EFFECTS OF NITROGEN AND CLIPPING TERMINATION DATES ON FORAGE PRODUCTION, GRAIN YIELD, AND YIELD COMPONENTS OF TAM W101 WHEAT

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INTRODUCTION

Throughout most of the United states, wheat (Triticum aestivum L.) is primarily grown for grain. However, in the Southern Plains, winter wheat often serves a dual purpose as a forage crop for fall and winter grazing and as a grain crop following livestock removal near the jointing stage of plant development in the spring. Therefore, the economic return from wheat includes the value of grain plus livestock gains produced. Additional information on the effect of forage utilization on grain production is needed to help producers make management decisions to maximize the economic return from their crop.

Government programs have been recently introduced to improve the unfavorable economic situations faced by wheat producers today by reducing the wheat acreage harvested for grain. These programs have increased the interest of grazing or haying the crop past the jointing stage of plant development. Therefore, additional information on forage production beyond jointing is needed.

It is well established that to minimize grain yield reductions grazing should be terminated when the apical meristem has elevated to a height it may be damaged or removed by grazing animals. However, a general management program that consistently optimizes forage and grain production has not yet been established because of the variable environmental conditions encountered from year to year.

Therefore, the objectives of this study were to determine:

A. Wheat forage production and grain yield when clipped over different schedules and nitrogen levels.

B. The effect of clipping termination at successive stages of plant development after jointing on grain yield and yield components over different nitrogen levels.

C. The effect of nitrogen levels on jointing dates.

D. The possibility of developing forage and grain yield prediction models that will consistently and reliably explain the trade off between increased forage production and decreased grain yield with clipping terminated at successive growing degree days after the jointing stage of plant development.

Chapter II of this thesis is a separate manuscript written in a form to be submitted for publication in Agronomy Journal.

CHAPTER II

EFFECTS OF NITROGEN AND CLIPPING TERMINATION DATES ON FORAGE PRODUCTION, GRAIN YIELD, AND YIELD COMPONENTS OF TAM W101 WHEAT

Abstract

A study was conducted in 1983-84 and 1984-85 at Perkins, Oklahoma. A randomized block design with a split plot arrangement was used where main units were three nitrogen (N) levels and subunits were eight clipping schedules. Objectives were to determine (1) wheat (*Triticum aestivum* L.) forage and grain production when clipped over different schedules and N levels (2) the effect of clipping termination at successive stages of plant development after jointing on grain yield and yield components over different N levels (3) the effect of N levels on jointing dates and (4) the possibility of developing forage and grain yield prediction models in response to clipping termination based on growing degree days (GDD) after early joint.

Effects of clipping and N on forage and grain production differed between years. In year 2, 66% less forage was produced than in year 1. In year 1, no difference in forage production was found between clipping at early joint only (E_0) and in December plus early joint (DE_0), but both produced about 50% more forage than treatments clipped in December only (D_0). Preplant N (N_1) resulted in nearly twice as much forage as for unfertilized checks (N_0). Plots receiving additional topdress N

(N_2) yielded slightly more forage than the N_1 plots when clipping was terminated at early joint (DE_0 and E_0), but greater benefits of topdress N appeared when clipping was terminated after jointing. Grain yield decreased as forage utilization increased, while N depressed grain yields slightly. In contrast, for year 2, DE_0 produced 27% more forage than E_0. Preplant N increased forage yields, by a greater relative amount than in year 1, but additional topdress N did not result in significantly more forage. Grain yields were again depressed with forage removal, but were increased with N. Jointing dates were not affected by N in year 1, but an 11 day delay for N_0 occurred in year 2. The development of a single prediction model for forage and grain yield response to clippings delayed by successive GDD after early joint was not possible since years differed. Instead, individual models were derived for each environment. No specific grain yield component accounted for all yield variability, but fertile spikes $area^{-1}$ was the one most closely associated.

Additional index words: Triticum aestivum L., Simulated grazing, Growing degree-days, Nitrogen fertility, Prediction model.

