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Nitrogen Management in No-till and Conventional-till Dual-use Wheat/Stocker Systems[1]

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ABSTRACT

Winter wheat in the Texas Rolling Plains is utilized both as forage and grain crop on more than 50% of the wheat sown, and employs conventional tillage in a semi-arid region prone to severe soil erosion by wind and water. The study compared forage and grain yield response to pre-plant and top-dress N application in no-till and conventional-till dual-use wheat production systems. Five pre-plant N levels, two tillage systems, and one top-dress N application were evaluated. There was a linear increase in forage production with increasing pre-plant N application, and no significance difference in forage yield between conventional- and no-till in 3 of 4 yr. Grain production increased with increased pre-plant N, while top-dressed N enhanced grain yield an additional 20 to 40%. In 2 of 4 yr, conventional-till resulted in increased grain yield over no-till by about 10 to 12 %. Top-dressed N resulted in significant yield increases in all pre-plant N treatments but with the greatest yield increases from the 0 and 34 kg ha^{-1} pre-plant N treatments. Soil analysis data indicate that following poor wheat production years, residual nitrate N can be substantial and could offset N fertilizer requirements for the following wheat crop.

KEY WORDS: nitrogen fertility, dual-purpose wheat, grazing systems, conservation tillage

INTRODUCTION

More than 5 million hectares of hard red winter wheat are planted annually in the semiarid regions of Texas, Oklahoma, and New Mexico (Taylor et al., 2010). Crop production in the winter-active southern Great Plains is unique and versatile compared with other wheat-producing regions in the U.S. because of the common practice of utilizing wheat forage in stocker cattle grazing systems, with the option to terminate wheat grazing and still produce a grain crop (dual-use or dual-purpose systems), or as a hay crop (MacKown and Carver, 2005). Most research on winter wheat is conducted on grain-only systems. Less information is available concerning dual-use wheat production. Furthermore, studies that involve conservation tillage systems in dual-use wheat production are virtually non-existent, but important due to increasing wheat production costs and public sensitivity to environmental and land management issues.

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The use of winter wheat as a dual-use crop is a vital component of the agricultural economies of Texas, southern Kansas, eastern New Mexico, Oklahoma, and southeastern Colorado (Pinchak et al., 1996; Ralphs et al., 1997; Redmon et al., 1995; Shroyer et al., 1993). Furthermore, the wheat-stocker industry has a comparative advantage in this region because of the proximity of feedlots. In a 20-yr study, Epplin et al. (2001) showed net returns from dual-use wheat production in Oklahoma exceeded net returns from grain-only production 3 out of 4 years. Furthermore, Sij et al. (2007) in their phosphorous placement study showed that the dual-use system was clearly superior to the graze-out system. Dual-use wheat production is complex and requires a higher level of management than a grain-only wheat production system. Successful dual-use wheat production depends on planting date, planting rate, wheat variety, nitrogen fertility, grazing and livestock management, and grain yield (Kaitibie et al., 2003; Shroyer et al., 1993). Introducing an animal component in a dual-use wheat system increases the complexity of a host of management decisions in order to optimize economic return from forage, grain yield and quality, and beef production. For example, planting date is important to the development of adequate forage prior to placement of calves. Research has shown that forage production decreases with delayed planting dates while grain potential increases with delayed planting (Epplin et al., 2000; Hossain et al., 2003; Arzadun et al., 2006).

