APPLICATION OF NITROGEN FERTILIZER IN DUAL-PURPOSE WHEAT (*Triticum aestivum* L.)

By

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IN DUAL-PURPOSE WHEAT (*Triticum aestivum* L.)

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Abstract

In the Southern Great Plains winter wheat (*Triticum aestivum L.)* is mostly used as a dual purpose grain crop and forage crop. Wheat pasture is considered as a valuable source of high-quality forage during the late fall or early spring, when there is no other good quality source of forage available. Pre-plant nitrogen plays an important role for the growth and development of wheat forage. The cost of nitrogen fertilizer has increased significantly in the past few years. Knowledge about the optimal nitrogen level for fall forage production in wheat would allow dual-purpose wheat producers to minimize fertility costs. This study was conducted to evaluate the forage response of the wheat varieties (Jagger, Jagalene, 2174 and OK 102) to pre-plant nitrogen fertilizer. The study was conducted in 2004, 2006 and 2007 in Stillwater, OK. Six levels (0, 30, 60, 90, 120, 150 kg ha^{-1}) of pre-plant nitrogen fertilizer were applied in a split-block design with four replications. In 2004, N rate of 90, 120 and 150 kg ha^{-1} produced more forage than other rate of N, but there was no significant difference among N rate. In 2007, N rate of 90 and 150 kg ha^{-1} produced more forage than other rates of N and there was no significant difference between these two N rates, whereas, in 2006, it took 150 kg ha^{-1} to optimize forage production. So, overall 90 kg ha^{-1} was sufficient to optimize agronomic forage production. The variety OK 102 produced the least forage but there were no large difference in the production of forage among other three varieties. This experiment

indicates that when residual N (28 kg ha^{-1}) is present in the soil profile, farmers can maximize net returns without application of additional N for forage production.

I. INTRODUCTION

Wheat (*Triticum aestivum* L.), which can be grown for forage only, grain only, or for both forage and grain (known as dual-purpose), is known as one of the most important crops in the Southern Great Plains (Redmon et al., 1995). True et al. (2001) reported that about two-thirds of wheat planted in the fall of 1995 was grown for dual-purpose. Wheat pasture is a valuable source of high-quality forage and contains a high amount of protein, energy, minerals, and low fiber. Wheat forage is typically available in late fall, winter and early spring, when there is a scarcity of other forage sources available. When wheat is grown for a dual-purpose crop, it is sown in late August or early September and grazed by cattle until the development of first hollow stem, usually in early March. Several environmental and management factors can influence wheat fall forage production, such as planting date, seeding rate, variety and nitrogen fertilization rate. When wheat is grown for dual purpose, producers use 50 to 100% more seed and plant 2-3 weeks earlier than grain-only wheat for enough growth to allow fall grazing. Torell et al. (1999) concluded that if soil moisture allowed rapid germination and emergence, early-planted wheat has the potential to produce excellent fall growth. However, Bowden (1997) found problems with early planting in his experiment in Kansas. He mentioned that early planting increased the duration of time exposed to the environment that might cause several diseases including wheat streak mosaic, high plains virus, barley yellow dwarf, sharp eyespot and common root rot.

Redmon (1995) found three factors that promote dual-purpose winter wheat production in the southern Great Plains. The risk of severe Hessian fly infestation is reduced by biotic and abiotic conditions in the region. That allowed early planting which increases the forage production potential by increasing the vegetative growth period. In winter, the land is not covered by snow for long period of time, so winter grazing is permitted. Soil moisture is typically replenished by April and May rain which increases the grain production potential.

Hossain (2003) explained that dual-purpose wheat production is not an easy process, due to the sophisticated interactions of wheat grain production and variable weather with livestock production. He also stated that wheat planting date selection is also one of the most important management decisions for dual-purpose production. He further added that when winter wheat was seeded in mid-October or later, there will be insufficient fall-winter forage production to support winter grazing.

Fall-winter grazing is not expected to adversely affect grain yield of dual-purpose wheat, if grazing is managed properly for a given planting date, Christiansen et al. (1989); Winter and Thompson (1990); and Worrell et al. (1992) mentioned that grazing should start after plant roots were well anchored, sufficient amount of fertilizer should be added, and cattle should be removed before the development of first hollow stem to ensure grain production.

Kent and Evers (1994) found that wheat can be cultivated from sea level to 4600 m. The wheat crop occupies 32, 10 and 13% of the total area in irrigated systems, high rainfall regions, and low temperature environments, respectively (Acevedo et al., 1999). According to FAO (2003) in 2002, the world's total wheat production was estimated to be

573 million Mg, and the total amount of protein from that wheat would be about 68.7 million Mg.