Introduction and Literature Review

Throughout most of the United states, wheat (Triticum aestivum L.) is primarily grown for grain. However, in the Southern Plains, winter wheat often serves a dual purpose as a forage crop for fall and winter grazing and as a grain crop following livestock removal near the jointing stage of plant development in the spring. Therefore, the economic return from wheat includes the value of grain plus livestock gains produced. Additional information on the effect of forage utilization on grain production is needed to help producers make management decisions to maximize the economic return from the crop.

McMurphy (1976) reported that small grains produce the highest quality forages that can be grown over all of the Southern Plains. Small grain plants during the vegetative stage have a high protein content that may reach 30% and is seldom lower than 20% until spring when the reproductive stage of plant development begins (Elder, 1967). This highly palatable and nutritious vegetation is a relatively low cost forage that furnishes livestock an excellent source of protein and vitamin A during the winter and early spring when other green foliage is often limited.

The effect of grazing on grain production is influenced by environmental conditions and many management practices: seedbed preparation, fertilizer application, cultivar selection, seeding date and rate, pest control, and animal management (Donnelly and McMurphy, 1984; Dunphy et al., 1982; Denman and Arnold, 1970). It is well established that to avoid grain yield reductions, grazing should be terminated when the apical meristem has elevated to a height it may be damaged or removed by grazing animals. However, a general management program that consistently optimizes forage and grain production has not yet been established because of the variable environmental conditions encountered from year to year.

In general, small grain forage production in Oklahoma is good, but unpredictable environmental conditions from year to year make it difficult to predict forage yields. Aldrich (1959) noted that the stage of growth when the crop is grazed was of great importance in many experiments. Elder (1960, 1967) reported that only one third of the total forage is usually produced prior to March 1 and forage production could be almost tripled when grazed until May 15 instead of removing cattle earlier to receive substantial grain yield. Thus, the time of production during the growing season is often more important to the livestock producer than knowing the total forage production.

Holt (1962) suggested that defoliation of small grains results in halted growth and losses in dry weight of lower stems and crown, which indicates new growth after clipping occurred by using carbohydrate reserves and that defoliation should be mild and delayed as long as possible for plants to develop and build up reserves. Holt et al. (1969) noted from clipping management studies that if maximum forage yields are to be obtained, it is important to allow plants to become well established at 15 to 20 cm in height before grazing. Clipping poorly established plants may reduce forage yields by 20 to 80 percent. Holt (1962) further reported that small grains produced as much forage when severely defoliated as when less severely defoliated if adequate time, four to six weeks, was allowed between clippings for recovery and regrowth. Plants from these studies clipped at higher heights usually recovered faster which was attributed to greater reserves and residual leaf area left for photosynthesis.

Much work has been directed toward the practical problem of how to obtain maximum forage production with minimal loss of grain yield. A very critical factor is the timing of grazing and clipping termination. However, many previous studies have terminated grazing or clipping on the basis of an arbitrary calendar date with no specific regard to plant development (Aldrich, 1959; Shipley and Regier, 1972; Finkner, 1974;

Phillips, 1972; Srisangchantara, 1976). Since jointing dates varied widely among cultivars and years, Dunphy et al. (1982) noted that consistent grain yield differences can be obtained by timing the forage harvests in relation to the stage of plant development rather than using calendar dates as a reference. Grain yield differences between treatments clipped throughout fall and winter with the last clipping at early joint (when growing points first begin to elevate above ground level) and those never clipped were significant in only one of three years. This indicates that considerable vegetation can be removed without seriously affecting grain yields when proper precautions are taken. A problem using developmental stages rather than calendar dates as a basis for termination is that frequent plant observations are required to carefully monitor apical meristem elevation. However, the finanical advantage of increased animal gains should greatly offset this slight drawback if conditions allow a longer grazing period.

