha^{-1}. Conversely, differences were found on most dates at the high N rate. Dry matter on June 17th was 1,097 kg ha^{-1} higher in the top-dress method than in the knife method. Fescue N concentration was slightly lower in the knifed method than in the top-dress method early in the growing season, but increased rapidly to a much higher level as the season progressed. On June 17th the knife method had 0.33 % and 0.34 % more forage N than the top-dress method respectively for the low and high N rates. Measurements of N uptake on this date showed 22.4 kg N ha^{-1} more uptake in the knifed method than in the top-dress method at the low N rate and 13.4 kg N ha^{-1} more uptake at the high N rate.

 ACCEPTED MANUSCRIPT

Collectively, the dry matter, % N, and N uptake data indicate that top-dressed N was assimilated more rapidly than knifed N early in the season, whereas significant absorption of knifed N by roots occurred at later stages of plant development. Spreading N over the entire surface root mass in a zone of higher soil temperatures for greater root absorption of N is a plausible reason why more N was absorbed early from the top-dress method. In contrast, early absorption of the knifed N is limited to the fewer roots that are adjacent to the fertilizer band. Also, root activity may be lower at the band depth due to low soil temperatures.

Despite the greater N uptake with the knifed method, particularly with the higher N rate, dry matter yield was significantly less than with the top-dress method. This likely resulted because of less N absorption by plants located farther from the band. In general, plants growing directly over the knifed band grew more than plants between bands, creating a wavy pattern of growth and thereby reducing overall yield.

Fertilizer N levels in soil decreased more rapidly when N was top-dressed than when knifed (Figure 3). A significant amount of fertilizer N remained unused by June 17th in the high N rate knifed treatment (280 kg N ha^{-1} knifed). On the first sampling date (March 28) all fertilizer N was accounted for in the high N rate knifed treatment as soil inorganic N. In the low and high N rate top-dressed treatments the fertilizer N accounted for as inorganic N was 25% and 49%, respectively. Because of the existing low soil surface temperatures, and because the fescue was still in a dormant stage, we anticipated to find much of the unaccounted N in the root system.

A total of 113.5 kg N ha^{-1} of the top-dressed 280 kg N ha^{-1} (40.5 % of the applied N) was found in roots on May 9th (table 2). Most of this N was present in the upper 10 cm soil layer (105.3 kg N ha^{-1} or 37.6 % of the applied N). As shown by the June 17th data, much of this N remained in the upper 10 cm root mass by final harvest. About 29.2% of the top-dressed N (81.8 kg N ha^{-1}) was found in roots on June 17th suggesting that little of the N absorbed early by roots moved to plant tops. Much of this N may have been present in plant crowns since they were included with the upper 10 cm root samples. In general, these results suggest that below ground plant components were N deficient and because of the large crown and root mass, large amounts of fertilizer N were assimilated and immobilized. Below-ground plant components have been recognized as significant sinks of applied fertilizer N (Power and Alessi, 1971) and this N may remain immobilized for long time periods (Power, 1980).

Fertilizer N recoveries in plant tops, roots, and soil for the high N rate top-dress and knife treatments are shown in table 3. Fertilizer N recovered in plant tops did not differ between treatments averaging 40.2%. More than half (58.1 %) of the knifed N remained as soil inorganic N, whereas only 6.9 % remained in the top-dress treatment. Roots in the top-dress treatment contained 28 % of the applied N fertilizer. Root fertilizer N was not measured in the knifed treatment but it was presumably low based on the 99.7 % recovery when plant tops and soil N are added. The unaccounted fertilizer N (26.5 %) in the top-dress treatment may have been lost by volatilization or immobilized by soil microbes. Whichever mechanism was involved the loss occurred early in the growing season since inorganic N levels depleted fastest during this time. In a fescue study in southeast Kansas, using N^{15}-tagged fertilizer, gaseous losses were 23 % of the top-dressed urea N (Raczkowski and Kissel, 1989).

CONCLUSIONS

We found greater total N recovery of applied fertilizer N by tall fescue with both N rates when knifing UAN, and greater forage yield with top-dressed UAN at the higher N rate. The yield advantage with the top-dress treatment was the result of greater initial N uptake with this method. Specifically, top-dressed N was uniformly and readily available to the stand of fescue early in the growing season, whereas knifed N was available initially only to those plant roots growing in the direct vicinity of the fertilizer band. However, because the knifed N was below the soil surface and placed in a concentrated zone, a greater accounting of that N was ultimately measured in plant tissue and in the soil. At the final forage harvest, more than half (58.1%) of the knifed N remained in the soil as inorganic N, still available for subsequent cropping. On the other hand, only 6.9% of the applied broadcast N remained in soil. With the knifed treatment, 99.7% of the N applied could be accounted for in plant tissue and in the soil. Whereas with the top-dress method nearly 27% was unaccounted for and presumed to be either denitrified or lost as ammonia from the soil surface. The significant suspected losses of broadcast N to the atmosphere is an important finding with respect to fertilizer use efficiency and to atmospheric gas exchange.