Numerous authors found that wheat production has been related to the development of civilization over the last 12000 years as it provides energy and protein in human nutrition (Gooding and Davies, 1997; Stone and Savin, 1999; Simmonds, 1981). Humans consume about 65 to 90% (Orth and Shellenberger, 1988) of wheat production. Wheat is used for different purposes because of its chemical and physical properties. Stone and Savin (1999) found the uniqueness of wheat flour when mixed with water, which produce gluten. Nitrogen (N) fertilizer management can influence grain quality, protein concentration (Gooding and Davies, 1997), as deposition of starch and protein in the grain are regulated by different mechanisms (Fischer et al., 1993; Jenner et al., 1991). A study by Johnson and Raun (2003) explained that N fertilizer management is not only the reason for the fluctuation in crop yield but also the difference in temperature and precipitation affected the availability of nutrient in soil as well as crop uptake.

Numerous researchers found that more N was demanded by modern wheat production and this N is typically supplied in the form of N fertilizers (Cassaman et al., 2002; Raun and Johnson, 1999). The researchers also mentioned that there was low recovery of N fertilizer by crop plants. Vidal et al. (1999) demonstrated that when N was over applied, aquatic and terrestrial environments were negatively affected as the excess amount of N leached into the ground water, and represents an unnecessary cost for wheat producers. This is also supported by Raun and Johnson (1999). Nitrogen use efficiency (NUE) for cereal production is only 33% (Raun and Johnson, 1999). Olson and Swallow

(1984) found that only 27 to 33% of the fertilizer N was recovered in the grain, after applying 56-112 kg N ha^{-1} annually for five years in winter wheat under conventional tillage. Where as Evers (2001) found in his experiment with bermudagrass, forage yield increased from l8.9 to a maximum of 13.4 Mg ha^{-1} when 56 kg N ha^{-1} was applied up to three times a year.

According to Moll et al. (1982), NUE is defined as grain production per unit of N available in soil. With the application of different practices such as rotations, forage production systems, hybrid or cultivar, conservation tillage, N source, in–season and foliar-applied N, split-application of N fertilizer, NUE can be increased (Boman et al. 1995). This was supported by Badaruddin and Meyer (1994). They showed that nitrogen use efficiency for wheat following legumes was greater than wheat following fallow or continuous wheat. But Southern Great Plains farmers have not easily adopted crop rotation systems, as they are accustomed to monoculture production systems and crop rotation requires broader knowledge and additional purchase of equipment.

Altom et al. (1996) found that N loss was greater during flowering, but in forage-only production system, plants are not allowed to approach flowering; therefore, NUE was improved and plant gaseous N loss was also low in this system. This was supported by Thomason (1998), who found that uptake of N was greater in dual-purpose wheat than wheat grown for grain only and percent N was higher in wheat harvested prior to flowering than after flowering. Kent and Evers (1994) agreed with this and found that accumulation of N was low at the seedling stage and increased with tillering and stem elongation, and finally reached a maximum at anthesis. After which, the total N in the crop generally decreased. Likewise, Kanampiu et al. (1997) noticed that wheat varieties with low forage yield and high harvest index have increased NUE and low plant N loss. Carver et al. (2001) stated that in the central plains area of The United States, a single N application before seeding was sufficient for the hard winter wheat. They also state about 50 to 100 kg of N was required for each Mg of grain yield and advised multiple N applications in higher rainfall regions for deep sandy soils where leaching is the major problem. Krenzer (1994) estimated that 1000 pounds of dry forage requires 30 pounds of N and each bushel of grain requires 2 pounds of N. These quantities are based upon the assumption that no N is available from other sources such as breakdown of organic matter. Thomason et al. 2004 found that with 448 kg N ha^{-1} applied all in April and three harvests, high yields was obtained (18.0 Mg ha^{-1}) and with 0 kg N ha^{-1} and harvesting three times produced almost the total biomass (16.9 Mg ha^{-1}).

Bacon (2001) found that soil type, previous crop, manure application, tillage system and weather conditions determined the N fertilizer rate and timing of fertilization and recommended higher rates for no-till fields. Many researchers (Welch et al., 1966; Olson and Swallow, 1984; Lutcher and Mahler, 1988; Fowler and Brydon, 1989; Wuest and Cassman, 1992) found that pre-plant N application may lead to immobilization before plant uptake, greatly affecting NUE. About 1 (Blevins et al., 1996) to13% (Chichester and Richardson, 1992) of the total N applied was lost in surface runoff. Some researchers mentioned that volatilization can be a major loss pathway too. Nitrogen fertilizer loss as NH_3 when urea was applied to soil surface without incorporation (Fowler and Brydon, 1989; Hargrove et al., 1977) and also found that with increasing temperature, soil pH, and surface residue, the loss of N from urea was greater.

Numerous researchers have published that about 20 to 50% of N from fertilizer was lost in cereal production and these losses were due to the combined effects of denitrification, volatilization, runoff and leaching (Francis et al., 1993; Olson and Swallow, 1984; Karlen et al., 1996; Wienhold et al., 1999; Sanchez and Blackmer, 1988). Finney et al. (1957) mentioned that fall forage production might be reduced if N application was delayed until spring, as forage production was influenced by early N rate. Bosley (2008) stated that adequate amounts of all essential plant nutrients were needed for maximum forage production and mentioned that more soil nutrients were removed in wheat used for grazing than for grain and recommended to increase nitrogen rates by 30 to 50 pounds per acre for wheat as forage.