Nelson et al. (1982) found that grazing and clipping may increase the grain yield of some varieties, decrease grain yields of others, and have no effect on others. Croy (1984) and Aldrich (1959) summarized that grazing will tend to increase or have no effect on grain yields when 1) fertility is adequate, 2) plants are not severely defoliated, 3) removal of excessive transpiring leaf area decreases excessive water usage, and 4) lodging is reduced. However, grazing could be detrimental to grain yield when 1) soil nutrients are limited, 2) defoliation is too severe, 3) there is little or no water limitation, and 4) lodging is not a problem.

Dunphy et al. (1982) found grain yield reductions ranging from 4 to 84 percent when forage was clipped throughout the winter and discontinued at early, mid (when 50% of main tillers had growing points above ground level), and late jointing (when any growing points within plots were elevated as high as 7.5 cm, the clipping height). Kernels spike^{-1} was the grain yield component most affected by forage removal. Being highly correlated with grain yield, kernels spike $^{-1}$ was decreased proportionally as clipping was delayed. Forage harvests at early, mid, and late joint occurred during the same period seed initials are expected to be set. Therefore, it is evident that removal of leaf tissue at this time would greatly reduce the photosynthetic machinery required to provide energy for reproductive tissue and other vegetative growth since jointing is the initiation of rapid stem growth. The weight kernel^{-1} and fertile tillers area^{-1} yield components were only slightly affected by defoliation and were significantly reduced only at the late joint clipping treatment.

Donnelly and McMurphy (1984) stated that the primary nutrient usually associated with limiting maximum forage production of small grains is nitrogen (N). In order to receive 4482 to 6722 kg ha^{-1}, a reasonable forage production goal for graze-out in Oklahoma, 179 to 269 kg ha^{-1} N would be required. Denman and Arnold (1970) reported that under dryland conditions, small grains respond favorably to 67 to 112 kg ha^{-1} N if moisture and other factors are not limited. The Oklahoma Cooperative Extension Service soil test recommendations (Johnson and Tucker, 1982) base N needs on a yield goal and suggest that 33.6 kg ha^{-1} N be applied for every 1120 kg ha^{-1} forage removed by grazing of small grains. If both forage and grain are produced an additional 2.24 kg ha^{-1} N per 27.2 kg of grain yield goal is required.

In many areas of the Southern Plains a split application of N is often applied at or prior to planting for adequate early establishment, while a later portion is applied as a topdressing in the mid-winter. Fribourg (1973) and Donnelly and McMurphy (1984) suggested that split applications of N could increase forage yield of small grains, and since it is difficult to estimate total N needs at planting it would be beneficial to use split applications. Sufficient N should be applied at or prior to planting for early forage production based on a reasonable forage yield goal. When conditions are favorable for high amounts of forage to be removed in the fall and/or spring, then additional N may be needed, especially if a grain crop is to be taken. However, no information is available on the effects of the interaction of N status with grazing or clipping termination dates on forage and grain production of wheat.

The purpose of this research is to provide additional information on wheat forage and grain production. Objectives included the evaluation of: 1) wheat forage production and grain yield when clipped over different schedules and N levels, 2) the effect of clipping termination at successive stages of plant development after jointing on grain yield and yield components over different N levels, 3) the effect of N levels on jointing dates, and 4) the possibility of developing forage and grain yield prediction models that will consistently and reliably explain the trade off between increased forage production and decreased grain yield with clipping terminated at successive growing degree days beyond the jointing stage of plant development.

Methods and Materials

A field experiment was conducted at the Oklahoma State University Agronomy Research Station near Perkins, Oklahoma, during the 1983-84 (year 1) and 1984-85 (year 2) growing seasons. The soil at the test site was a Zaneis loam (Udic Argiustolls). Monthly and annual precipitation data which pertain to the course of these studies, including long term means, are presented in Table 1. The station has a long term average of approximately 89 cm precipitation yearly, with about 51 cm falling between October 1 when the wheat is established and May 31 when the crop is senescing. In year 1 and year 2, 70 and 92 cm precipitation, respectively, were received during the growing season. Therefore, moisture was probably not a critical limiting factor in these studies after stands were established.