Knifing fertilizer N in fescue fields of east-central Kansas will maximize the availability of N, reduce potential losses of N and increase forage quality.

REFERENCES

Bremner, J.M., and C.S. Mulvaney. 1983. Total nitrogen. In L.A. Page et al. (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:595-624.

Lamond, R.E., and J.L. Moyer. 1983. Effects of knifed vs. broadcast fertilizer placement on yield and nutrient uptake by tall fescue. Soil Science Society of America Journal 47:145-149.

Lamond, R.E., L.S. Murphy, and P.J. Gallagher. 1984. Effect of nitrogen solution application method on smooth bromegrass performance. Journal of fertilizer Issues 1: 91-94.

Moyer, J.L., R.E. Lamond, and K.W. Kelly. 1985. Effect of fertilizer solution application method on tall fescue performance. Journal of fertilizer Issues 2:111-116.

Moyer, J.L., and D.W. Sweeney. 1995. Response of tall fescue to fertilizer placement at different levels of phosphorus, potassium, and soil pH. Journal of Plant Nutrition 18:729-746.

Power, J.F., and J. Alessi. 1971. Nitrogen fertilization of semiarid grasslands: Plant growth and soil mineral N levels. Agronomy Journal 63:277-280.

Power, J.F. 1980. Response of semiarid grassland sites to nitrogen fertilization: I. Plant growth and water use. Soil Science Society of America Journal 44:545-555.

Raczkowski, C.W., and D.E. Kissel. 1989. Fate of subsurface-banded and broadcast nitrogen applied to tall fescue. Soil Science Society of America Journal 53: 566-570.

Sweeney, D.W., and J.L. Moyer. 1987. Effect of fluid fertilizer placement and fertilization schemes on yield and N content of tall fescue. Journal of fertilizer Issues 4:36-42.

Technicon Industrial Systems. 1977a. Industrial/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Industrial method no. 334-74W/Bt. Tarrytown, NY.

Technicon Industrial Systems. 1977b. Nitrate and nitrite in soil extracts. Industrial method no. 487-77A. Tarrytown, NY.

 ACCEPTED MANUSCRIPT

Table 1. Soil and plant sampling dates during the 1983 growing season.

Date	Samples Collected
March 18†	Fertilizer Applied – No samples
March 28	Soil
April 29	Soil, Plant Tops
May 9	Soil, roots, plant tops
May 31	Soil, plant tops
June 17	Soil, roots, plant tops

† - no samples were collected on this date.

Table 2. Fertilizer N in roots for the 280 kg N ha^{-1} top-dressed treatment.

Soil depth -- cm --	Sampling Date	
	May 9th	June 17th
	kg N ha^{-1}	
0 - 10	105.3 (37.6) †	79.5 (28.4)
20-Oct	7.1 (2.5)	2.3 (0.8)
20 - 30	1.1 (0.4	0.0 (0.0)
0 - 30	113.5 (40.5)	81.8 (29.2)

† - fertilizer N in roots was calculated as: (kg N ha^{-1} fertilized treatment) – (kg N ha^{-1} unfertilized treatment); value in parentheses is % of N applied.

Table 3. Estimated N fertilizer recoveries for top-dress and knife application methods at the 280 kg N/ha rate.

Treatment	N Component			Component Sum
	Plants	Roots	Soil	
280 kg N/ha	kg N/ha			
Top-dressed	108.9	77.6	19.2	575.7
(% Fertilizer Recovered)	*-38.9*	*-27.7*	*-6.9*	*-73.5*
280 kg N/ha				
Knifed	116.6	Not Measured	162.6	279.2
(% Fertilizer Recovered)	*-41.6*		*-58.1*	*-99.7*