Some researchers ranked the modes of N loss due to ammonia volatilization from the wheat canopy and soil surface (Havlin et al., 1999; Nannipieri et al., 1999) that could occur in intensive wheat systems where N fertilizers are applied (Daigger et al., 1976; Papakosta and Gagianas, 1991). According to Daigger et al. (1976) the principal difference in ranking was because volatilization losses were higher than other losses such as denitrification, runoff and leaching in wheat fields. Papakosta and Gagianas (1991) found about 25 to 80 kg N ha^{-1} was lost from the wheat canopy, depending on yield levels. Powlson (1988) noticed that the risk of losses from denitrification and leaching were reduced if the soil nitrate concentration is kept low as these losses required nitrate. Havlin et al. (1999) and Richter and Roelcke (2000) found that if N fertilizer application timing matched the crop's temporal uptake, N losses can be kept low. However, Raun and Johnson (1995) reported that when high N rates were applied to wheat, the risk of ground water contamination with nitrate from leaching was not high under dry land conditions with 765 to 1057 mm of annual rainfall. They suggested that volatilization, immobilization, denitrification, and higher protein concentrations in wheat were "buffer" mechanisms against the accumulation of inorganic N in soil.

Soil testing has long been used to determine the nitrogen fertilizer requirement for wheat; however, this method does not allow the producer to accurately account for N additions from organic matter and other sources during the growing season. Raun et al. (1997) highlighted that in-season nitrogen (N) deficiencies can be detected by sensor-based methods. Stone et al. (1996) found that the normalized difference vegetation index (NDVI) can estimate the N deficiency in winter wheat and can be used for making in-season top-dress N applications. They found that this method could significantly increase nitrogen fertilizer use efficiency.

If growers choose to apply the bulk of nitrogen fertilizer to the wheat crop in-season, however, they must first know how much N to apply pre-plant to ensure that fall forage production does not suffer.

II. OBJECTIVES

A. To determine if wheat varieties differ in their response to fall Nitrogen (N).

B. Identify the economic optimal fall N rate for wheat forage.

III. MATERIALS AND METHODS

Field experiments were conducted at the Oklahoma State University EFAW research facility in Stillwater, OK in 2004, 2006 and 2007. The soil type was Easpur clay loam. Four winter wheat cultivars (Jagger, Jagalene, 2174, and OK102) and six levels of pre-plant N fertilizer (0, 30, 60, 90, 120, or 150 kg ha^{-1}) were applied in a split-block design with four replications (Figure 1). Nitrogen fertilizer was the whole plot and the interaction of nitrogen fertilizer and wheat variety was the sub plot. Each plot measured 1.5 m wide and 2.4 m long. The experiment was moved to a different area of the field each year. In each year, before sowing, soil sample from surface (0-15 cm) and sub surface (15-45 cm) were collected and analyzed in Soil, Water and Forage Analytical Laboratory (SWFAL) to check the amount of residual No_3-N present. Soil testing results are reported in Table 1. Urea fertilizer (46-0-0) was applied and incorporated approximately 2 weeks prior to wheat sowing. Canopy closure and forage production data were collected from each plot at regular interval (approximately 25 days) from emergence until late December. Wheat was sown at 90 kg ha^{-1} into a conventional seedbed within one week of 15 September, each year of the experiment. Seed emerged after five days of planting in each year. Canopy closure was determined via digital photography and green pixel quantification using Sigma Scan software (Systat software, Point Richmond, CA). To quantify the response of fall wheat forage to pre- plant N fertilizer, 1-m by 1-row forage samples were harvested three times by hand during the wheat forage production season. Harvesting was not done in the same place of the row.

For each harvesting new place was selected in the row. Dates of forge harvest are listed in Table 2. Samples were dried at approximately 50° C for a period of 7-10 days and weighed. In 2007, plant damage occurred due to army worm. Lambda-cyhalothrin 1 (83.22 g ha^{-1}) was sprayed as the control measure for the pest.

The marginal net return was calculated as shown in Table 3. Forage weights were obtained from clipping data. Price of forage kg^{-1} was assumed to be $ 0.07. A fertilizer cost of $ 1.1 kg^{-1} N was assumed. Marginal return refers to the additional output resulting from a one unit increase in the use of inputs, while other inputs are held constant. Marginal cost refers to additional costs required to produce the additional one unit. Marginal net return was calculated by subtracting the marginal cost of N fertilizer from the marginal return of forage within a N fertilizer rate. The statistical analysis of data was performed by using SAS Mixed procedure with SLICE option of the LSMEANS statements. Year, N rate and Variety are the fixed effect and harvesting date and replication are random effects.

IV. RESULTS AND DISCUSSION

In 2004, more N was present in the soil profile prior to planting compared to 2006 and 2007 (Table 1). Nitrogen fertilizer was not applied to areas of the field not being used for the experiment. Decreases in soil test N in subsequent years were likely due to this practice and N lost due to leaching.

