ABOVEGROUND NITROGEN ACCUMULATION AS A FUNCTION OF TIME IN CORN AND WINTER WHEAT

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

Midseason fertilizer nitrogen (N) rates based on predicted yields can be projected since both corn (*Zea mays L.*) and winter wheat (*Triticum aestivum L.*) can accumulate significant quantities of N early in the growing season. This study was conducted to establish the amount of N accumulated in corn and winter wheat over the entire growing season. Plots representing three N fertilization rates (0, 45, and 90 kg ha^{-1}) and (0, 67, and 112 kg ha^{-1}) were selected from two long-term wheat experiments located at research stations in Stillwater and Lahoma, OK, in 2006 and 2007. For corn, three N fertilization rates (0, 112 and 224 kg ha^{-1}) and (0, 56 and 112 kg ha^{-1}) were selected from N studies, located at Lake Carl Blackwell (LCB) and Perkins, OK, also in 2006 and 2007. Sequential biomass samples were collected from 1 m^2 area clippings of wheat, and 1.5 m of row (0.76 cm spacing) for corn, throughout their respective growing seasons. Differences in total N uptake over the course of the growing season were strongly influenced by the environment. Thus, N uptake curves for either wheat or corn were noted to be unique by year and location. In general, this work showed that more than 45 percent of the maximum total N accumulated could be found in corn plants by growth stage V8. For winter wheat, more than 61 percent of the maximum total N accumulated at later stages of growth could be accounted for by Feekes growth stage 5. Our findings are consistent with those of others showing that yield potential can be predicted mid-season since such a large percentage of the total N accumulated was accounted for early on in the growing cycle of both wheat and corn.

CHAPTER I

INTRODUCTION

After water, nitrogen (N) is generally the most limiting factor in cereal crop production. Continuous crop production depletes soil N, therefore, the addition of N fertilizer is necessary to maintain yields. Since N is required in such large amounts, it tends to be a major economic factor in crop production. Raun and Johnson (1999) estimated N use efficiency (NUE) for world cereal grain production systems, encompassing all application schemes, to be close to 33 percent. A twenty percent increase in NUE for cereal production around the world would be worth \$10 billion annually (Raun, 2005). This low efficiency is partly due to loss of plant available N through several mechanisms which are primarily attributed to the lack of synchronization of plant demand and soil/fertilizer supply of N. The root cause of this problem is lack of technology and information on the peak time of N application during the growth of the crop where demand is high. Attempts have been made by researchers to understand peak growth stages of N uptake and accumulation by crops, optimum time of application, and movement and translocation of N within the plant. The literature documented contradicting information as to the growth stage in which wheat and corn accumulate N, the appropriate time of N fertilizer application to optimize use efficiency, and the translocation of N within the plant system. The previous research addressed specific work documenting N uptake in wheat and corn with limited number of sampling times. It is indispensable to collect comprehensive data over critical growth stages of these two crops to define the optimum growth stage for mid-season N application. Furthermore, accumulation of N as a function of time under limiting and non-N limiting conditions within the same trial has not been documented. Therefore the objectives of this study were to quantify the amount of N accumulated in winter wheat and corn over the entire growing season under limiting and non-N limiting conditions.

CHAPTER II

REVIEW OF LITERATURE

Dry matter accumulation and N uptake are closely associated (Justes et al., 1994; 1997) with critical N concentration. Previous research on wheat has shown that N accumulation by the grain is generally assumed to occur mainly before anthesis. Thus, by maturity, the plant already contains greater than 80 percent of its final N content (Austin et al., 1977). Hanway (1962) observed that early season N accumulation was relatively rapid; it decreased later in the season, and continued at a decreased rate until maturity, whereas Roy and Wright (1974) observed an almost linear increase in the accumulation of N until maturity.

According to Shanahan et al. (2004), in corn, a steady increase in dry matter and N uptake was observed between the V4 and V8 corn growth stages, after which a fast increase was measured between V8 and R2 where corn N requirements were anticipated to be high. From R2, another steady state increase was observed until R4, after which no increase in dry matter or N-uptake was measured. These authors recommended the window between V8 and R2 as the best time to apply side-dress N. Walsh (2006) recommends following pre-plant N applications with midseason side-dress N at or before the V10 growth stage to supply the growing corn with adequate N when it is required in the greatest quantities. Ma et al. (1999) found that only 20 percent of the total plant N was accumulated by V6, whereas N uptake increased considerably until two weeks after silking, accumulating 50-60 percent of the total plant N, then N uptake slowed and ultimately stopped. A by-plant corn study shows that forage N uptake can be predicted from growth stages V8 to V10 (Raun, 2005). A study by Licht and Al-Kaisi (2005) found that greater than half of the total N accumulated by VT was present by the V12 growth stage. Another study at Oklahoma State University (Freeman et al., 2007) confirmed these results, reporting over 50 percent of the total N was accumulated by V10.

Wuest and Cassman (1992) found that increasing the rate of pre-plant N fertilizer in wheat had little effect on post-anthesis uptake of N, and that grain N content could be increased by applying N fertilizer at anthesis as opposed to pre-plant. The pre-plant applied N is easily lost by leaching, volatilization, and various other routes before crop uptake. In the same line of work, Stevens et al. (2005a) reported that while the percentage decreased with increasing rate, 20 to 55 percent of applied fertilizer N was converted to non-plant available forms during the growing season. Dhugga and Waines (1989) found the amount of post-anthesis accumulation of N to be determined by the demand for N in the grain. Mossedaq and Smith (1994) reported that wheat grain yields were usually maximized when N fertilizer was applied just before stem elongation; this is due to crop N demand being great at the most rapid phase of crop growth. In corn, N applied at V6 resulted in greater N recovery (Sainz Rozas et al., 2004) when compared with fertilizer N applied at planting.

Although wheat (Garabet et al., 1998) and corn (Stevens et al., 2005b) accumulate a greater proportion of soil N than fertilizer N, total N uptake increased with increasing N fertilizer rate (Garabet et al., 1998; Kanampiu et al., 1997; Sainz Rozas, et al., 2004; Stevens et al., 2005a; Stevens et al. 2005b). Cox et al. (1993) found N concentrations of corn plants at V8 and V16 display linear responses to increasing N rates, which suggests that forage quality improves with additional N. Devienne-Barret et al. (2000) observed that the rate of N uptake of a crop is determined by both its growth rate (without any N deficiency) and the soil N concentration.

Differences in both the level of translocation of pre-anthesis N and rates of N uptake, contribute to differences in grain yield and grain N content in corn (Muchow, 1988). Also, Hanway (1962) suggested that the demand of N during the grain-filling process is so great it may not be possible for the plant to maintain the level of uptake required to fulfill that need. Therefore, the plant compensates by translocating N from other parts of the plant.

Unlike research findings presented above, Ma et al. (1999) found N in vegetative parts of corn was lost between anthesis and R6, and it is assumed that N taken up pre-anthesis must have been stored in vegetative parts of the plant and later translocated to the grain during grain-fill. According to these authors, only a small portion of the N content in corn grain is due to root uptake after flowering. Similarly, the greatest portion of N in wheat grain, 65-80 percent, is translocated from the vegetative portions of the plant (Spiertz, 1983). However, the rate of N accumulation and translocation within the wheat plant is related to the amount of plant available N in the soil (Vouillot and Devienne-Barret, 1999; Hanway, 1962). Vouillot and Devienne-Barret (1999) further indicated that high N availability stimulates the N assimilation capacity of the roots. They also found that roots accumulated much of the N remobilized from the lower leaves and that N taken up from the soil for further root development (Vouillot and Devienne-Barret, 1999). Conversely, regardless of N status, corn remobilizes N during the grain-filling process (Cox et al., 1993). Nitrogen uptake during the grain-filling process, and the mobilization of pre-anthesis N, combine to satisfy the demand of N by the grain (Muchow, 1988). It is important to note that the N uptake capacity of grain is an influential factor for the amount of post flowering N uptake (Dhugga and Waines, 1989).

The literature documents contradictory information as to the growth stage in which wheat and corn accumulate N, the appropriate time of N fertilizer application to optimize use efficiency, and the translocation of N within the plant system. Also, previous research documenting N uptake in wheat and corn is inconsistent, and many have very limited sampling times. This study was conducted to resolve these issues.

CHAPTER III

MATERIALS and METHODS

Two years of data (2006 and 2007) were collected to assess biomass and N accumulation in winter wheat and corn throughout their respective growing seasons. Experiments included, and the treatments sampled are reported in Table 1. Two winter wheat experiments were superimposed on previously established long-term trials. The first experiment was superimposed on Experiment 222 located at the Stillwater Agronomy Research Station, in Stillwater, Oklahoma. Experiment 222 was established in 1969 on a Kirkland silt loam (fine, mixed, superactive, thermic Udertic Paleustoll). The second experiment was superimposed on long-term Experiment 502 initiated in 1970 at the North Central Experiment Station in Lahoma, OK. Experiment 502 is located on a Grant silt loam (fine-silty, mixed, superactive, thermic Udic Argiustoll). The experimental design for Experiment 222 was a randomized complete block with a total of 13 treatments and four replications. The experimental design for Experiment 502 was also a randomized complete block with 14 treatments and four replications. For the objective at hand, only those treatments that received either no N fertilizer, or pre-plant only N, were used from these long-term fertility experiments. Four treatments (1, 2, 3 and 10) were used from Experiment 222, representing application rates of 0, 45 and 90 kg N ha^{-1}, and an unfertilized (0-0-0) check, while three treatments (2, 5 and 7) were used from Experiment 502, representing N application rates of 0, 67 and 112 kg N ha^{-1}, respectively. Both experiments were established under conventional tillage and represent long–term wheat fertility trials. Individual plots of both experiments measured 18 m long, however, they differed in widths, with plots at Experiment 222 measuring 6 m wide while those at 502 measured only 5 m wide. The variety ‘Endurance’ was planted on 15 cm wide rows at seeding rates of 95 kg ha^{-1} at Experiment 222. The variety ‘Overley’ was planted on 19 cm rows at a seeding rate of 83 kg ha^{-1} at Experiment 502 in both years. At Experiment 222, N was applied pre-plant using urea (46-0-0, N-P-K) with a blanket rate of 30 and 37 kg ha^{-1} P and K, respectively (Table 1). At Experiment 502, P and K were applied pre-plant to all treatments at rates of 20 and 56 kg ha^{-1}, respectively. For both locations, the P source was triple super phosphate (0-20-0) while the K source was potassium chloride (0-0-50). For the control of weeds, 2.34 L ha^{-1} of ‘Hoelon’ was applied in January for all site years. In addition, 22 mL ha^{-1} ‘Finesse’ was applied to Experiment 222 in January of 2006 and both years to Experiment 502. Furthermore, ‘Olympus Flex’ was applied at a rate of 55 mL ha^{-1}, to Experiment 222 in November of 2006.