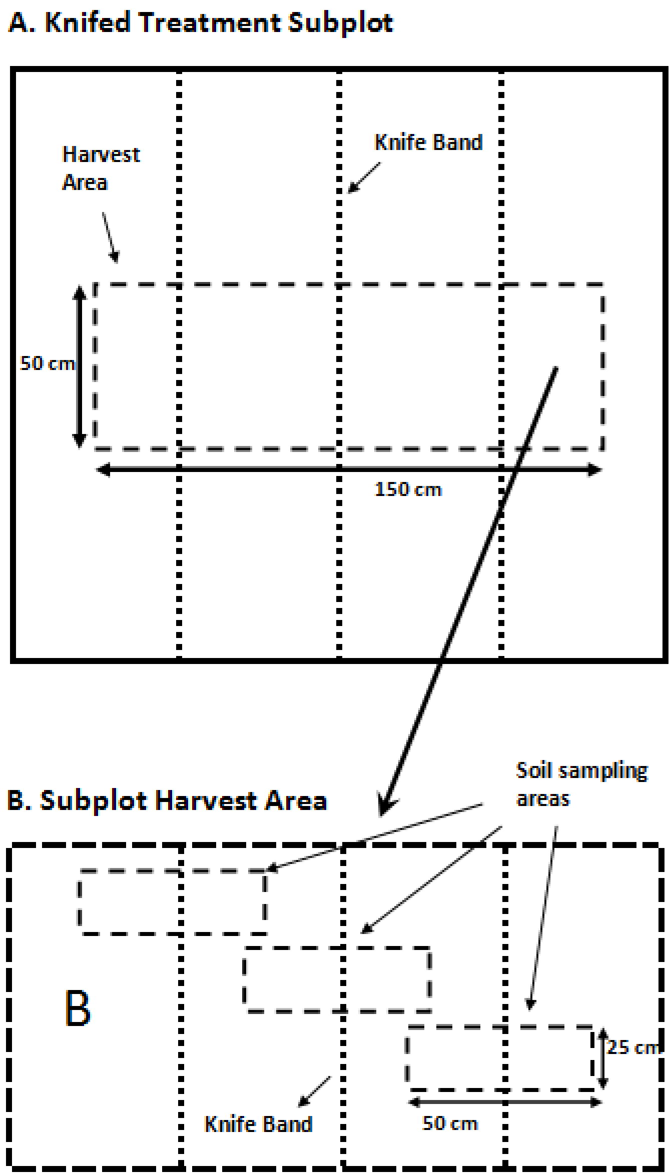

Figure 1 Layout showing a harvest area within a knifed treatment subplot (A) and soil sampling areas within the harvest area (B).