Fall forage production by winter wheat was affected by variety, N fertilizer, replication, harvesting date and year (Table 4). The interaction between variety and nitrogen rate was not significant; hence the effects of variety and N fertilizer rate on forage production are presented separately. During the first harvest in 2004, variety did not affect forage production (Table 5). In the second harvest, 2174 was not significantly different from Jagger and these two varieties produced more forage than other varieties. Likewise in the last harvest there was, no significant difference among 2174, Jagger and Jagalene but less forage was produced by OK 102 than other varieties. Nitrogen fertilizer did not affect wheat forage production in the first harvest (Table 6). In the second harvest, the forage yield obtained by applying 60 kg N ha^{-1} was similar to that obtained from 120 kg N ha^{-1}. The forage yield obtained by applying 30 kg N ha^{-1} was equivalent to that obtained from the 60 kg N ha^{-1} rate. In the last forage harvest, forage production increased with increasing N rate up to 120 kg ha^{-1}.

In 2006, no significant difference in first harvest forage yield was noticed among varieties (Table 7). In the second harvest, OK 102 produced less forage than the other three varieties. In the third harvest there was no significant difference between 2174 and

Jagalene. Jagger and OK 102 produced less forage than the other two varieties. Nitrogen fertilizer did not affect forage production during the first forage harvest in 2006 (Table 8). Forage yield increased with increasing rate of N in the second and third harvest of forage. However, all nitrogen fertilizer treatments produced more forage than the 0 kg ha^{-1} N rate in the second harvest, but there was no response to N rates greater than 30 kg N ha^{-1}. All nitrogen fertilizer treatments produced more forage than the 0 kg N ha^{-1} rate in the third harvest and 150 kg ha^{-1} N produced the greatest amount of forage.

In 2007, there was no significant difference between the forage production of Jagger and Jagalene in the first and second harvest (Table 9). In the last harvest, 2174 produced more forage than other varieties. The variety OK 102 consistently produced the least forage in 2007. There was no response of wheat forage yield to N in the first forage harvest (Table 10). In the second harvest, there was little response to N rates above 30 kg N ha^{-1} and the least amount of forage was produced with 0 kg N ha^{-1}. Likewise, in the last harvest, 60 kg N ha^{-1} and 120 kg N ha^{-1} produced equivalent forage yield the forage yields obtained from 90 kg N ha^{-1} was not significantly different from that obtained from 150 kg N ha^{-1}.

In this experiment, different varieties and different levels of N fertilizer were used to determine the best variety and optimum amount of N for wheat forage production. There is no fixed amount of N rate to apply as the N requirement may vary from year to year. N requirement is influence by the residual soil nitrate N, amount of N mineralized from soil organic matter etc. In this experiment, nitrogen fertilizer did not increase the forage yield of four varieties in the first harvest of each year due to plant size as well as high residual N content of the soil. As smaller plant did not need much nitrogen, so the first harvest of forage was unaffected by N fertilizer but affected in the second and third harvest of forage. During planting (September), the average temperature was high and there was rainfall (Table 11).

During first harvest, there might be mineralization of N, as significant mineralization usually requires 2 to 4 weeks under moist and warm condition. The last forage harvest date of each year was considered as it is agronomically most important, that reflects the ability of the wheat crop to produce forage throughout the winter. From the last harvest of each year, we found that 90 kg N ha^{-1}.produced the maximum forage (approximately 2700 kg ha^{-1}) than other rates of N. This result is similar to the N recommended by Zhang et al. (2006). The authors mentioned that average N fertilizer requirement by wheat is 2 lb/bu of grain. They further added that the amount of N in the soil test (No_3-N) should be subtracted from the recommended amount and if wheat is grown for dual purpose pre-plant N rate should be increased by 20 to 30 %.

Nitrogen fertilizer had little impact on canopy closure when N rate exceeded 60 kg N ha^{-1} (Figure 2). The total amount of forage increased with increase in N rate (Figure 3). Response of variety and year related to marginal net return were not significant (Table 12). In all three years, marginal net return was greatest at 0 kg N ha^{-1} (Table 13). This was due to the high cost of N (\$ 1.1 kg^{-1}) and low marginal increases in forage production relative to marginal increases in fertilizer cost. The economic analysis might have changed if grain yield was collected too.

V. CONCLUSION

Different rates of N fertilizer and different varieties of winter wheat were used in this experiment to determine if wheat varieties differ in their response to fall nitrogen and to identify the economic optimal fall nitrogen rate for wheat forage. In this experiment, in 2004 and 2007, 90 kg ha^{-1} of N was sufficient to optimize agronomic forage production. But in 2006, it took 150 kg ha^{-1} to optimize forage production. There was significant difference between 150 and 90 kg ha^{-1}, but the difference was low (219 kg ha^{-1}). Overall, in this experiment 90 kg ha^{-1} optimized the forage production. In case of variety, in all three years, wheat variety OK 102 produced the least forage, whereas, there was no large difference in the production of forage among other three varieties. Since our highest N rate was 150 kg ha^{-1}, we were unable to determine if there was a response to N applications above 150 kg ha^{-1}. Due to the high cost of nitrogen fertilizer compared to the value of wheat forage, marginal net return was higher for all varieties at 0 kg N ha^{-1}. Our study indicates that when residual N (28 kg ha^{-1}) is present in the soil profile, farmers can maximize net returns by not applying additional N for forage production and by applying N rates on the requirements of the grain crop.