Two experiments were also superimposed on previously established long-term experiments to address the objective for corn. In the spring of 2006, the first corn experiment was superimposed on the Lake Carl Blackwell (LCB) N Study at the Robert L. Westerman Irrigated Research Facility. This site is located on a Paluski fine sandy loam (coarse-loamy, mixed, superactive, nonacid, thermic Udic Ustifluvent) at LCB, OK. In the spring of 2007, an additional experiment, the Perkins N Study was included to further evaluate cereal N uptake. This site is located on a Teller fine sandy loam (fine-loamy, mixed, active, thermic Udic Argiustoll) at the Cimarron Valley Research Station located in Perkins, OK. The experimental design of both long-term corn experiments consisted of 13 treatments arranged in a randomized complete block design with three replications. Only those treatments that receive no N fertilizer, or pre-plant only N, were used from these long-term fertility experiments. Three treatments (1, 3 and 5) were used from both experiments representing 0, 112 and 224 kg N ha^{-1} from LCB, and 0, 56 and 112 kg N ha^{-1} from Perkins. The individual plots measured 3 m wide by 6 m long with 4 rows, of which 1.5 m of row were harvested at each growth stage, from the border rows. Over the whole cycle, the entire length of these rows was used to quantify N uptake at their respective stages of growth. Nitrogen was applied using urea ammonium nitrate (28-0-0), while P and K were applied using triple super phosphate fertilizer (0-20-0) and potassium chloride (0-0-50) to sufficiency level. The variety 'DKC 66-23' was planted on 76 cm wide rows at a seeding rate of 78,332 seeds ha^{-1} at LCB, while the variety 'DKC 50-20' was planted on 76 cm wide rows at a seeding rate of 60,000 seeds ha^{-1} at Perkins. For weed control, 4.7 L ha^{-1} and 3.5 L ha^{-1} of 'Brawl II ATZ' was applied at planting at LCB and Perkins, respectively, for all site years. Additionally, 'Roundup' was spot sprayed by hand as needed in 2007.

Winter wheat and corn forage biomass samples were collected from 1m^2 areas and 1.5 m of row for wheat and corn, respectively, at various growth stages throughout their respective growing seasons (Table 2.). Forage was clipped at the crown of the wheat plant at each growth stage using hand clippers, and hand chopped at the crown of the corn plant using a corn knife. Wet forage samples were weighed and dried in a forced air oven at 60 ^{o}C for 10 days, and weighed again before grinding. Samples were ground to pass a 0.125 mm (120-mesh) sieve. The total forage and grain N content was analyzed using a Carlo-Erba (Milan, Italy) NA-1500 dry combustion analyzer using the procedure outlined by Schepers et al. (1989) for both crops. At the later growth stages, the straw and grain of wheat, and stover and grain of corn, were separated for analysis. Forage N uptake, grain yield, grain N, grain N uptake, straw yield, straw N, straw N uptake, stover yield, stover N, and stover N uptake were then recorded. The sum of the separated components was used to obtain the dry biomass produced per plot. Total N uptake was computed by summing the total of the parts times percent N when morphological separation was required (grain and straw for wheat, stover and grain for corn). Total rainfall by month for each site and year is reported in Table 3. Growth stages sampled in wheat and corn followed that defined by Large (1954) and Hanway and Ritchie (1984), respectively. All data were subjected to Analysis of Variance (ANOVA) using procedures in SAS (SAS, 2001). Non-orthogonal, single degree of freedom contrasts from GLM were performed, and least squares means were used for mean separation.

CHAPTER IV

RESULTS

Results from linear and quadratic contrasts of N rate on dry biomass and forage N uptake for wheat are reported in Table 4, and Table 5, for corn. Results are presented for each site-year separately and no attempt was made to analyze over sites, or over years, since response was variable and error terms were heterogenous.

Dry Biomass Accumulation in Winter Wheat

In 2006 at Experiment 502, the accumulation of biomass increased until reaching a maximum at Feekes growth stage 11 for all N rates, after which biomass accumulation decreased (Figure 1). There were differences in biomass between the check and the treatments that received N, with the highest N rate of 112 kg N ha^{-1} accumulating the highest amount of biomass, while the 0 kg N ha^{-1} treatment accumulated the least amount of biomass throughout the growing season. The 67 and 112 kg N ha^{-1} treatments accumulated similar amounts of dry biomass until growth stage F7, in which 3746 and 4095 kg ha^{-1} were accumulated, respectively. By F11, the treatment effects became more pronounced having 4570, 6239 and 7446 kg ha^{-1} for the 0, 67 and 112 kg N ha^{-1} treatments, respectively. Looking at that same growth stage, 3.55, 3.37 and 3.75 times as much dry biomass had been accumulated since growth stage F4 in the 0, 67 and 112 kg N ha^{-1} treatments, respectively. At all stages of growth sampled, the main effect of N rate was significant on dry biomass (Table 4).

In 2006 at Experiment 222, both check plots accumulated biomass slowly from Feekes growth stages 3 to 5, after which the rate of accumulation steadily increased accumulating an additional 1201 kg ha^{-1} until F11.2 (Figure 2). Dry biomass accumulation continued to increase until achieving the highest accumulation at F11.4, near 1842 kg ha^{-1}. The unfertilized check plot mirrored the 0-30-37 check plot, except no additional dry biomass was accumulated after F11.2, thus having 492 kg ha^{-1} less at F11.4. Similar to Experiment 502, the accumulation of biomass between the treatments that received fertilizer N and the 0 kg N ha^{-1} treatments differed. While the 90 kg N ha^{-1} treatment's most rapid rate of accumulation was during the early growing season (F3 to F7), the 45 kg N ha^{-1} treatment accumulated biomass slowly during that time, followed by an increased rate of accumulation gaining an additional 626 kg ha^{-1} of biomass by F11.2. The maximum accumulation for all treatments except the high rate was at F11.4; however, the 0-0-0 check and the 45 kg ha^{-1} treatment increased only slightly from F11.2. The maximum for the 90 kg N ha^{-1} treatment was F11.2, with 2533 kg ha^{-1}, showing a loss of biomass at F11.2. Excluding the final stage of growth sampled, Feekes 11.4, the main effect of N rate on dry biomass was highly significant (Table 4).

In 2007 at Experiment 502, the accumulation of biomass increased slowly until F6, after which the rate of accumulation increased to it's most rapid rate until F10.5.3, gaining an additional 4444 kg ha^{-1} in that period (Figure 3). Biomass decreased until F11.1 where a small net loss of 806 kg ha^{-1} biomass was observed. Dry biomass increased again, reaching its maximum accumulation with an average of 9267 kg ha^{-1} at F11.2. The treatment effects became evident at F11.1 ($p<0.05$), and were greatest at

F11.4 ($p<0.001$), with the 0 kg N ha^{-1} treatment having 4462 and 4418 kg ha^{-1} less biomass than the 67 and 112 kg N ha^{-1} treatments, respectively.

In 2007 at Experiment 222, for all N rates, biomass accumulation increased reaching a maximum of 5034 kg ha^{-1} at Feekes growth stage 11 (Figure 4). Differences in accumulation among the treatments began to show after F6 ($p<0.0001$) with the 90 kg N ha^{-1} treatment accumulating the highest amount at all later growth stages. Prior to F5, however, the 45 kg N ha^{-1} treatment had the largest amount of biomass, with 1212, 1660 and 366 kg ha^{-1} more dry biomass than the 0-30-37, 0-0-0, and 90 kg N ha^{-1} treatments, respectively ($p<0.001$). The treatment effects were most evident at F11 ($p<0.0001$) with differences in biomass that received fertilizer N averaging 5348 kg ha^{-1} dry biomass, while the check treatments averaged 3012 kg ha^{-1}.

It was important to note the large differences in dry biomass production between 2006 (Figures 1 and 2) versus 2007 (Figures 3 and 4) for Experiments 222 and 502. Conditions were good for mid-season biomass production in 2007, whereas in 2006, prolonged drought existed through much of the season. Dry biomass accumulated in the 2007 growing season was 3572 and 3182 kg ha^{-1} more for Stillwater and Lahoma, respectively, than that of the 2006 growing season. These differences may be attributed to the 2007 season achieving a higher yield potential due to large differences in rainfall between the two years (Table 3). The total rainfall for the 2006 growing season was 25 and 42 cm, while the total rainfall for the 2007 growing season was 43 and 73 cm, for Lahoma and Stillwater, respectively.

N Uptake in Winter Wheat

In Experiment 502 for 2006, the main effect of N rate on N uptake was significant throughout the entire growing season (Table 4). For this location and season, no significant changes were observed from Feekes 4 to Feekes 7, largely because very little rainfall was received during this time period. After Feekes 7, N uptake dramatically increased reaching a maximum uptake at the high N rate of 140 kg N ha^{-1} at F10.4 (Figure 5). There was little change in N uptake for the 0-N check plot throughout the growing season. Again, this may be due to having received only 25 cm of rainfall during the growing season; thereby the check plot received little N from atmospheric deposition or mineralization. The smallest difference among the treatments occurred at F11.4 ($p<0.01$), whereas the largest difference occurred at F10.4 ($p<0.01$). By the Feekes 5 growth stage, 62 percent of the total N accumulated throughout the cycle had been taken up in the 0 and 112 kg N ha^{-1} treatments, while 63 percent of the total was already incorporated in the plant in the 67 kg N ha^{-1} treatment, respectively (Table 6).

For Experiment 222 in 2006, N uptake slowly increased reaching a maximum accumulation early in the growing season (Figure 6). Although the total N accumulation was low, the treatment effects were evident throughout all growth stages with the largest differences occurring at F7 ($p<0.0001$). Again, this low N uptake was attributed to the low yield potential and drought stress conditions present throughout much of the growing season. Both 0 kg N ha^{-1} check treatments slowly accumulated N reaching a maximum at F10.5, while the 45 kg N ha^{-1} treatment did the opposite, reaching a maximum accumulation early and declining as the season progressed. Likewise, the 90 kg N ha^{-1} treatment reached a maximum accumulation at F7. The application of pre-plant N resulted in enhanced early season growth, but as the season progressed with virtually no rainfall from November to early March (Table 3), those treatments receiving N actually lost biomass due to tiller abortion and sloughing off.

In 2007 at Experiment 502, N accumulation of the 0-N check decreased from F4 to F6, followed by an increase until F10.5.3 (Figure 7). Nitrogen uptake then slightly declined to F11.1, followed by another increase to reach its highest accumulation at F11.2. The 67 kg N ha^{-1} treatment began a slow increase of N accumulation during the early growing season. The accumulation of N declined at F11.1, followed by a more rapid increase to a maximum accumulation at F11.2. The 112 kg N ha^{-1} treatment's accumulation of N steadily rose reaching a maximum at F11.2, except for showing a slight decline at F11.1, similar to the 67 kg N ha^{-1} treatment. Thirty-seven, 55 and 68 percent of the total N was accumulated by F5 for the 0, 67 and 112 kg N ha^{-1} treatments, respectively (Table 6).