Due to the high nutritive value of wheat forage (Schlehuber and Tucker, 1967; Shroyer et, al., 1993), it has been estimated that, annually, 30 to 80% of the wheat planted in the southern Great Plains is grazed to varying degrees (Krenzer et al., 1992; Pinchak et al., 1996; True et al., 2001). The value of forage based animal weight grains relative to the value of grain (Epplin et al., 2000; Hossain et al., 2003) is the single most important consideration in dual-use wheat production since management decisions need to be made on planting date, availability of stockers, stocking rate, beef prices, fertility, soil moisture, wheat cultivar, field by field grazing potential, and grain yield potential (Arzadun et al., 2003; Shroyer et, al., 1993). Farmers and ranchers tend to utilize wheat entirely as a forage crop (graze-out) if cattle prices are high relative to wheat grain, whereas they tend to remove cattle prior to the onset of the reproductive stage and allow the wheat to develop grain if wheat prices are high relative to cattle (graze-plus-grain). Termination of grazing is also a critical management decision. Pull-off date is dependent on when a given wheat variety reaches the early stages of reproductive development. Highest grain yields are associated when cattle are pulled off at ‘first hollow stem’ stage of growth (Redmon et al., 1996). A late cattle pull-off date can significantly affect grain yield and subsequent net returns from a dual-use system (Taylor, et al., 2010). Grazing 2 wk beyond first hollow stem can reduce grain yields 10% and additional 10% for each of the following 2 wk (Fieser et al., 2006).

Variable environmental conditions in semiarid regions of the world largely determine wheat forage and/or grain production (Arzadun et al., 2006; Bowman et al. 2008). In dual-use systems, wheat is generally planted in September under the conventional-till system that requires numerous field operations to prepare “clean” fields prior to seeding. Unfortunately, soil moisture is lost in the process. Without residue, wheat seedlings are unprotected from the desiccating and abrasive action of wind and blowing soil, or an unanticipated high rainfall event. Large areas become subject to replanting, creating costly delays in wheat establishment and plant growth needed in a graze and grain production system. Although many producers in the Southern Great Plains have been reluctant to adopt conservation tillage systems, conservation tillage holds promise in mitigating soil, nutrient, and moisture losses while reducing several key production costs (Ribera et al., 2004).

Inadequate weed control is cited as a limiting factor for producers in adopting reduced-tillage systems (Camara et al., 2003). Studies by Epplin et al. (1991) showed weed control costs were mainly responsible for no-till's uncompetitiveness with conventional-till in grain-only systems. More recently, herbicides, particularly glyphosate, have become more cost effective in controlling weeds. In a dual-use system, Bowman et al. (2008) showed no-till to be as effective as conventional-till and reduced-till in establishing small grain pasture when fall rainfall was adequate to establish the crop and superior to conventional-till and reduced-till when fall rainfall was delayed and soil moisture was maintained by summer chemical fallow. Although no-till has been reasonably successful on large farms in grain-only systems in north Texas, no-till has not been adopted in dual-use wheat due to perceived problems with compaction, forage production, seedling establishment, weed control, and grain yield. Tillage studies in Oklahoma in 2002-2005 by Decker et al. (2009) showed higher net returns for the conventional tillage, dual-use system while no-till generated greater returns for the forage-only systems on the larger farms. However, their results also show grain yield from the dual-use system to be higher than the later-planted grain-only system, which is not normally the case (Epplin et al. 2000; personal communication, Stan Bevers, Texas AgriLife Extension Economist). Machinery and equipment costs as well as herbicide, fuel, labor, and fertilizer costs (plus farm size) impact profitability. However, farm size continues to increase due to economies of scale which impacts equipment costs, labor, and time spent in the field. Longer-term studies with no-till versus conventional-till are needed, since it is generally recognized by promoters of no-till that it may take 4 or 5 years to fully recognize the benefits of this conservation tillage practice..

For producers to accept no-till under dual-use wheat management, the system must be economically competitive with traditional conventional-till and produce adequate forage for beef cattle as well as grain yield. Nutrient management in dual-use systems, particularly N, can be more complex than forage-only and grain-only systems. Since N is an expensive input cost in wheat production, the main objective of this research was to evaluate and identify pre-plant and top-dress N fertilizer requirements on forage and grain production in a conventional-till and no-till wheat-stocker production system using free-ranging cattle.