Table 1. Soil test data prior to sowing each year of the experiment.

Year	No_3-N †	P	K	pH
	kg ha^{-1}	--------------mg kg^{-1}-------------		
2004	75	30	105	5.3
2006	58	14	91	7.1
2007	28	33	88	6.5

† Nitrogen is the sum of surface (0-15 cm) and sub-surface (15-45cm) soil pre-plant nitrogen

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Table 2. Dates of wheat forage harvest at Stillwater, OK in 2004, 2006 and 2007.

Year	First harvest	Second harvest	Third harvest
2004	10/21/2004	11/12/2004	12/2/2004
2006	10/20/2006	11/10/2006	11/28/2006
2007	10/16/2007	11/13/2007	12/20/2007

Table 3. Example of wheat forage marginal net return calculation.

N Rate	Forage† weight (Kg ha^{-1})	Forage‡ value ($0.07 ha^{-1})	Marginal Return	Increase in N rate	Marginal Cost (Assumes $ 1.1 Kg^{-1} N)	Marginal Net Return
0	X	X x 0.07=a	a	0	0 x 1.1=0	a-0
30	Y	Y x 0.07=b	b-a	30	30 x 1.1=33	(b-a)-33
60	Z	Z x 0.07=c	c-b	30	30 x 1.1=33	(c-b)-33

† Forage weight is the total forage weight from the final forage harvest for each respective nitrogen rate.

‡ Forage value calculated using a price of $ 0.07 Kg^{-1} for wheat forage.

Table 4. Mean square of forage yield and significance values from ANOVA of 4 varieties of wheat, 6 rates of nitrogen from 4 replication, 3 harvesting dates and 3 years, Efaw, Stillwater, OK.

Source	df	Mean Squre	Pr>F
Replication	3	3149310.3	<.0001
Variety	3	2538884.1	<.0001
Replication x Variety	9	581709.9	<.0001
Nitrogen rate	5	3832359.3	<.0001
Replication x Nitrogen rate	15	295233.2	<.0001
Variety x Nitrogen rate	15	51119.3	0.8588
Replication x Variety x Nitrogen rate	45	46732.1	0.9901
Year	2	1335875.6	<.0001
Harvesting date	2	259297137.2	<.0001
Year x Harvesting date	4	952275.6	<.0001
Variety x Year	6	327367.8	0.0006
Variety x Harvesting date	6	330584.8	0.0006
Variety x Year x Harvesting date	12	254995.2	0.0003
Nitrogen rate x Year	10	205909.9	0.0059
Nitrogen rate x Harvesting date	10	1242236.8	<.0001
Nitrogen rate x Harvesting date x Year	20	108133.8	0.1615

Table 5. Wheat forage yield of four varieties in 2004 at three harvest dates

Variety	1st harvest	2nd harvest	3rd harvest
	------------------------------------kg ha^{-1}	----------------------------------	
2174	467[a]	1727[a]	2413[a]
Jagalene	413[a]	1462[c]	2399[a]
Jagger	450[a]	1644[ab]	2333[ab]
OK 102	345[a]	1486[bc]	2181[b]

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$

Table 6. Forage yield obtained from different rates of pre-plant N fertilizer in 2004

Applied N	Total N*	1st harvest	2nd harvest	3rd harvest
		$kg\ ha^{-1}$		
0	75	390[a]	1287[c]	1590[d]
30	105	399[a]	1492[b]	2025[c]
60	135	429[a]	1718[ab]	2398[b]
90	165	415[a]	1598[b]	2582[ab]
120	195	435[a]	1799[a]	2719[a]
150	225	446[a]	1583[b]	2677[a]

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$.

* Applied N plus residual soil No_3-N from table 1.

Table 7. Wheat forage yield of four varieties in 2006 at three harvest dates.

Variety	1^{st} harvest	2^{nd} harvest	3^{rd} harvest
	-----------------------------------kg ha^{-1}	-----------------------------------	
2174	692^{a}	1780^{a}	2496^{a}
Jagalene	729^{a}	1740^{a}	2386^{ab}
Jagger	619^{a}	1655^{a}	2262^{bc}
OK 102	576^{a}	1506^{b}	2203^{c}

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$

Table 8. Forage yield obtained from different rates of pre-plant N fertilizer in 2006

Applied N	Total N*	1st harvest	2nd harvest	3rd harvest
----------	----------	----------kg ha^{-1}----------	----------	----------
0	58	664^{a}	1409^{b}	1857^{d}
30	88	634^{a}	1620^{a}	2204^{c}
60	118	672^{a}	1671^{a}	2309^{bc}
90	148	644^{a}	1724^{a}	2469^{b}
120	178	669^{a}	1789^{a}	2476^{b}
150	208	641^{a}	1809^{a}	2688^{a}

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$.