At Experiment 222, in 2007, the 45 and 90 kg N ha^{-1} treatments accumulated essentially the same amount of N at the F4.5 growth stage ($p<0.01$), however, by F5, the 90 kg N ha^{-1} treatment had an additional 43 kg N ha^{-1}, reaching its maximum accumulation of 109 kg N ha^{-1} (Figure 8). Both 0-N checks, and the 45 kg N ha^{-1} treatment showed a slight trend for loss of N from the F4.5 to the F5 growth stages, which may be explained by having 9 days prior to F5 in which temperatures were at or below freezing, which would hinder biological activity, and thus restrict N accumulation. However, this was the same time period when the 90 kg N ha^{-1} treatment resulted in increased accumulation. Both 0-N checks, and the 45 kg N ha^{-1} treatment reached a maximum N uptake at F6. For the high N treatment (90 kg N ha^{-1}), 100 percent of the total N uptake had been accumulated by Feekes 5 (Table 6).

Dry Biomass Accumulation in Corn

In 2006, at LCB, for all treatments, dry biomass slowly increased from growth stages V6 to V8, after which the rate of accumulation increased to V12 for all treatments (Figure 9). Accumulation continued to increase until VT for the 0 and 224 kg ha^{-1} N rates, while the 112 kg N ha^{-1} treatment showed a slight decrease in the amount of biomass after V12, which was not understood. There were differences in the 0 kg ha^{-1} treatment and those that received fertilizer throughout the entire growing season, however, they were greatest at V12 (Table 5), with differences of 3325 and 3048 kg N ha^{-1} when comparing the 112 and 224 kg N ha^{-1} treatments with the 0 kg N ha^{-1} treatment, respectively.

In 2007 at LCB, for all treatments, biomass accumulation increased slowly from growth stage V10 to R1, followed by a rapid accumulation reaching a maximum at R5 (Figure 10). Regardless of N treatment, biomass production was very similar until V10 ($p<0.05$), and differences due to N were not pronounced until after this stage of growth. The largest differences in biomass yield occurred at R5 ($p<0.1$), with the 0 kg N ha^{-1} treatment having 7171 and 12,560 kg ha^{-1} less dry biomass than the 112 and 224 kg N ha^{-1} treatments, respectively.

At Perkins in 2007, for all N treatments, biomass accumulation increased throughout the entire growing season reaching a maximum accumulation at R6 (Figure 11). The 0 kg N ha^{-1} treatment accumulated only slightly less biomass at V8 ($p<0.001$), afterwards, however, biomass differences due to N treatment became more pronounced. The 112 kg N ha^{-1} treatment had the highest biomass at all growth stages after V8, and by R6, had 2282 and 1062 kg ha^{-1} more dry biomass than the 0 and 56 kg N ha^{-1} treatments, respectively. The differences in biomass yield among the treatments were significant at all growth stages, being highly significant at V8 and VT-R1 (Table 5).

Nitrogen Uptake in Corn

At LCB in 2006, N accumulation increased slowly from V6 to V8, followed by a rapid increase until reaching its' maximum at V12, in which an average of 13 and 49 kg N ha^{-1} were accumulated at each time interval, respectively (Figure 12). There were significant differences among the treatments (Table 5), in which the largest difference occurred at V12 where the 0 kg ha^{-1} N treatment had 83 and 98 kg ha^{-1} less N than the 112 and 224 kg N ha^{-1} treatments, respectively. By the V8 growth stage, 46, 51 and 44 percent of the total N was already accumulated for the 0, 112 and 224 kg N ha^{-1} treatments, respectively (Table 7).

At LCB in 2007, N accumulation increased from V10 reaching a maximum accumulation of 130 kg N ha^{-1} at R5, gaining an average of 88 kg N ha^{-1} (Figure 13). The fertilized treatments accumulated significantly more N than the 0 kg N ha^{-1} treatment, having > 88 kg ha^{-1} more N than that of the check treatment in which the greatest differences in N uptake were found at R5. Twenty-eight, 31 and 35 percent of the total N was accumulated by V10 for the 0, 112 and 224 kg N ha^{-1} treatments, respectively.

At Perkins in 2007, N uptake increased from V6 to V8 accumulating an average of 10 kg N ha^{-1}, followed by a further increase to VT-R1, accumulating an additional 12 kg N ha^{-1}, reaching a maximum accumulation of N at R6 (Figure 14). Differences among treatments were significant at all growth stages (Table 5). The 112 kg N ha^{-1} treatment accumulated the highest amount of N at all growth stages, and had taken up an additional 39 and 50 kg N ha^{-1} when compared to the 0 and 56 kg N ha^{-1} treatments, respectively. Twenty, 31, and 25 percent of the total N taken up had been accumulated by V8 for the 0, 56 and 112 kg N ha^{-1} treatments, respectively. Unlike what was observed at the other locations and years, N uptake continued to increase, even late in the growing season (R6, Figure 14). However, at this site, total amounts accumulated were much lower, consistent with the lower yield potential on this sandy soil that is commonly characterized by moisture stress.

CHAPTER V

DISCUSSION

This study supports previous findings on the accumulation of N in wheat and corn, and assists in quantifying total N uptake as a function of time. The importance of the environment on N uptake was clearly evident over sites and years, where the differences in N uptake were striking. However, this is not altogether surprising since yield levels are known to vary from year to year, thus, these types of differences should, in fact, be expected.

Results also showed that total N uptake increased with increasing levels of N fertilizer (Garabet et al., 1998; Kanampiu et al., 1997; Sainz Rozas, et al., 2004; Stevens et al., 2005a; Stevens et al. 2005b), and typically had a linear response to those increasing N rates (Cox et al., 1993). However, in corn, we found more N accumulated by V6 (averaged 30 percent) than what was reported by Ma et al. (1999) who noted that only 20 percent of the total N uptake was accumulated by V6 (Table 7). Licht and Al-Kaisi (2005) also showed increased N uptake at earlier stages of growth, with more than 55 percent of the total N accumulated by V12. Unlike corn, at some sites, winter wheat accumulated > 60 percent of the total N accounted for at harvest early on in the growth cycle, and as early as Feekes 5 (Tables 6 and 7). Some of this is due to the fact that the percent N in wheat plant tissue is generally higher than that found in corn, especially at early growth stages. Francis et al. (1993) and Harper et al. (1987) showed that beyond anthesis, both corn and wheat could lose N from plant tissue as NH_3 during the grain-fill process. Other researchers have also shown net N losses from anthesis to maturity in corn (Licht and Al-Kaisi 2005; Freeman, 2007). Net N losses from anthesis to maturity were further confirmed in winter wheat using ^{15}N by Lees et al. (2000). Although this was not the objective of this work, winter wheat results at Experiment 502 in 2006 (Figure 5), and Experiment 222 in 2006 (Figure 6), and corn results at LCB in 2006 (Figure 12), and LCB in 2007 (Figure 13) support this finding, since net N losses were observed from anthesis to maturity.

Work by Raun et al. (2001) showed that yield potential could be predicted early in the season from sensor readings collected from winter wheat. This was followed by similar findings by Teal et al. (2007) who noted that normalized difference vegetative index (NDVI) readings of corn could be used to predict grain yield potential from observations made at the V8 growth stage. This work complements these findings showing large N accumulations at early stages of growth, which was to some extent consistent over sites and years. Averaged over sites and years where stages of growth were consistent, 61 percent of the total N accumulated was present by Feekes growth stage 5 in winter wheat, and 45 percent of the total N accumulated was present by V8 in corn (Tables 6 and 7, respectively).

CHAPTER VI

CONCLUSIONS

The ability of the wheat and corn plants to accumulate N early in the season was evident from this work. Averaged over sites and years where stages of growth were consistent, 61 percent of the total N accumulated was present by Feekes growth stage 5 in winter wheat, and 45 percent of the total N accumulated was present by V8 in corn. The large amounts of N accumulated in wheat and corn early in the season is significant considering that the accurate prediction of yield potential depends heavily on our ability to quantify the size of the plant factory. Knowing that corn and wheat provide early season evidence of yield potential via the amount of total N taken up will be useful for later determination of top-dress N needs.

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Table 1. Treatments sampled for winter wheat trials (Experiment 502, Experiment 222) and corn experiments (Lake Carl Blackwell N study, and Perkins N Study), 2006–2007.

Experiment	**Treatment**	**N**	**P**	**K**
		-----------------kg ha^{-1}--------------		
502 Lahoma	2	0	20	56
	5	67	20	56
	7	112	20	56
222 Stillwater	1	0	30	37
	2	45	30	37
	3	90	30	37
	10	0	0	0
LCB N Study	1	0	sufficiency	
	3	112	sufficiency	
	5	224	sufficiency	
Perkins N Study	1	0	sufficiency	
	3	56	sufficiency	
	5	112	sufficiency	

Sufficiency – P and K applied at rates to achieve 100 percent sufficiency according to soil test recommendations at LCB and Perkins.

Table 2. Wheat varieties, corn hybrids, planting date, harvest date, growth stages sampled, and number of days from planting to sensing where growing degree days (GDD) were greater than 0.

Experiment	Variety	Planting Date	Harvest Date	Growth Stage	GDD>0
Exp. 502	Overley	10-15-05	1-19-06	F4	70
			3-7-06	F5	97
			3-13-06	F6	103
			3-29-06	F7	114
			4-14-06	F10.4	130
			5-5-06	F11	151
			6-5-06	F11.4	182
Exp. 222	Endurance	10-7-05	1-4-06	F3	67
			1-12-06	F5	72
			3-27-06	F7	124
			4-4-06	F10.5	143
			5-3-06	F11.2	162
			5-26-06	F11.4	185
Exp. 502	Overley	10-2-06	2-20-07	F4	82
			3-6-07	F5	95
			3-15-07	F6	104
			4-24-07	F10.5.3	142
			5-5-07	F11.1	152
			5-17-07	F11.2	164
			6-11-07	F11.4	189
Exp. 222	Endurance	10-3-06	2-8-07	F4	79
			2-22-07	F4.5	84
			3-8-07	F5	96
			3-19-07	F6	107
			4-3-07	F10	122
			4-16-07	F10.5	132
			4-30-07	F10.5.4	146
			5-14-07	F11	160
			6-6-07	F11.4	183
LCB	P 33B51	3-31-06	5-16-06	V6	46
			2-22-06	V8	52
			6-2-06	V12	63
			6-13-06	VT	74
LCB	DKC 66-23	4-6-07	6-5-07	V10	61
			6-19-07	R1	75
			7-2707	R5	113
			8-17-07	R6	134
Perkins	DKC 50-20	5-16-07	6-18-07	V6	34
			7-3-07	V8	49
			7-13-07	VT-R1	59
			7-27-07	R2-R3	73
			9-12-07	R6	120

GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

Table 3. Monthly rainfall accumulation at Stillwater, Lahoma, Lake Cark Blackwell and Perkins, for the 2005-06, and 2006-07 growing seasons.