MATERIALS AND METHODS

Research was initiated with a grain crop in 2004 and forage and grain crops in 2005, 2007 and 2008 at the Smith/Walker field research unit located about 16 kilometers south of Vernon, Texas (lat 34.057; lon -99.243). The soil was an Abilene clay loam (fine, mixed, superactive, thermic Pachic Argiustolls) with a 1 to 3% slope. Dryland crop production in semi-arid environments like the southern Great Plains poses a greater risk due to unforeseen prolonged droughts, hail, and high winds, as evidenced by failed grain yield in 2006 due to extreme drought.

The study was nested in a larger 14-hectare pasture that had been in no-till management for 4 yr. Crossbred stocker cattle (*Bos taurus* L) had initial average weight of 200 kg. Plot size was 6 m by 15 m. All fertilizer was surface applied as liquid material. Two tillage systems (no-till and conventional-till) were used. Only chemical weed control was used in the no-till system. The conventional-till system included multiple discings to remove the previous year's wheat stubble, maintain weed control, and prepare a clean seed bed. Fertilizer treatments were applied to the same plots each year in each tillage system. Pre-plant N treatments included 0, 34, 67, 101, and 135 kg N ha^{-1}, with and without 50 kg N ha^{-1} top-dressed each year in the January-early February time frame (tillering stage). A randomized complete block design with four replications was used. The entire test site received a pre-plant application of 45 kg ha^{-1} P_2O_5 as phosacid prior to initiating the study. The "Cutter" wheat variety was planted in mid-September each year at 67 kg ha^{-1}.

Approximately one week before animal placement, forage dry matter was determined for each plot by harvesting all forage to ground level with hand shears in two randomly-selected 0.5 m^2 quadrats. Subsequently, two 1.7 m^2 circular cages were randomly placed on each plot. Forage was harvested inside and in randomly-selected grazed areas outside one of the cages to determine forage production and forage availability in each plot. Following clipping, one cage was randomly repositioned (excluding clipped areas) within each plot and the procedure was repeated until cattle were removed at first hollow stem. Depending on environmental conditions and plant development, there were two to four forage harvest dates per year. The other cage remained in place to determine seasonal forage production in an ungrazed environment. Forage samples were dried at 50^0 C for 72 hours in a forced-air oven to determine dry weights. Forage protein was determined by Olsen's Agricultural Laboratory (McCook, NE) using the combustion method (AOAC method 968.06 and a Perkin Elmer 2410 combustion analyzer).

Two, 6 -m by 1.5 -m strips were machine-harvested with a plot combine from each plot and grain samples bulked to determine plot yield. Grain yield was adjusted to 130 gm kg^{-1} moisture content. Grain protein was determined by a NIR INFRATEC 1226 Grain Analyzer (Cereal Quality Laboratory, Texas A&M University, College Station). Data were analyzed using the Proc Mixed model procedure of SAS Institute (1996). Treatment effects were considered significant at $P \leq 0.05$.

There have been questions concerning the amount of N remaining in the soil profile following a failed wheat crop. Knowing this information would be helpful in determining pre-plant N application rates the following season, and perhaps improve the economics of dual-use wheat production. To aid in answering this question, soil samples were taken in August of each year following wheat harvest. Soil samples from all plots were separated into three sampling depths, bulked, and analyzed by year. In 2006, wheat was not harvested for grain due to drought (Figure 1). In 2007, wheat yields were the lowest of the 3 yr that produced grain (Figure 4).

RESULTS AND DISCUSSION

The distribution and timeliness of rainfall in late summer and fall are critical factors in establishing wheat stands and adequate forage production to support stocker cattle through the winter. In the southern Great Plains, drought is a constant threat to the dual-use production system. Figure 1 shows the rainfall patterns during wheat production over the course of the study and typical of the semiarid environment. Due to environmental conditions, it is uncommon to have two good wheat production years in sequence. Years that resulted in forage production for stocker cattle from December through February due to either pre-season or in-season rainfall include 2004-2005, 2005-2006, and 2006-2007. Forage production was inadequate due to drought during the typical grazing season in 2007-2008. However, precipitation beginning in February 2008 was adequate to produce a grain crop.