* Applied N plus residual soil No_3-N from table 1.

Table 9. Wheat forage yield of four varieties in 2007 at three harvest dates

Variety	1st harvest	2nd harvest	3rd harvest
	---kg ha^{-1}---		
2174	469^{bc}	1529^{b}	2888^{a}
Jagalene	540^{ab}	1874^{a}	2587^{b}
Jagger	628^{a}	1801^{a}	2525^{b}
OK 102	333^{c}	1400^{b}	2240^{c}

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$

Table 10. Forage yield obtained from different rates of pre-plant N fertilizer in 2007

Applied N	Total N*	1st harvest	2nd harvest	3rd harvest
--------------------	--------------------	kg ha^{-1}	--------------------	--------------------
0	28	504[a]	1285[c]	2243[d]
30	58	464[a]	1574[b]	2251[d]
60	88	488[a]	1699[ab]	2567[c]
90	118	499[a]	1810[a]	2784[ab]
120	148	460[a]	1676[ab]	2593[bc]
150	178	539[a]	1860[a]	2922[a]

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$.

* Applied N plus residual soil No_3-N from table 1.

Table 11. Temperature and rainfall data of 2004, 2006 and 2007

	2004		2006		2007	
	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall
	--°c--	--cm--	--°c--	--cm--	--°c--	--cm--
September	23.11	1.93	21.05	3.35	23	11.68
October	17.11	11.6	15.66	4.01	17.22	8.38
November	9.83	12.59	10	3.14	10	2.2
December	4.88	2.43	4.7	7.13	2.5	2.66

Table 12. Mean square of marginal net return and significant values from ANOVA of 4 varieties, 6 rates of nitrogen fertilizer from 4 replication and 3 years, Stillwater, OK

Source	DF	Mean Square	Pr> F
Replication	3	597.9	0.7151
Variety	3	175.33	0.9402
Replication x Variety	9	29.17	1
Nitrogen rate	5	209786.86	<.0001
Replication x Nitrogen rate	15	2628.77	0.0208
Variety x Nitrogen rate	15	2426.49	0.0363
Replication x Variety x Nitrogen rate	45	1458.09	0.3267
Year	2	3566.92	0.0708
Variety x Year	6	19.13	1
Nitrogen rate x Year	10	3994.29	0.0002
Replication x Variety x Year	24	96.2	1
Replication x Nitrogen rate x year	30	1826.86	0.1109

Table 13. Marginal net return associated with different rates of pre-plant N fertilizer in 2004, 2006 and 2007

N rate	2004	2006	2007
		---$ ha^{-1}---	
0	111[a]	158[a]	157[a]
30	-2[b]	7[b]	-32[bc]
60	-7[b]	-6.3[bc]	-11[b]
90	-20[bc]	-20[c]	-18[b]
120	-23[bc]	-29[c]	-46[c]
150	-36[c]	-17[bc]	-10[b]

Means followed by the same letter in the same column indicate no significant difference at $p \leq 0.05$