	Exp. 502		**Exp. 222**		**LCB**		**Perkins**
	2005-06	2006-07	2005-06	2006-07	2006	2007	2007
Month	rainfall, cm‡						
Sept	2.9	0.9	9.0	3.4			
Oct	6.4	1.5	4.8	4.0			
Nov	0.2	1.8	0.0	3.2			
Dec	1.0	4.3	0.2	7.1			
Jan	0.3	1.9	1.8	3.4			
Feb	0.0	0.7	0.2	1.1			
Mar	7.0	12.4	4.7	13.9	4.7	13.9	13.4
Apr	5.1	6.7	13.1	10.5	13.1	10.5	7.1
May	1.9	13.1	8.5	26.5	8.5	26.5	25.8
Jun					6.1	42.5	35.2
Jul					8.0	17.8	17.6
Aug					4.5	0.0	5.8
Sept							6.2
Total (cm)	24.7	43.2	42.1	73.0	44.8	111.2	111.1

‡ data obtained from the Oklahoma Mesonet

Table 4. Significance of pre-plant fertilizer N rate on dry biomass and forage N uptake for the growth stages sampled in winter wheat trials (Experiment 502, and Experiment 222) 2006 and 2007.

Experiment	Year	Model	Growth Stages Sampled								
Dry Biomass											
Exp. 502	2006		F4	F5	F6	F7	F10.4	F11	F11.4		
		Linear	**	**	**	**	**	*	*		
		Quadratic									
	2007		F4	F5	F6	F10.5.3	F11.1	F11.2	F11.4		
		Linear	NS	NS	**	NS	*	*	***		
		Quadratic									
Exp. 222	2006		F3	F5	F7	F10.5	F11.2	F11.4			
		Linear	***	***	***	***	***	NS			
		Quadratic									
	2007		F4	F4.5	F5	F6	F10	F10.5	F10.5.4	F11	F11.4
		Linear	*	**	***	***	***	***	***	***	***
		Quadratic		**							
N Uptake											
Exp. 502	2006		F4	F5	F6	F7	F10.4	F11	F11.4		
		Linear	***	**	**	**	**	ND	**		
		Quadratic									
	2007		F4	F5	F6	F10.5.3	F11.1	F11.2	F11.4		
		Linear	ND	**	***	NS	**	NS	ND		
		Quadratic									
Exp. 222	2006		F3	F5	F7	F10.5	F11.2	F11.4			
		Linear	***	ND	***	***	ND	**			
		Quadratic				*					
	2007		F4	F4.5	F5	F6	F10	F10.5	F10.5.4	F11	F11.4
		Linear	***	***	***	***	***	***	***	ND	ND
		Quadratic		*							

***, **, * significant at the 0.001, 0.01, and 0.05 probability levels, respectively. ND- no data; NS- not significant.

Table 5. Significance of pre-plant fertilizer N rate on dry biomass and forage N uptake for the growth stages sampled in corn experiments (Experiment LCB N Study, and Perkins N Study) 2006-2007.

Experiment	**Year**	**Model**	**Growth Stages Sampled**				
Dry Biomass							
LCB	2006		V6	V8	V12	VT	
		Linear	*	NS	*	*	
		Quadratic	*	*	*	*	
LCB	2007		V10	R1	R5	R6	
		Linear	*	*	*	*	
		Quadratic		*			
Perkins	2007		V6	V8	VT-R1	R2-R3	R6
		Linear	*	***	***	*	*
		Quadratic		*			
N Uptake							
LCB	2006		V6	V8	V12	VT	
		Linear	**	*	**	**	
		Quadratic		*			
LCB	2007		V10	R1	R5	R6	
		Linear	**	ND	ND	*	
		Quadratic					
Perkins	2007		V6	V8	VT-R1	R2-R3	R6
		Linear	*	***	*	**	*
		Quadratic					

***, **, * significant at the 0.001, 0.01, and 0.05 probability levels, respectively.
ND- no data
NS- not significant

Table 6. Percent of total N uptake accumulated at selected stages of growth for winter wheat trials (Experiment 502, and Experiment 222) 2006-2007.

Experiment	Year	N-P-K	Growth Stage	Percent of Total N Uptake
502	*2006*	0-20-56	F4	68
			F5	62
			F6	91
			F7	64
			F10.4	100
			F11.4	68
		67-20-56	F4	57
			F5	63
			F6	65
			F7	56
			F10.4	100
			F11.4	38
		112-20-56	F4	52
			F5	62
			F6	64
			F7	59
			F10.4	100
			F11.4	46
222	*2006*	0-30-37	F3	48
			F7	86
			F10.5	100
			F11.4	93
		45-30-37	F3	100
			F7	99
			F10.5	73
			F11.4	62
		90-30-37	F3	87
			F7	100
			F10.5	85
			F11.4	52
		0-0-0	F3	39
			F7	82
			F10.5	100
			F11.4	81
502	*2007*	0-20-56	F4	73
			F5	55
			F6	54
			F10.5.3	100
			F11.1	59
			F11.2	87
			F11.4	58
		67-20-56	F4	63
			F5	57
			F6	81

			F10.5.3	100
			F11.1	70
			F11.2	93
			F11.4	ND
		112-20-56	F4	51
			F5	56
			F6	100
			F10.5.3	97
			F11.1	90
			F11.2	99
			F11.4	79
222	*2007*	0-30-37	F4	73
			F4.5	65
			F5	53
			F6	100
			F10	66
			F10.5	51
			F10.5.4	64
		45-30-37	F4	67
			F4.5	86
			F5	69
			F6	100
			F10	91
			F10.5	73
			F10.5.4	63
		90-30-37	F4	61
			F4.5	61
			F5	100
			F6	97
			F10	82
			F10.5	74
			F10.5.4	89
		0-0-0	F4	61
			F4.5	53
			F5	37
			F6	100
			F10	56
			F10.5	27
			F10.5.4	59

Percent total N uptake accumulated determined dividing total N uptake found for each respective stage of growth by the maximum value (varied by site and year) observed for a given site and year.

ND- no data

Table 7. Percent of total N uptake accumulated at selected stages of growth for corn experiments (Lake Carl Blackwell and Perkins), 2006-2007.

Experiment	**Year**	**N rate**	**Growth Stage**	**Percent of Total N Uptake**
LCB	*2006*	0	V6	28
			V8	35
			V12	76
			VT	100
		112	V6	34
			V8	51
			V12	100
			VT	59
		224	V6	32
			V8	44
			V12	100
			VT	80
LCB	*2007*	0	V10	28
			R5	100
			R6	66
		112	V10	31
			R5	100
			R6	64
		224	V10	35
			R5	100
			R6	80
Perkins	*2007*	0	V6	8
			V8	20
			VT-R1	35
			R2-R3	58
			R6	100
		56	V6	14
			V8	31
			VT-R1	41
			R2-R3	52
			R6	100
		112	V6	12
			V8	25
			VT-R1	49
			R2-R3	56
			R6	100

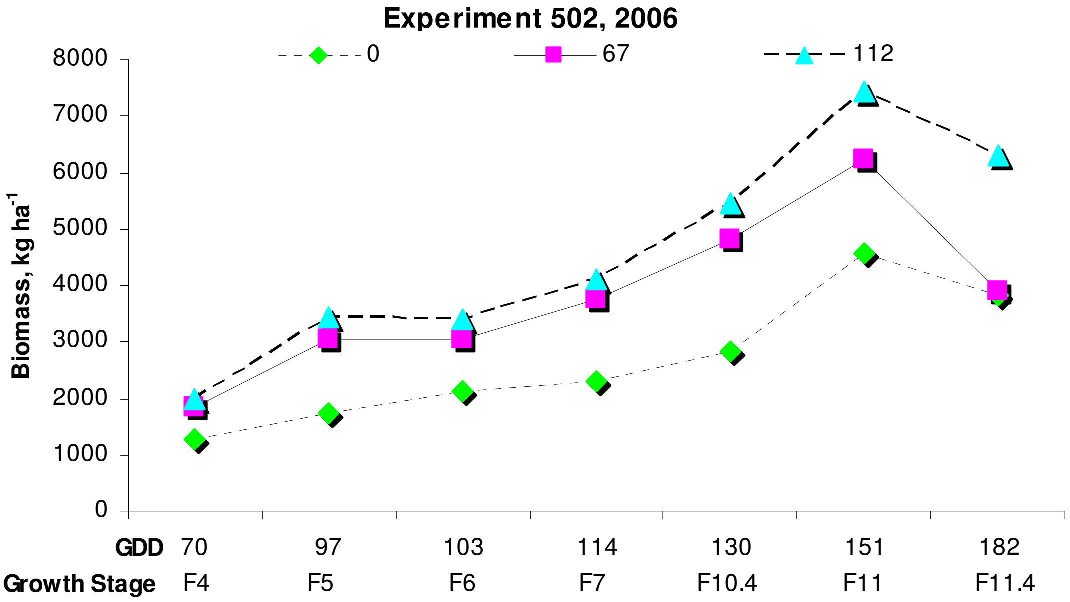


Figure 1. Winter wheat biomass accumulation as a function of growth stage, Experiment 502, Lahoma, OK, 2006. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

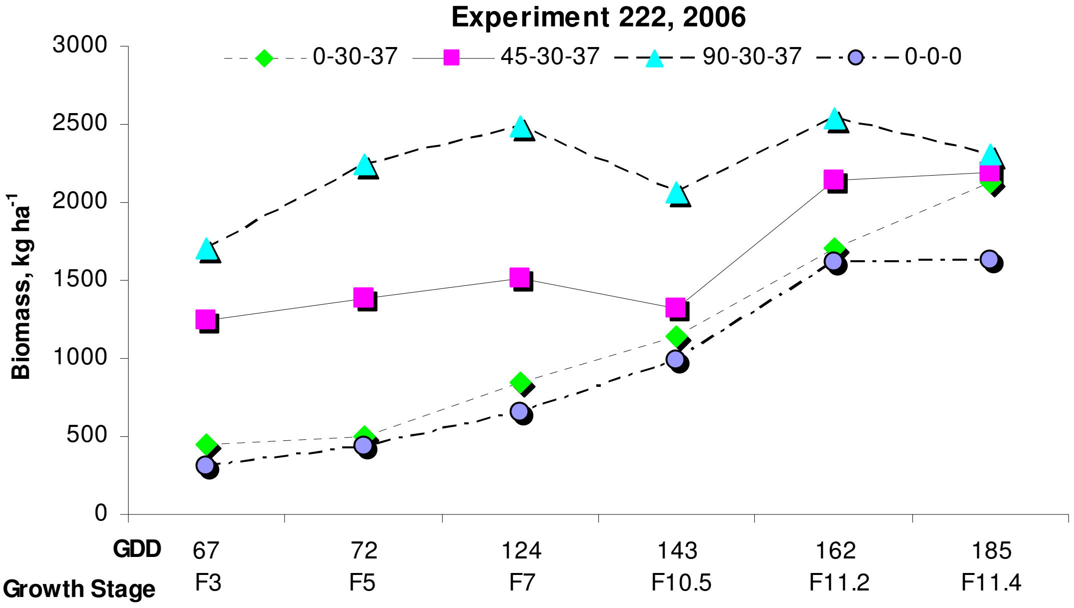


Figure 2. Winter wheat biomass accumulation as a function of growth stage, Experiment 222, Stillwater, OK, 2006. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