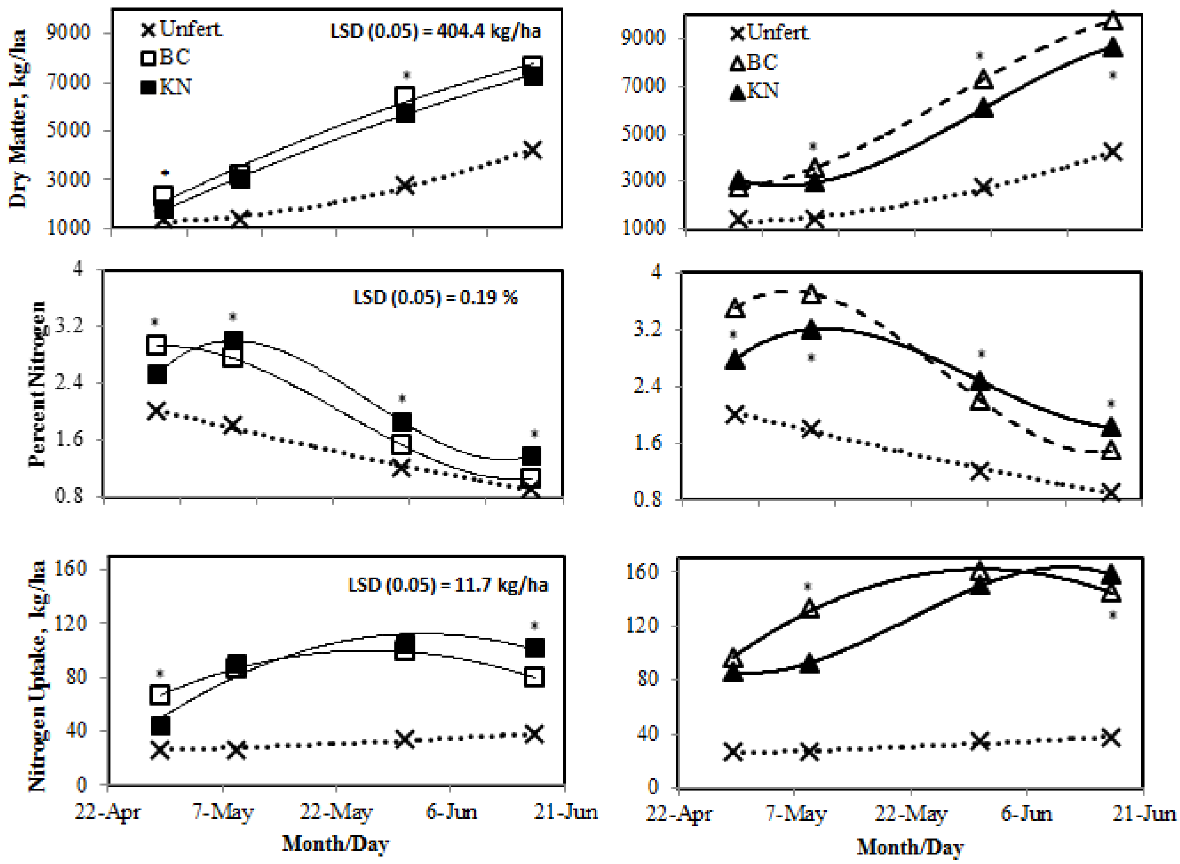

Figure 2 Fescue dry matter, N concentration and N uptake as affected by top-dressed and knifed N at the 140 and 280 Kg N/ha rates. Fisher's protected LSD values are to compare any two treatments (application method/N rate combination) at a specific date. A significant BC vs. KN effect tested using Fisher's Protected LSD at the 5% probability level is denoted as '*'.

 ACCEPTED MANUSCRIPT

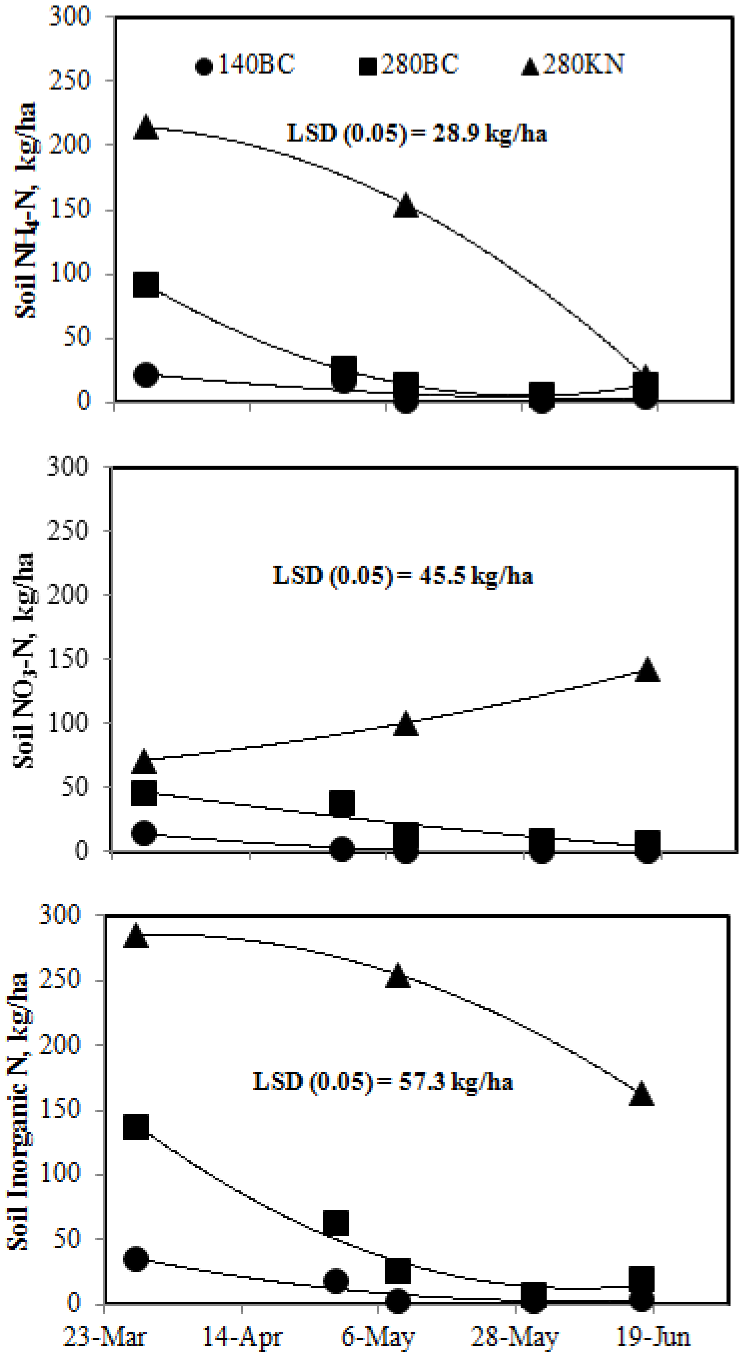

Figure 3 Fertilizer N (fertilized treatment N – unfertilized treatment N) in the upper 90 cm of soil

following knifed UAN fertilizer at 280 kg N/ha (280KN) and top-dressed UAN at 140 kg N/ha (140BC). Fisher's protected LSD values are to compare any two treatments (application method/N rate combination) at a specific date.