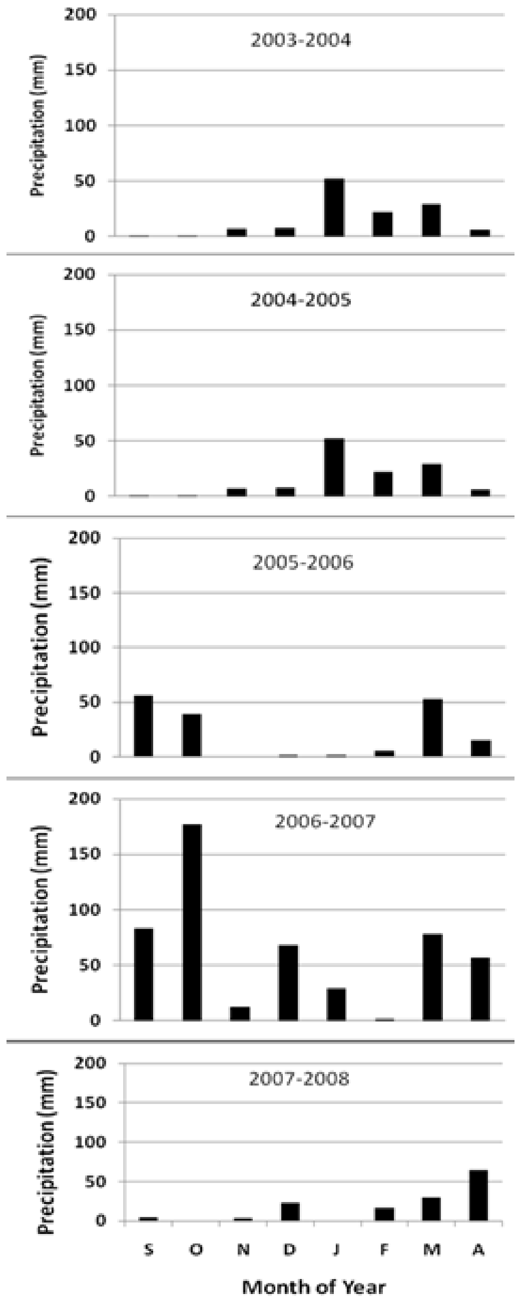

Figure 1. Precipitation patterns from September through April from 2003 to 2008 at Vernon, TX.

There was no interaction between tillage system and pre-plant N for forage production. Soil moisture level prior to planting and the rainfall pattern prior to the onset of cold weather that retards plant growth greatly affects forage development essential for acceptable beef cattle production. Due to adequate and timely rainfall, forage production in 2004-2005 increased linearly with increasing pre-plant N (Figure 2). Sparse rainfall the following growing season resulted in little forage production and no response to pre-plant N. The 2006-2007 growing season received excessive moisture, resulting in higher, but erratic, forage production among the pre-plant N treatments. Erratic forage production among N treatments may be due to field drainage patterns and low areas that allowed saturated soils to persist. This affected plant development in some plots and mean forage yield, most notably the 101 N kg ha^{-1} pre-plant treatment.

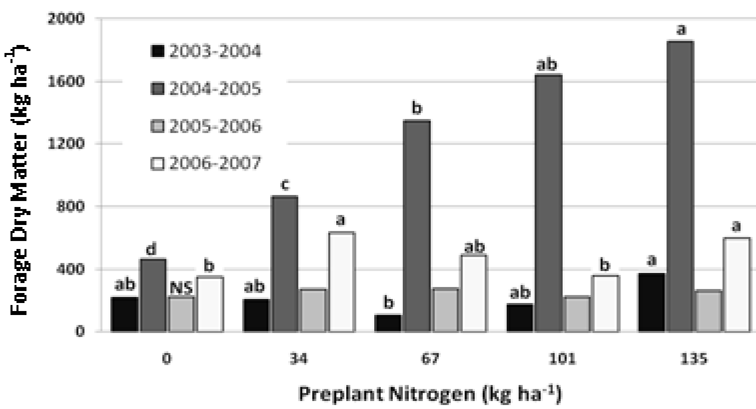

Figure 2. Effect of pre-plant N on forage production in the 4 yr that produced biomass. Within years, values followed by different letters within pre-plant N treatments are significantly different at $P \leq 0.05$.