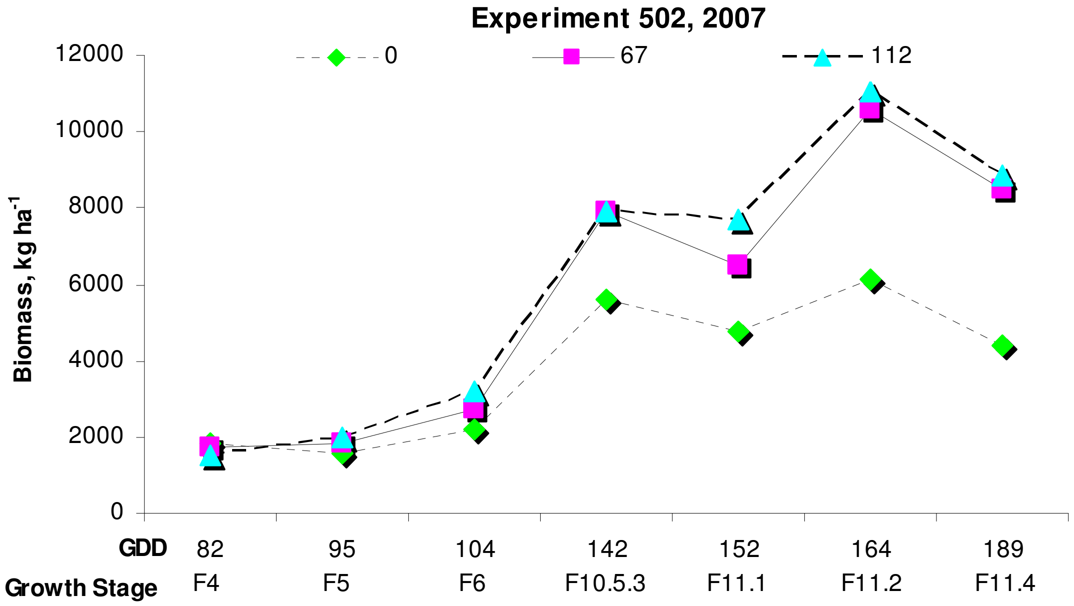


Figure 3. Winter wheat biomass accumulation as a function of growth stage, Experiment 502, Lahoma, OK, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

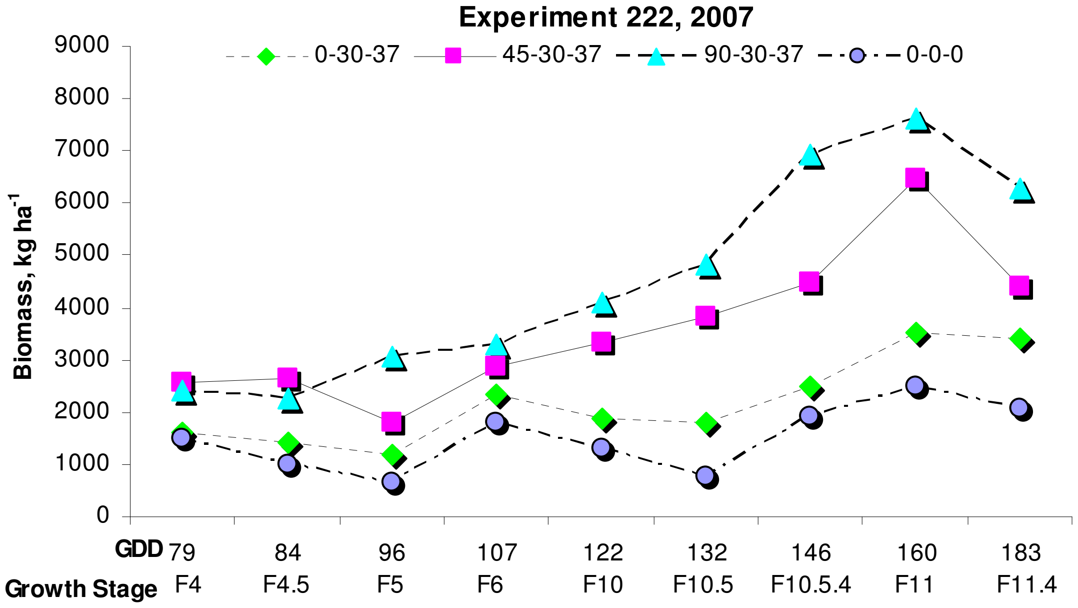


Figure 4. Winter wheat biomass accumulation as a function of growth stage, Experiment 222, Stillwater, OK, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

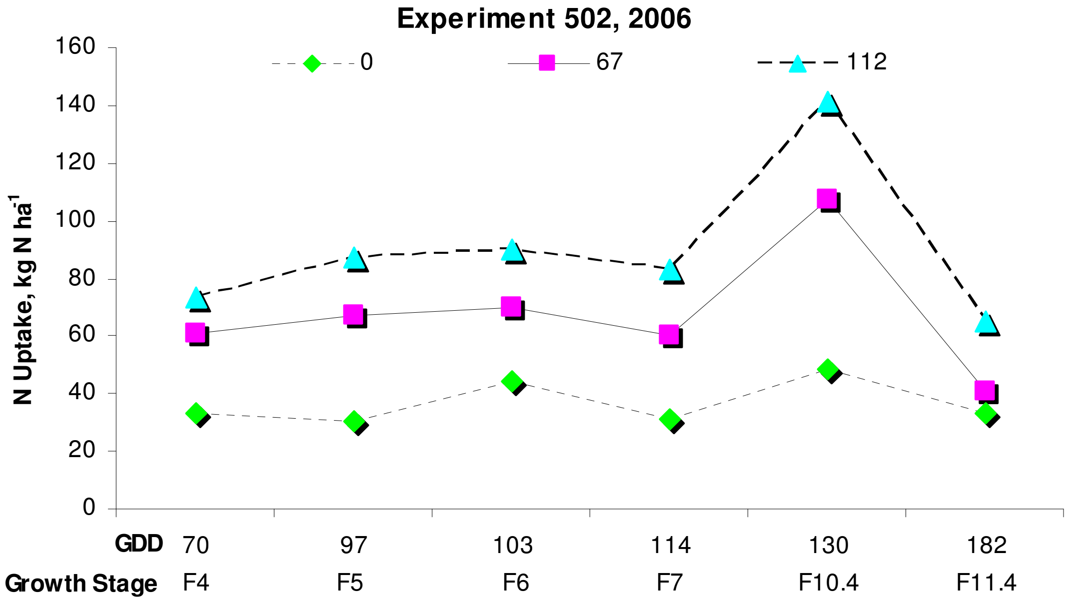


Figure 5. Winter wheat total N uptake accumulation as a function of growth stage, Experiment 502, Lahoma, OK, 2006. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

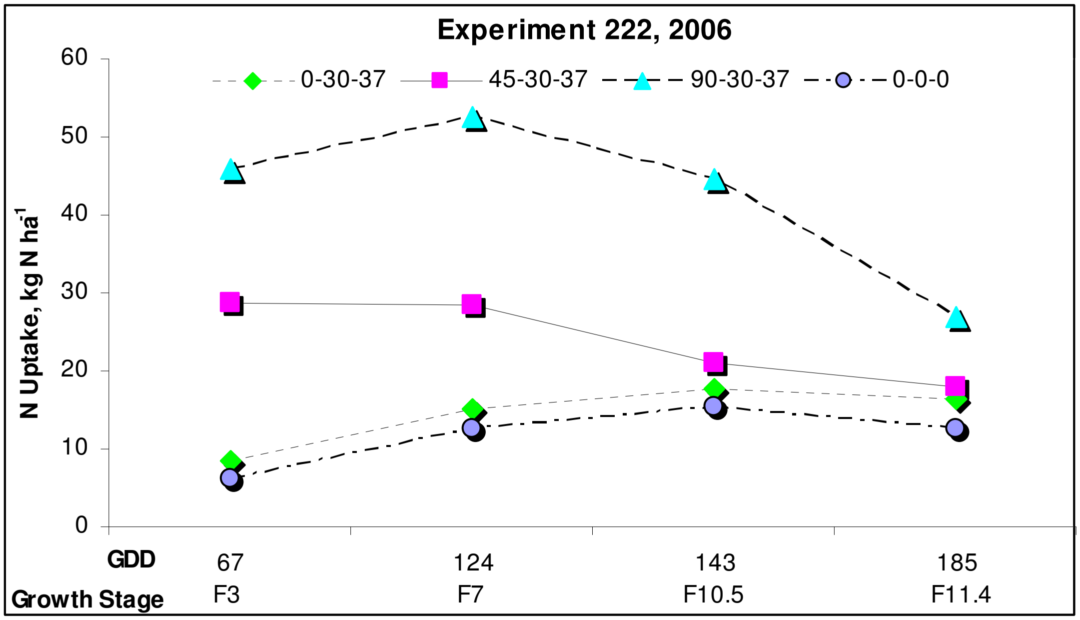


Figure 6. Winter wheat total N uptake accumulation as a function of growth stage, Experiment 222, Stillwater, OK, 2006. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

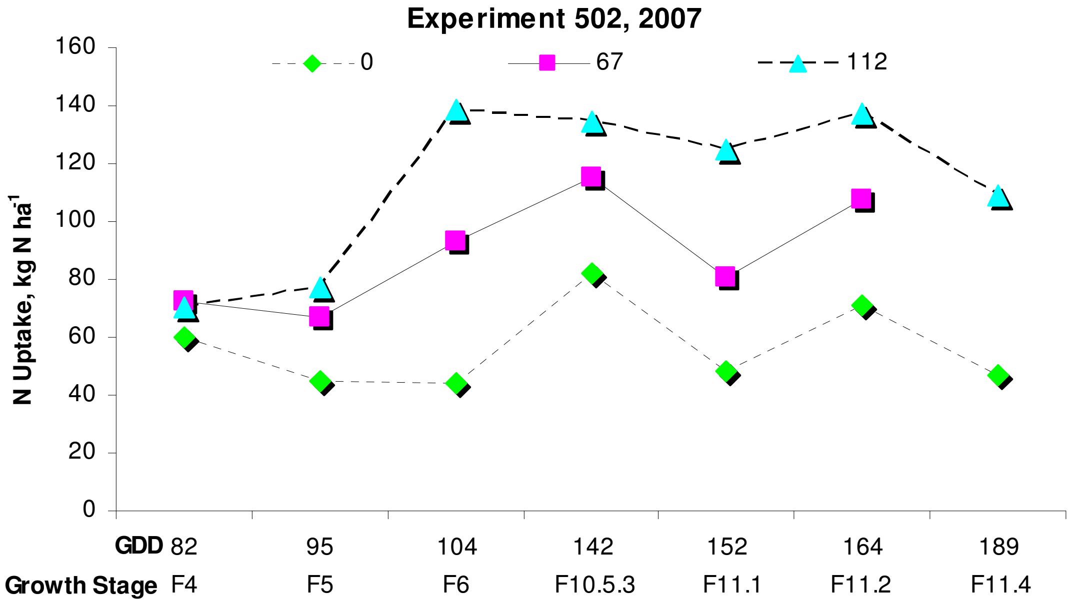


Figure 7. Winter wheat total N uptake accumulation as a function of growth stage, Experiment 502, Lahoma, OK, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