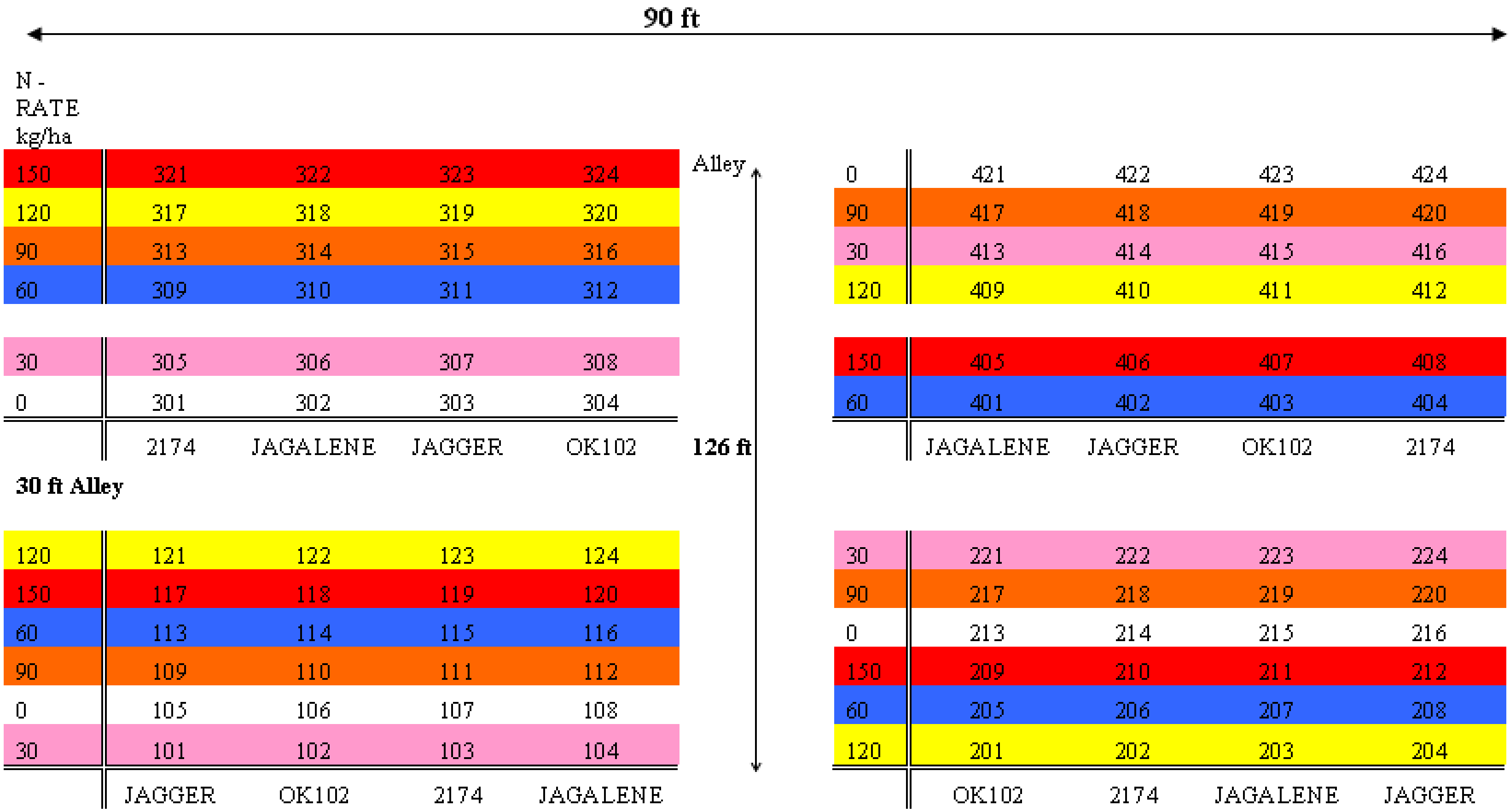

Figure 1. Schematic representation of experimental site and design.

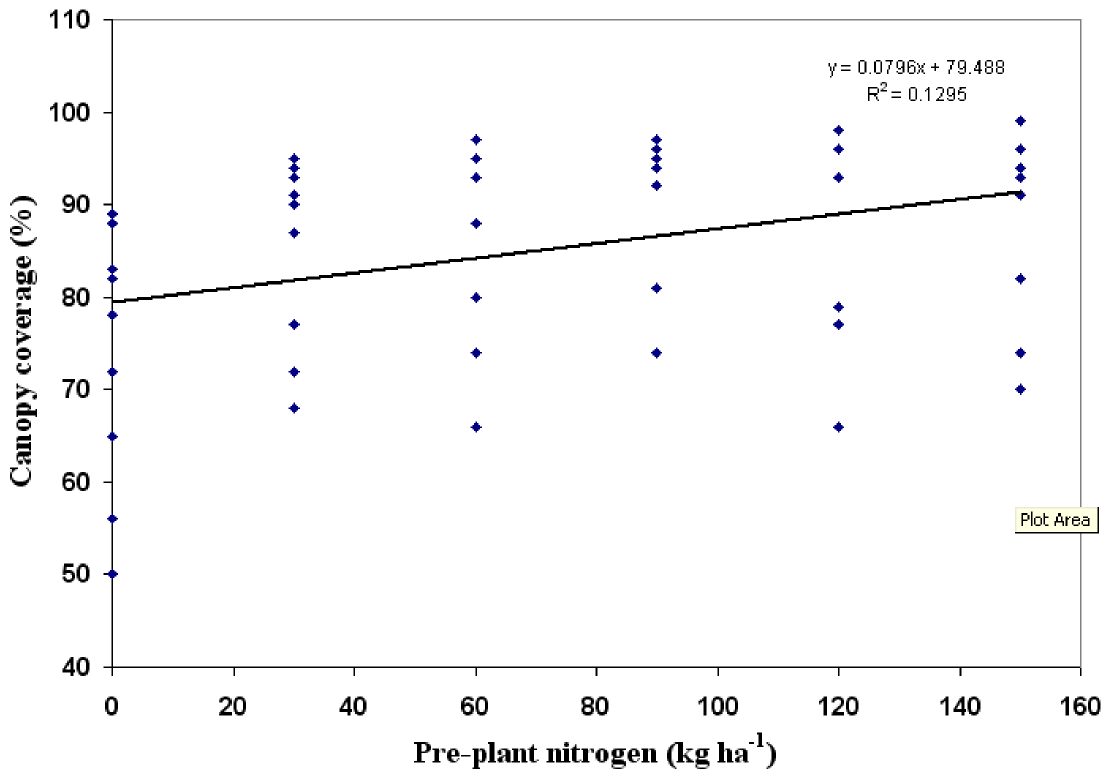

Figure 2. Response of fraction of canopy covered by wheat leaves to pre-plant nitrogen fertilizer at last forage clipping in 2004, 2006 and 2007.