Averaged over all pre-plant N treatments, only forage production from the 2005-2006 growing season was significantly different between conventional-till and no-till (Figure 3). It should be noted that the 2005-2006 growing season resulted in forage production that was also insufficient for commercial beef production. Therefore, in our opinion, the 2005-2006 data are questionable in interpreting tillage system benefits on forage production.

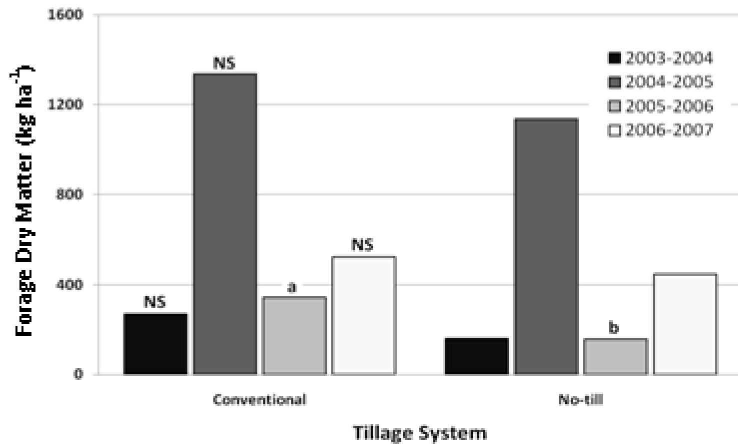

Figure 3. Forage production response by year to tillage system across pre-plant N treatments. Values followed by different letters within years are significantly different at $P \leq 0.05$.

There was no interaction between pre-plant N and tillage system for grain yield; therefore, the data were averaged over all pre-plant N treatments (Figure 4). In 2 out of 4 yr, there was no significant difference between tillage system and grain yield.

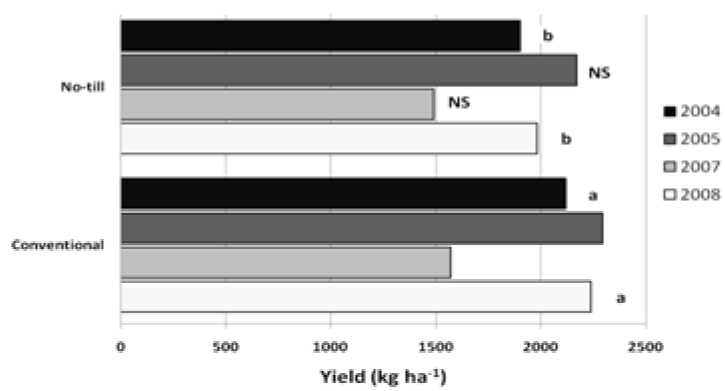

Figure 4. Grain yield response to pre-plant N treatment and two tillage treatments. Values followed by different letters within years are significantly different at $P \leq 0.05$.

There was no interaction for yield between tillage system and pre-plant and top-dressed applications of N fertilizer. Figure 5 shows the 4-yr average yield response to different levels of pre-plant N fertilizer with and without 50 kg N ha^{-1} top-dressed N. Pre-plant N at about 67 kg ha^{-1} appeared to maximize grain yield under the environmental conditions of this experiment. Top dressing N increased grain yield at all pre-plant N applications, except at the 67 kg ha^{-1}. Except perhaps at the highest pre-plant N application, top dressing 50 kg N ha^{-1} appeared to increase grain yield regardless of the amount of pre-plant N up to 101 kg ha^{-1} N (Figure 5). Our results are similar to those obtained in a grain-only, N application timing study that showed N application at tillering resulted in the highest grain yield (Melaj, et al. 2003). However, the greatest yield response to top-dressed N occurred at the 0 and 34 kg ha^{-1} pre-plant N treatments, and presumably provides the greatest economic return for the total amount of N applied.