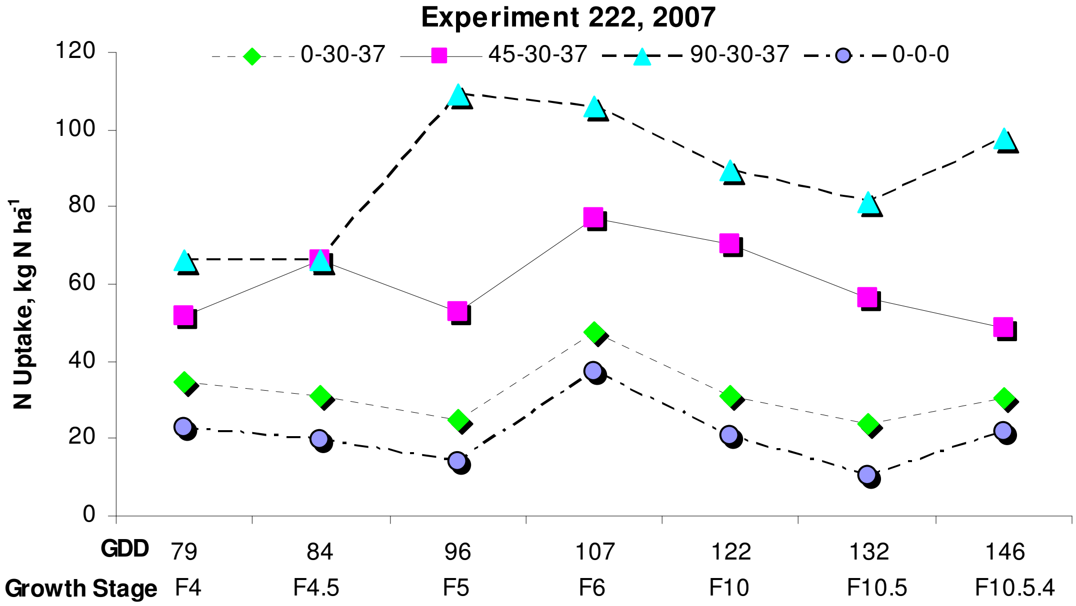


Figure 8. Winter wheat total N uptake accumulation as a function of growth stage, Experiment 222, Stillwater, OK, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

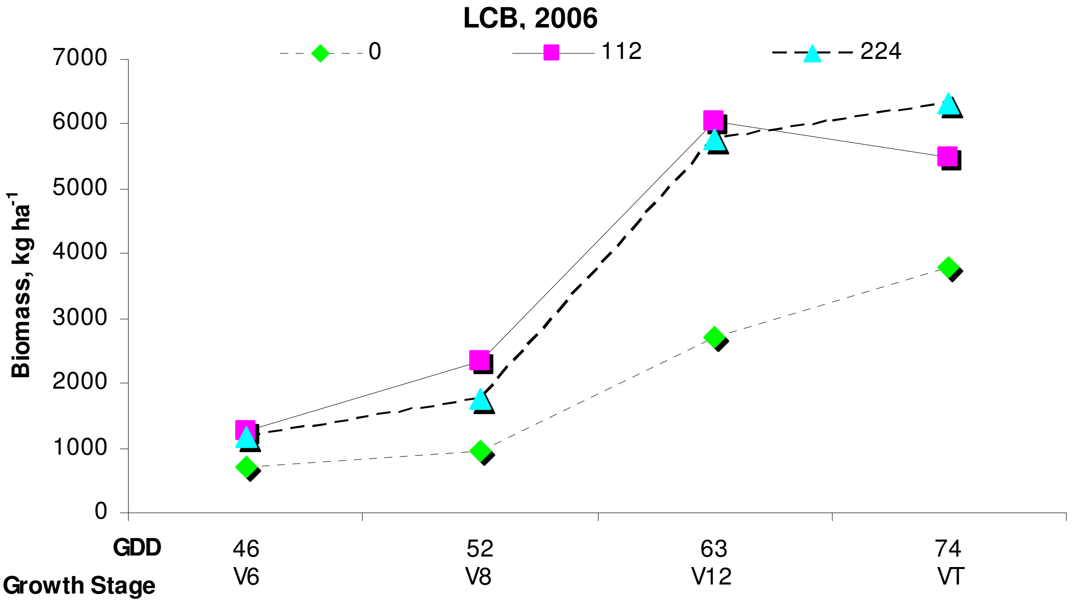


Figure 9. Corn biomass accumulation as a function of growth stage, Lake Carl Blackwell, OK, 2006. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

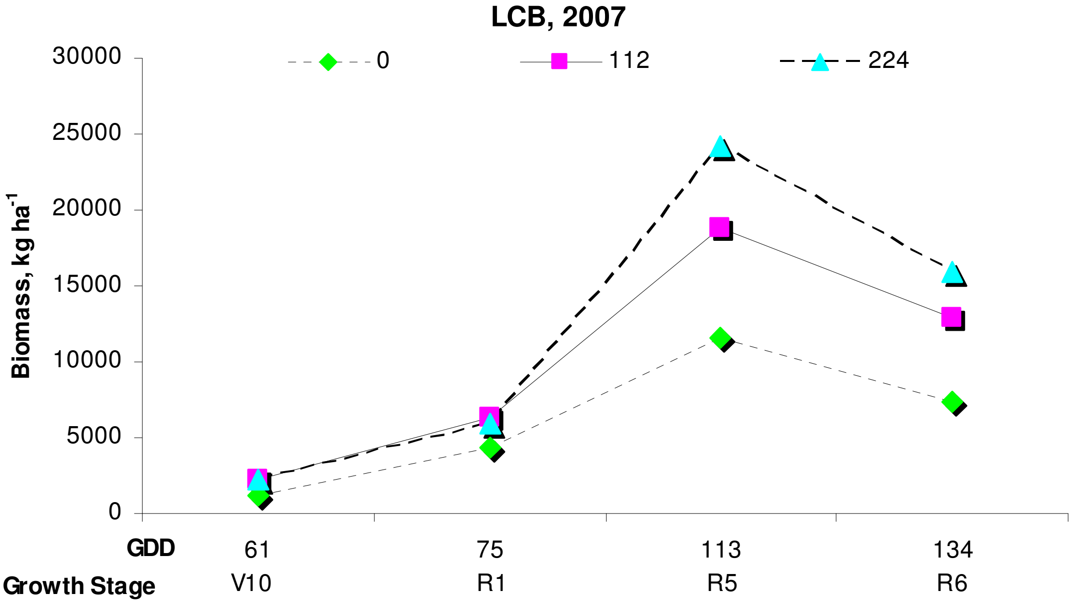


Figure 10. Corn biomass accumulation as a function of growth stage, Lake Carl Blackwell, OK, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

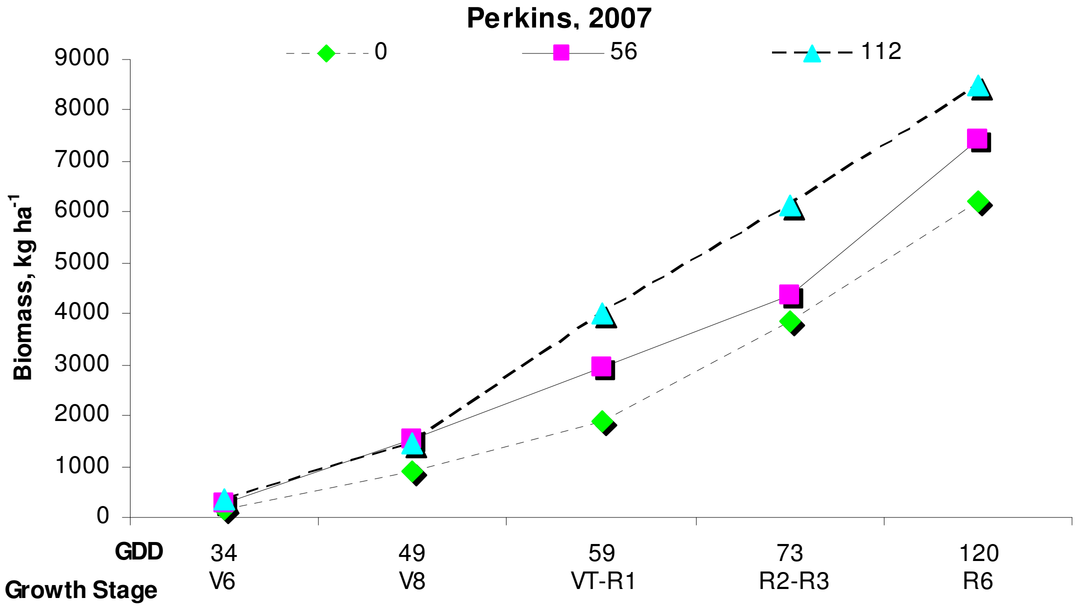


Figure 11. Corn biomass accumulation as a function of growth stage, Perkins, OK, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

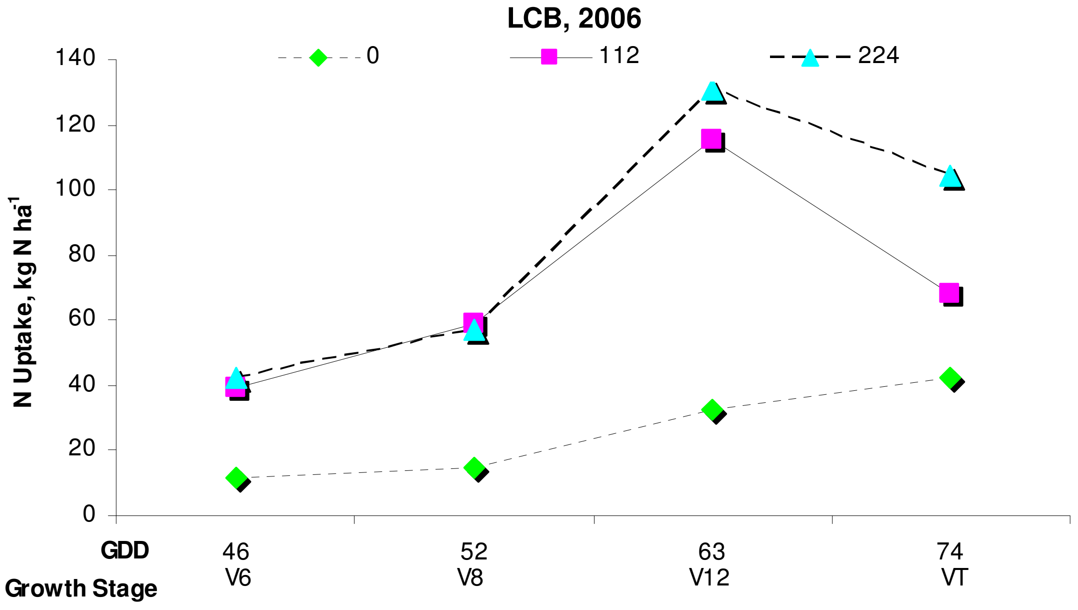


Figure 12. Corn total N uptake accumulation as a function of growth stage, Lake Carl Blackwell, 2006. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