In both year 1 and year 2, the test was conducted on an area of known N deficiency and was fallowed during the summer, following removal of the previous wheat crop. Conventional tillage practices were used for weed control and seedbed preparation. On the day prior to planting, 4.9 by 9.1 m main plots isolated by 1.5 m buffer zones were marked. Those requiring pre-plant N applications received ammonium nitrate (34-0-0) and were tandem disked to incorporate N and finalize seedbed preparation for planting.

Cultivar 'TAM W101', a well adapted hard red winter wheat widely grown throughout the Southern Plains, was evaluated. TAM W101 was derived from crosses between five parents (Norin 16, Nebraska 60, Mediterranean, Hope, and Bison) and was released by Texas in 1971. It is a medium maturing semidwarf with strong straw and intermediate winterhardiness. It is resistant to bunt and moderately resistant to loose smut (Johnston et al., 1981).

In year 1, the test was planted on Sept. 15, 1983, into soil with adequate moisture for seed germination. In year 2, the seedbed was less desirable and the test was planted on Sept. 21, 1984, into warm and dry soil which delayed germination until after adequate rains were received six days later. The seeding rate was 90 kg ha^{-1} and 25 cm row spacings were used.

The experimental plots were arranged in a split-plot randomized complete block design with four replications. The main plots consisted of three N fertility levels: 1) a check which received no N fertilizer, 2) a pre-plant application of N (90 kg ha^{-1}), and 3) a pre-plant application of N (90 kg ha^{-1}) plus an additional 90 kg ha^{-1} N topdress application during mid-winter. Hereafter, N fertility levels will be designated as N_0, N_1, and N_2, respectively. Soil tests were used to determine the exact quantity of pre-plant N needed to reach the set 90 kg ha^{-1} treatment. In 1983-84 and 1984-85, soil tests revealed 8.9 and 2.2 kg ha^{-1} residual N, respectively, within the surface (0 to 15 cm) layer. No measureable residual N was found within the subsoil (15 to 46 cm) layer in either year.

During mid-February, routine plant samples were collected from all plots and dissected to monitor plant development at the apical meristematic regions. As in studies conducted by Dunphy et al. (1982), early joint was defined as the time any growing point in the plot began to elevate above ground level. After early joint was identified and all appropriate treatments were clipped, the high and low temperatures were recorded daily (Table 2 and Table 3). Growing degree days (GDD) were calculated as the mean daily temperature minus a base temperature of 0 C for each day following early joint. The summation of GDD was then used as the basis of terminating the delayed clipping treatments. Negative daily GDD encountered were summed as zero.

Subplots, which were randomly selected within the main plots, consisted of seven clipping treatments: 1) a December treatment (D_0) which was clipped only in December, 2) an early joint treatment (E_0) which was clipped only at the early joint stage of plant development, 3) a December and early joint treatment (DE_0) which was clipped in December and at early joint. 4) a December, early joint, and delay level 1 treatment (DE_1), 5) a December, early joint, and delay level 2 treatment (DE_2), 6) a December, early joint, and delay level 3 treatment (DE_3), and 7) a December, early joint, and delay level 4 treatment (DE_4). All delayed clipping treatments were clipped in December, at early joint, and again when terminated progressively on the basis of accumulated GDD after early joint. Table 4 presents GDD after early joint when the DE_1, DE_2, DE_3, and DE_4 clipping treatments were actually terminated. A check treatment was included that was never clipped for forage. The D_0, E_0, and DE_0 clipping treatments are simulations of some typical grazing management systems that are currently practiced when grain production is desired. The delayed clipping treatments (DE_1 to DE_4) are intended to simulate situations where livestock are allowed to continue grazing after jointing until terminated at successively later stages of plant development. They were compared to DE_0, as a check treatment.