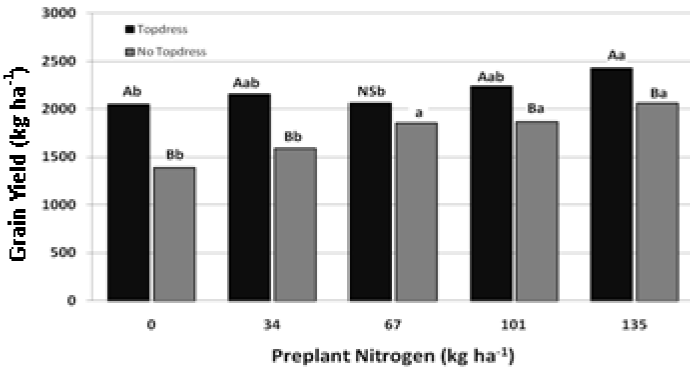

Figure 5. Effect of pre-plant N on grain yield with and without N top-dress across all years and tillage treatments (values followed by different capital letters within a pre-plant N treatment are significantly different at $P \leq 0.05$; similarly, values followed by different small case letters within no top-dress or top-dress treatments are significantly different at $P \leq 0.05$).

Forage protein is generally highest prior to the reproductive stage. Top dressing usually occurs in late January to early February in the Rolling Plains region while cattle are still on wheat pasture, but then removed in early March to allow a grain crop to develop. There was no tillage X year interaction on forage protein. Figure 6 shows forage protein from pre-plant only and pre-plant plus top-dressed plots on three selected N treatments. Over all years and tillage systems, forage protein increased with increased pre-plant N. Top-dressed N did not significantly increase forage protein over the pre-plant N-only treatments. Also, top-dressed N did not significantly increase forage protein with increased pre-plant N.

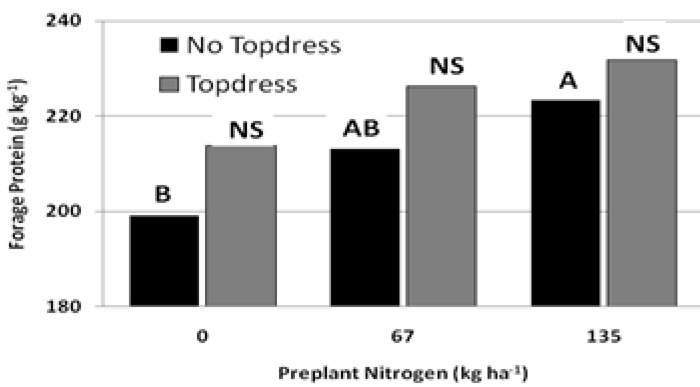

Figure 6. Forage protein from pre-plant only and pre-plant plus top-dressed plots on three selected N treatments. Values followed by different letters within no top-dress and top-dress N treatments are significantly different at $P \leq 0.05$.

There was no interaction between tillage system and N treatment on grain protein. In 3 of 4 yr, top-dressed N significantly increased grain protein (Figure 7). However, protein increases were marginal. Moreover, there is no economic justification to top-dress N for increased protein content alone, since producers in the Rolling Plains region do not receive a premium for grain protein content.

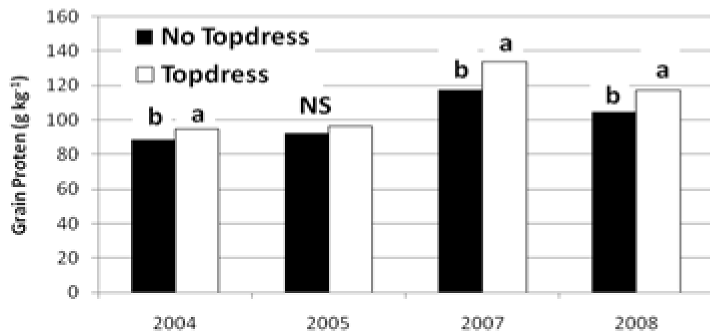

Figure 7. Effect of top-dressed N on grain protein for the 2004 – 2008 crop years. Values followed by different letters within years are significantly different at $P \leq 0.05$.