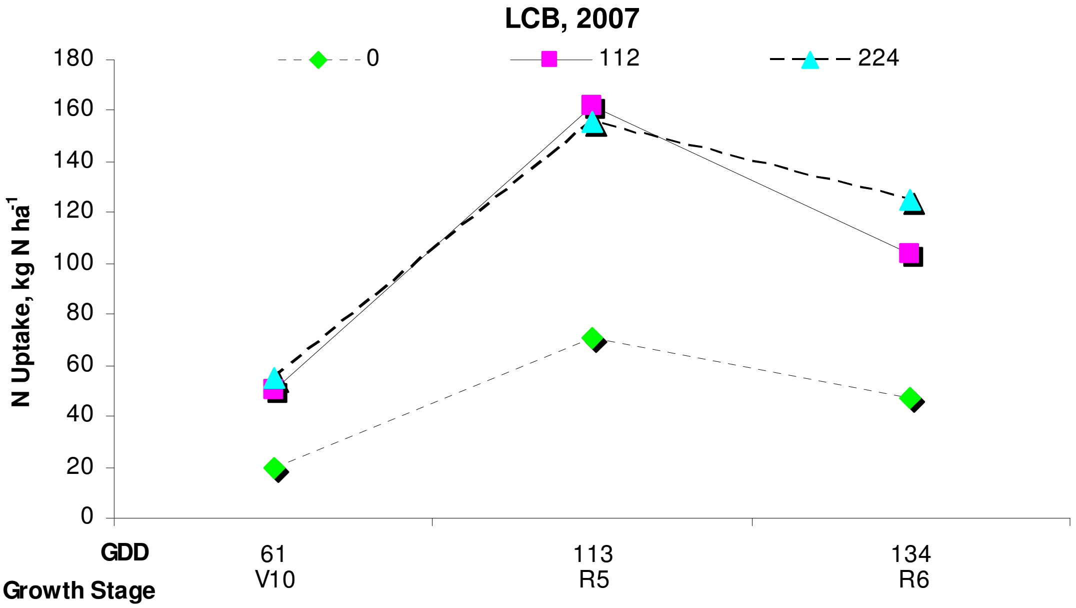


Figure 13. Corn total N uptake accumulation as a function of growth stage, Lake Carl Blackwell, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

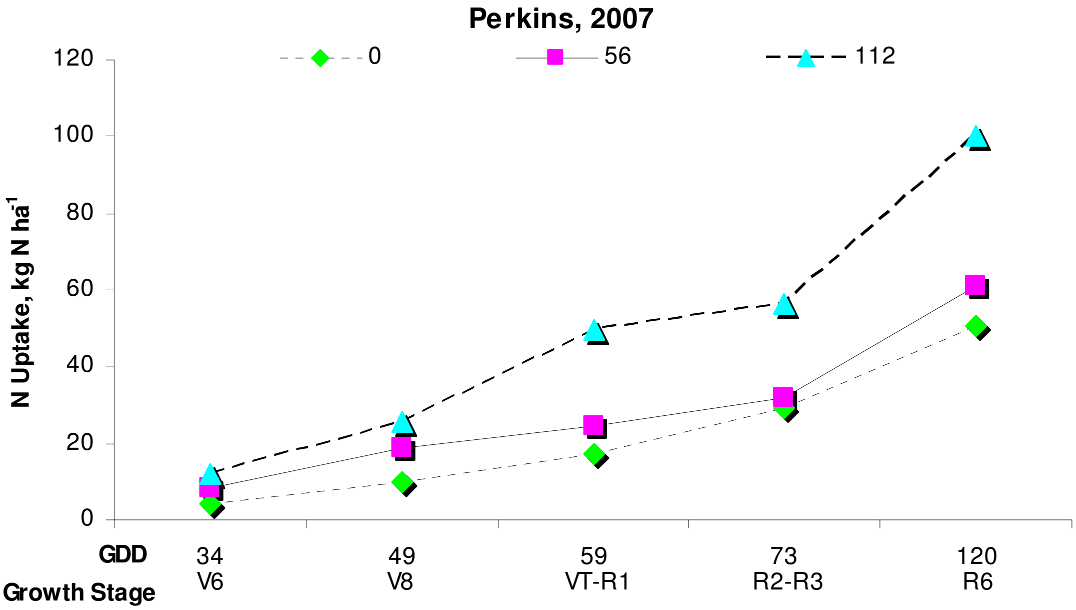


Figure 14. Corn total N uptake accumulation as a function of growth stage, Perkins, 2007. GDD – growing degree days. GDD>0 – number of days from planting to sensing where GDD [(Tmin +Tmax)/2 – 4.4 ºC] was more than 0.

APPENDIX

Appendix Table 1. Herbicides used, date applied, for winter wheat trials (Experiment 222, and Experiment 502) in Stillwater and Lahoma, and corn experiments (LCB N Study and Perkins N Study) Lake Carl Blackwell and Perkins, OK, 2006-2007.

Experiment					
222	**Product**	Finesse	Hoelon	Olympus Flex	Hoelon
	Rate	22 mL ha^{-1}	2.34 L ha^{-1}	55 mL ha^{-1}	2.34 L ha^{-1}
	Date Applied	Jan ‘06	Jan ‘06	Nov ‘06	Jan ‘07
502	**Product**	Finesse	Finesse	Hoelon	Hoelon
	Rate	22 mL ha^{-1}	22 mL ha^{-1}	2.34 L ha^{-1}	2.34 L ha^{-1}
	Date Applied	Jan ‘06	Jan ‘07	Nov ‘06	Jan ‘07
LCB	**Product**	Brawl II ATZ	Brawl II ATZ	Roundup	
	Rate	4.7 L ha^{-1}	4.7 L ha^{-1}		
	Date Applied	at planting 2006	at planting 2007	as needed 2007	
Perkins	**Product**	Brawl II ATZ	Roundup		
	Rate	3.5 L ha^{-1}			
	Date Applied	at planting 2007	as needed 2007		

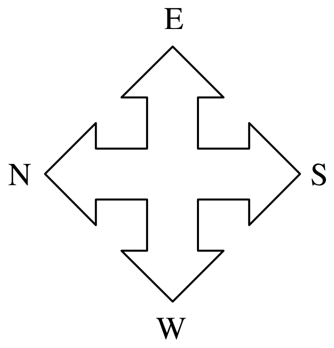
Appendix Table 2. Correlation of biomass and percent N for winter wheat trials (Experiment 502, Experiment 222) and corn experiments (Lake Carl Blackwell N study, and Perkins N Study), 2006–2007.

Year	**Experiment**	**Correlation Coefficient**	**Probability**	**Number of Observations**
Wheat				
2006	502	-0.38	***	69
	222	-0.27	*	63
2007	502	+0.01	NS	88
	222	-0.07	NS	112
Corn				
2006	LCB	-0.39	*	36
2007	LCB	-0.58	***	31
	Perkins	-0.71	***	42

***, **, * significant at the 0.001, 0.01, and 0.05 probability levels, respectively.
NS- not significant

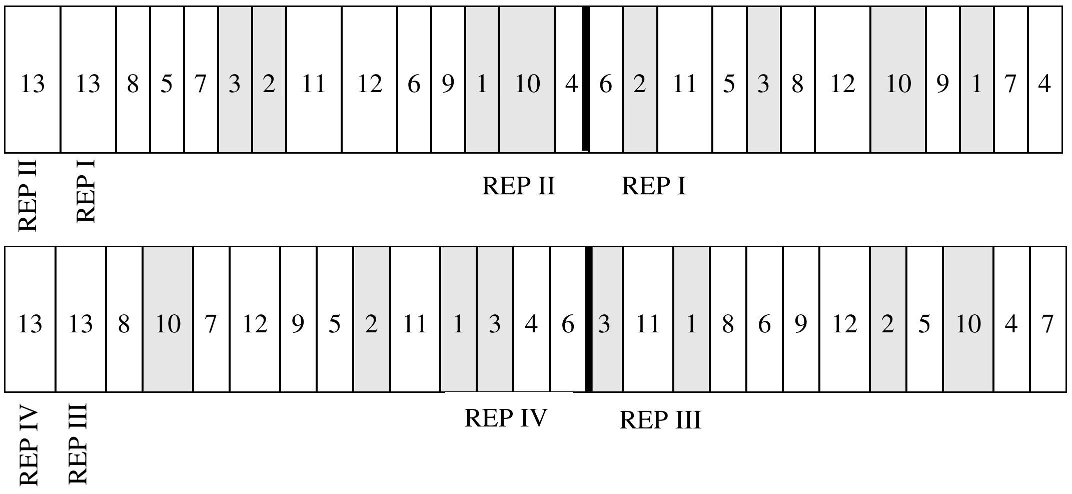
Wheat Fertility Experiment No. 222
Agronomy Research Station
Stillwater, Oklahoma
Established 1969

Plot Size: 6.1 m X 18.3 m
Alley: 5.2 m



Trt	--------kg ha^{-1}----------		
1	0	67	45
2	45	67	45
3	90	67	45
4*	135	67	45
5	90	0	45
6	90	34	45
7	90	101	45
8	90	67	0
9	90	67	90
10	0	0	0
11*	135	101	90
12*	135	101	0
13**	90	67	45

*Split 135 kg N ha-1 rates to 67.5 kg N ha-1 in the Fall and 67.5 kg N ha-1 in the Spring



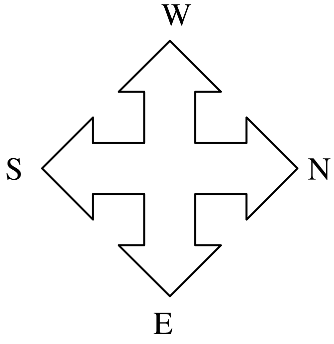
Appendix Figure 1. Treatment structure of Experiment 222 located at Stillwater, OK.