Uniform 1 m sections of rows were randomly selected within main plots for sampling purposes in year 2. In year 1, however, 0.5 m rows were used since uniform stands were limited due to soil crusting, which was caused by heavy rains soon after planting. Forage was cut with electric clippers at a height of approximately 5 cm, bagged, oven-dried for 96 hr at 54 C, weighed, and converted to kg ha^{-1}. Border areas around each clipping treatment were clipped after each harvest interval to ensure that treatments were never limited due to shading. Forage sampling rows were allowed to continue growth normally after cuttings for each treatment were collected.

At maturation, clipping treatment areas were hand harvested and bundled to determine forage utilization effects on grain yield and yield components. Fertile spikes $area^{-1}$, kernels $spike^{-1}$, and weight $kernel^{-1}$ were the grain yield components of interest. A subsample of fertile spikes was taken from the bundled wheat stems. The fertile spikes in the sample and subsample were counted prior to threshing with a small vogel head thresher. Grain collected from the sample was weighed and 1,000 kernels were counted to determine average weight $kernel^{-1}$. Grain collected from the subsample was weighed and all kernels were counted to determine average kernel number $spike^{-1}$. Actual grain yield was the total sample and subsample weights.

Analysis of variance was performed on all forage, grain, and grain yield component data by using a split plot design with N levels as whole units and clipping treatments as subunits. Clipping treatments which simulate typical grazing management systems (D_0, E_0, and DE_0) were analyzed separately from the delayed ones (DE_1 to DE_4) for two primary reasons. First, based on the objectives of this study, it was not logical to analyze the typical and delayed management systems together since they were expected to produce grain and forage yields that differ drastically. Secondly, when treatment means differ so greatly the variance may not be homogeneous across all treatments since the variance is proportioned to the means. LSD values were calculated at the 5% level of probability for comparison of treatment means when F values were significant. Simple correlation coefficients were calculated among all grain and yield component data. In addition, polynomial regression analyses were performed to provide yield equations for models that describe the effects of delaying clipping termination beyond the jointing stage. Data from clipping treatments DE_0, DE_1, DE_2, DE_3, and DE_4 were used in these analyses. The number of GDD following early joint when the final clipping was made was considered as the independent variable for fitting regression models. In the analysis of variance, clipping treatment effects were partitioned into 1, 2, 3, and 4 degree polynomial components to identify significant terms for the regression models and significant interactions with N levels.

Results and Discussion

The effect of clipping on the wheat plant is not necessarily the same as the effect of grazing. Clipping seems to be more severe than grazing since it removes all forage at one time compared to the gradual forage removal which occurs with livestock grazing. Therefore, results from these simulated grazing studies, although useful, must be interpreted carefully.

In 1983-84, adequate moisture and a combination of warm days and cool nights throughout the fall, which enabled early plant establishment, provided favorable conditions for good seasonal forage production. Total mean yields revealed 2934 kg ha^{-1} (Table 5) for clipping treatments that simulated typical grazing management systems (D_0, E_0, and DE_0) and 4578 kg ha^{-1} (Table 6) for those delayed (DE_0 to

DE_4). Total forage production for 1984-85 was not as good and averaged 1001 kg ha^{-1} for the D_0, E_0, and DE_0 treatments and 1806 kg ha^{-1} for the delayed clipping treatments. Low forage yields produced in year 2 were due primarily to dry conditions prior to planting which delayed plant establishment.

In both years, clipping treatments cut in December exhibited no significant forage yield differences, which indicated uniformity throughout experimental plots (Table 7). Significant differences between N_1 and N_0 and N_2 and N_0, but not between N_1 and N_2, further supported experimental uniformity since the N_2 plots had not yet received N topdress applications (Table 8).

In year 1, a large N effect on total forage production was observed. When averaged over D_0, E_0, and DE_0 clipping treatments, N_1 plots yielded almost twice as much forage as N_0 plots (Table 5). Topdress N resulted in an additional 21% more foliage for E_0 and 9% more for DE_0. No significant forage production differences between E_0 and DE_0 were observed. However, E_0 and DE_0 produced 46 and 52% more forage, respectively, than the D_0 clipping treatments. This same trend was not followed exactly in year 2. Instead, topdress N did not significantly increase forage production over N_1 plots. Although N_1 and N_2 plots did not differ statistically, they yielded over three times more forage than the N_0 plots. Furthermore, all three simulated typical grazing management systems differed significantly with DE_0 producing 27% more forage than E_0, and E_0 25% more than D_0.