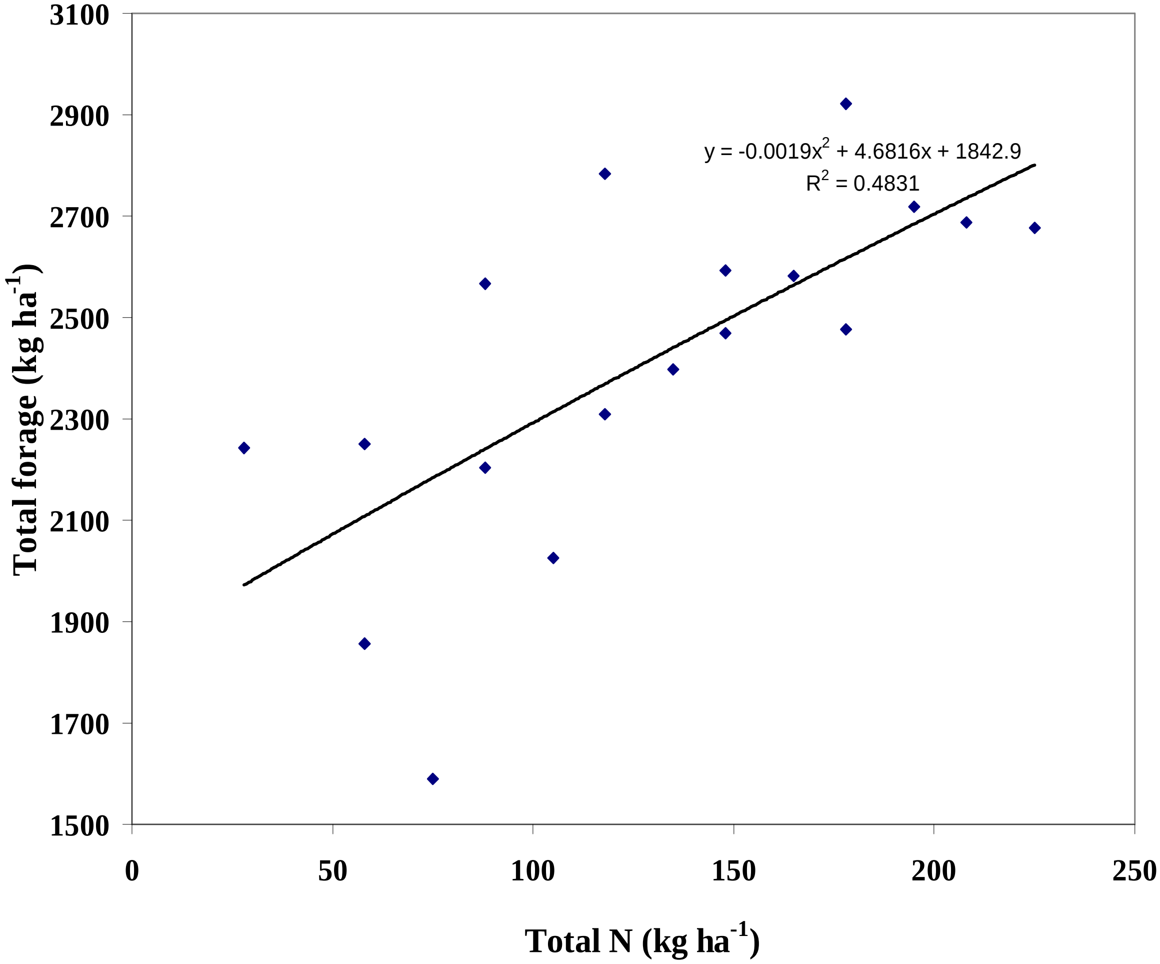

Figure 3. Response of total wheat forage to total amount of N (applied plus residual N) at last harvesting date in 2004, 2006 and 2007.

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VITA

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Scope and Method of Study:

This study was conducted to evaluate the forage response of the wheat varieties (Jagger, Jagalene, 2174 and OK 102) to pre-plant nitrogen fertilizer and to identify the economic optimal fall N for wheat forage. The study was conducted in 2004, 2006 and 2007 at Efaw, Stillwater, OK, six levels (0, 30, 60, 90, 120, 150 kg ha^{-1}) of pre-plant nitrogen fertilizer were applied in a split-block design with four replications.

Findings and Conclusions:

In two years, 2004 and 2007, 90 kg ha^{-1} was sufficient to optimize agronomic forage production, whereas, in 2007, it took 150 kg ha^{-1} to optimize forage production. Overall 90 kg ha^{-1} was the best rate. Wheat variety OK 102 performed worst for production of forage where as there were no large difference in the production of forage among other three varieties. This experiment indicates that when residual N is present in the soil profile, farmers can maximize net returns by not applying additional N for forage production and by applying N rates on the requirements of the grain crop.

ADVISER'S APPROVAL: Dr. Jeff Edwards____________________________________