Wheat Fertility Experiment
Experiment No. 502
North Central Experiment Sation
Lahoma, Oklahoma
Established 1970

Plot Size: 4.9 m X 18.3 m
Alley: 6.1 m

Trt	--------kg ha^{-1}----------		
1	0	0	0
2	0	45	67
3	22	45	67
4	45	45	67
5	67	45	67
6	90	45	67
7	112	45	67
8	67	0	67
9	67	22	67
10	67	67	67
11	67	90	67
12	67	67	0
13	112	90	67
14*	67	45	67

*S-P-MG



3	5	13	6	10	2	4	7	12	1	8	14	9	11

Rep 4

1	14	2	7	11	3	9	12	5	13	4	8	10	6

Rep 3

4	8	3	1	11	13	12	7	14	6	9	10	2	5

Rep 2

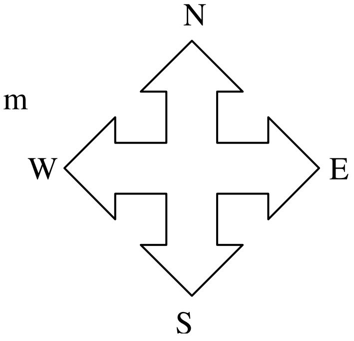
8	2	4	6	14	9	10	5	7	12	1	3	13	11

Rep 1

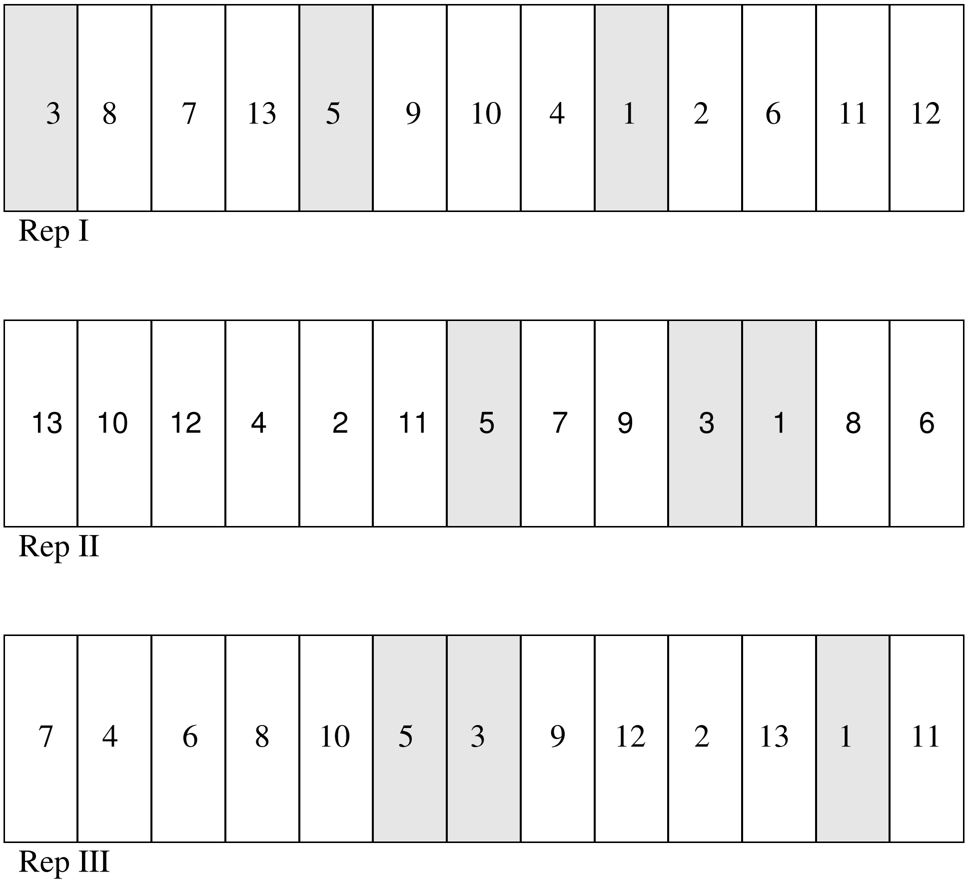
Appendix Figure 2. Treatment structure of Experiment 502 located at Lahoma, OK.

Corn N Study
Robert L. Westerman Irrigated Research Facility, LCB, Stillwater, Oklahoma
Established 2006

Plot Size: 6.1 m X 3.1 m
Alley: 4.6 m
Total Area: 27.4 m X 39.6 m



Trt	Pre-Plant	Top-Dress	Total N
	--------kg ha^{-1}	----------	
1	0	0	0
2	56	0	56
3	112	0	112
4	168	0	168
5	224	0	224
6	0	56	56
7	0	112	112
8	0	168	168
9	0	224	224
10	56	56	112
11	56	112	168
12	112	56	168
13	112	112	224



3	8	7	13	5	9	10	4	1	2	6	11	12

Rep I

13	10	12	4	2	11	5	7	9	3	1	8	6

Rep II

7	4	6	8	10	5	3	9	12	2	13	1	11

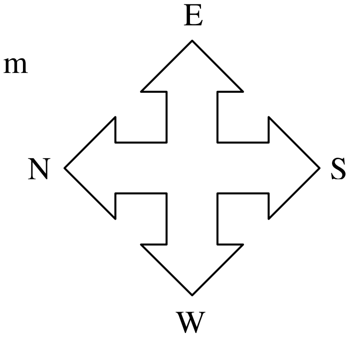
Rep III

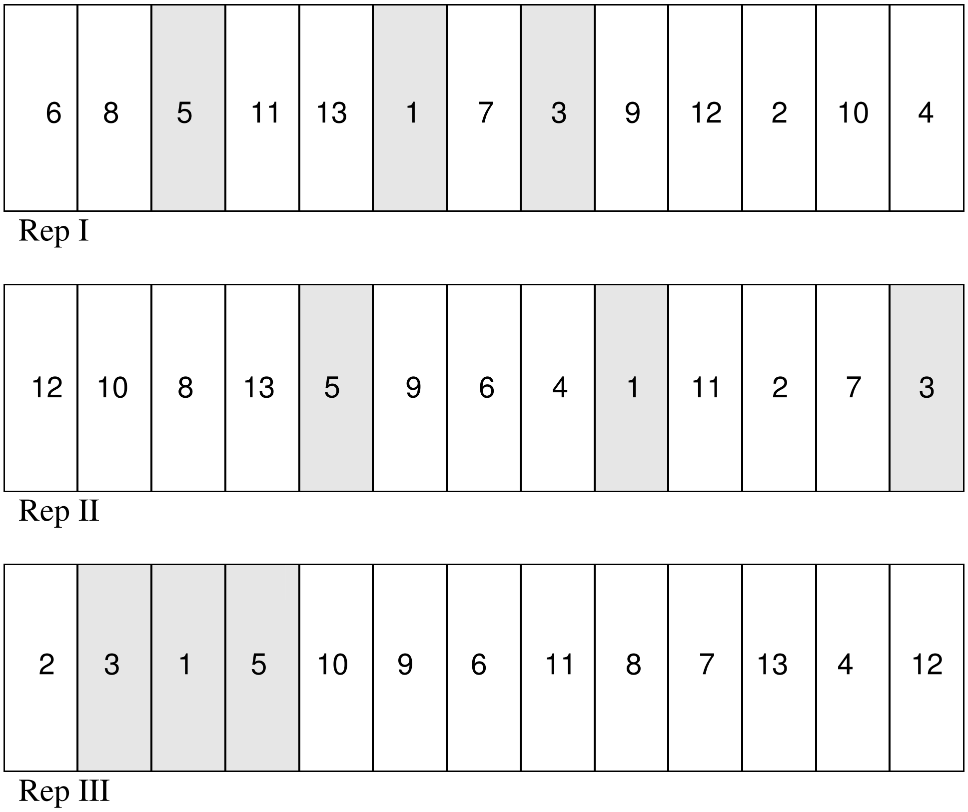
Appendix Figure 3. Treatment structure for the Lake Carl Blackwell N Study, located at the Robert L. Westerman Irrigated Research Facility, near Stillwater, OK.

Corn N Study
Cimarron Valley Research Station, Perkins, Oklahoma, Established 2006

Trt	Pre-Plant	Top-Dress	Total N
	--------kg ha^{-1}----------		
1	0	0	0
2	28	0	28
3	56	0	56
4	84	0	84
5	112	0	112
6	0	28	28
7	0	56	56
8	0	84	84
9	0	112	112
10	28	28	56
11	28	56	84
12	56	28	84
13	56	56	112

Plot Size: 6.1 m X 3.1 m
Alley: 4.6 m
Total Area: 27.4 m X 39.6 m





6	8	5	11	13	1	7	3	9	12	2	10	4

Rep I

12	10	8	13	5	9	6	4	1	11	2	7	3

Rep II

2	3	1	5	10	9	6	11	8	7	13	4	12

Rep III

Appendix Figure 4. Treatment structure for the Perkins N Study, located at the Cimarron Valley Research Station, Perkins, OK.

VITA

Starr LaChelle Holtz

Candidate for the Degree of

Master of Science

Thesis: ABOVE- GROUND NITROGEN ACCUMULATION AS A FUNCTION OF TIME IN CORN AND WINTER WHEAT

Major Field: Plant and Soil Science

Biographical:

Personal Data: Born in Pauls Valley, Oklahoma, on October 30, 1981

Education: Graduated from Pauls Valley High School, Pauls Valley, Oklahoma, in May 2000; attended East Central University, Ada, Oklahoma, for one year; received Bachelor's of Science degree in Plant and Soil Sciences from Oklahoma State University, Stillwater, Oklahoma, in May of 2005. Completed the requirements for the Master of Science degree with a major in Plant and Soil Sciences at Oklahoma State University, Stillwater, Oklahoma, in December 2007.

Experience: Employed as a waitress at Bob's Pig Shop in Pauls Valley, Oklahoma, 1992- 2001; library aid at East Central University, Ada, Oklahoma, 2000-2001; waitress at The Hideaway, Stillwater, Oklahoma, 2001-2003; employed as a wrangler for Camp Classen, YMCA, Davis, Oklahoma, 2003; laboratory assistant for the Department of Plant and Soil Sciences, Soil Fertility, Oklahoma State University, 2003-2005; employed by Oklahoma State University, Department of Plant and Soil Sciences as a Senior Research Associate, 2005-present.

Professional Memberships:
American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America

Name: Starr LaChelle Holtz Date of Degree: December 2007

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ABOVE-GROUND NITROGEN ACCUMULATION AS A FUNCTION OF TIME IN CORN AND WINTER WHEAT

Pages in Study: 48 Candidate for the Degree of Master of Science

Major Field: Plant and Soil Science

Scope and Method of Study:

This study was conducted to establish the amount of N accumulated in corn and winter wheat over the entire growing season. Plots representing three N fertilization rates (0, 45 and 90 kg ha^{-1}) and (0, 67 and 112 kg ha^{-1}) were selected from two long-term wheat experiments located at research stations in Stillwater and Lahoma, OK, in 2006 and 2007. For corn, three N fertilization rates (0, 112 and 224 kg ha^{-1}) and (0, 56 and 112 kg ha^{-1}) were selected from N studies, located at Lake Carl Blackwell (LCB) and Perkins, OK, also in 2006 and 2007. Sequential biomass samples were collected from 1 m^2 area clippings of wheat, and 1.5 m of row (0.76 cm spacing) for corn, throughout their respective growing seasons.

Findings and Conclusions:

Differences in total N uptake over the course of the growing season were strongly influenced by the environment. Thus, N uptake curves for either wheat or corn were noted to be unique by year and location. In general, this work showed that more than 45 percent of the maximum total N accumulated could be found in corn plants by growth stage V8. For winter wheat, more than 61 percent of the maximum total N accumulated at later stages of growth could be accounted for by Feekes growth stage 5. Our findings are consistent with those of others showing that yield potential can be predicted mid-season since such a large percentage of the total N accumulated was accounted for early on in the growing cycle of both wheat and corn.

ADVISER'S APPROVAL: William R. Raun