We attempted to determine the amount of residual nitrate in the soil following each wheat crop, since residual N impacts the cost of subsequent N inputs for the next season's crop. Except for 2007, nitrate levels were highest in the upper 15 cm of soil (Figure 8). The elevated nitrate level at the 15- to 30-cm depth in 2007 was most likely due to the leaching effect of higher precipitation in late spring (Figure 1) when over 400 mm of rainfall were recorded in May and June (data not shown). The elevated nitrate level in 2006 at the 0-15 cm depth reflects a failed wheat crop due to drought (Figure 1). These data indicate that following poor wheat production years, residual nitrate N may be substantial and could offset N fertilizer requirements for the following wheat crop. Soil testing to 60 cm is therefore suggested and could result in significant cost savings on N fertilizer.

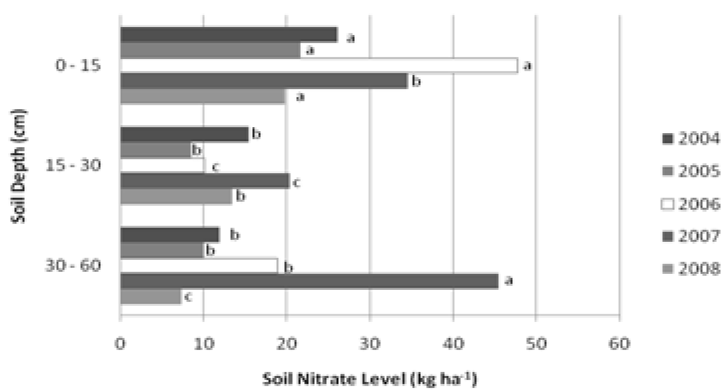

Figure 8. Residual nitrate levels following a wheat crop in the upper 60-cm of soil. Values followed by different letters within years are significantly different at $P \leq 0.05$.

CONCLUSION

A dual-use wheat production system increases the complexity of N fertilizer management in order to maximize forage, grain yield and quality, and beef yields. The current study evaluated and identified pre-plant and top-dress N fertilizer requirements on forage and grain production in a conventional-till and no-till wheat-stocker production system. There was a general linear increase in forage production with increasing pre-plant N application with no significant difference in forage yield between conventional- and no-till production systems in 3 of 4 years. Grain production increased with increased pre-plant N, while top dressed N further improved grain yield by 20 to 40%. In 2 of the 4 years conventional-till resulted in increased grain yield over that from no-till by about 10 to 12 %. Top dressing N resulted in significant yield increases in all pre-plant N applications but with the greatest yield increases when applied to the 0 and 34 kg ha^{-1} pre-plant N treatments, and presumably offers producers the greatest economic return for the amount of total N applied. Forage protein increased about 10% with increased pre-plant N applications from 0 to 135 kg ha^{-1} N, but top dressing N failed to increase protein over that of the top-dressed 0 kg ha^{-1} N pre-plant treatment. Top dressing N increased grain protein in 3 of 4 years, but the percent increase was marginal and would not bring a premium for grain quality. Our soil analysis data indicate that following poor wheat production years, residual nitrate N may be substantial and could offset N fertilizer requirements for the following wheat crop. Soil testing to 60 cm is therefore suggested and could result in significant cost savings on N fertilizer. With the prospect of improved management, technology, and equipment, our study provides supporting evidence that a no-till dual-use wheat production system can supply forage and grain yield comparable to a conventional-till dual-use wheat/stocker production system, while incorporating the positive environmental aspects of conservation tillage in a semi-arid environment.

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