The 2 and 3 fold forage yield increases for year 1 and 2, respectively, which were obtained prior to jointing when 90 kg ha^{-1} preplant N was applied stresses that adequate preplant N is necessary to receive maximum fall and early winter forage production when soils are low in residual N. In year 1, additional topdress N applied in January significantly increased forage yields prior to jointing, but the greatest benefit was observed when the final forage harvest occurred after jointing (Table 6). Therefore, it may be possible to increase forage production prior to jointing if the topdress N is applied earlier and/or preplant N rates are increased to allow a longer period for plants to utilize N. In year 1, the longer period that allowed plants in E_0 and DE_0 clipping treatments to utilize more N explains the 2 fold forage yield increase as compared to the shorter period allowed for plants clipped in December only. The similar trend in year 2, where DE_0 yielded 58% and E_0 25% more foliage than D_0 treatments, also explains this. Furthermore, the trend observed in year 2 suggests that clipping may stimulate plant growth since DE_0 yielded 27% more foliage than E_0.

In both years, forage utilization from D_0, E_0, and DE_0 clipping treatments reduced grain yields (Table 9). In 1983-84, grain reductions from the check were 23, 38, and 48% and in 1984-85 14, 19, and 27%, respectively. In both years, the check treatment was significantly different from D_0, E_0, and DE_0; D_0 and E_0 did not differ; and E_0 did not differ significantly from DE_0. In 1983-84, N levels had no effect on grain yields. However, in 1984-85, all three differed significantly where N_1 plots averaged 74% more grain than N_0 plots and N_2 24% more than N_1 plots.

Ratios that illustrate grain yield reductions of the simulated typical grazing management systems due to forage utilization were calculated by taking the difference between the average grain yield over all N levels of the check and each D_0, E_0, and DE_0 clipping treatment, divided by the total forage produced by each clipping treatment. In year 1 and 2, the average of these ratios indicate a 0.70 and 0.57 kg grain yield reduction, respectively, for every kg of forage removed. Two year averages of grazing and clipping studies conducted by Nelson et al. (1983) cited by Croy (1984) showed a 269 kg ha^{-1} sacrifice in grain yield for each 1120 kg ha^{-1} forage utilized. Based on the ratios previously figured, grain yield reductions were 784 kg ha^{-1} for year 1 and 630 kg ha^{-1} for year 2 for each 1120 kg ha^{-1} forage removed. Grain yield reduction due to forage utilization was greater in year 1 when more forage was produced.

The grain yield component most highly correlated with grain yields for the entire study was fertile spikes $area^{-1}$ (Table 10). For the typical management treatments fertile spikes $area^{-1}$ was progressively reduced as the forage removal increased (Table 11) reflecting the similar trend in grain yields. Fertile spikes $area^{-1}$ was not affected by N level in year 1 when grain yields were not affected by N level. However, in year 2, fertile spikes $area^{-1}$ increased dramatically with nitrogen as did grain yield (Table 13). Kernel weight was the yield component the least correlated with grain yield and least affected by forage utilization. Kernel weight was not affected significantly by forage harvests in either year and was only affected by N level in year 1 when it was significantly reduced in the N_2 plots. In year 2, the average number of kernels $spike^{-1}$ was not significantly affected at any N level or clipping treatment (D_0, E_0, and DE_0). However, in year 1, kernels $spike^{-1}$ were progressively reduced when forage utilization increased, partially accounting for the grain yield reduction.

Environmental conditions that prevailed during the two year span of this study produced inconsistent yearly jointing trends just as N effects on forage and grain yields differed. George (1982), based on his sequential growing point development scale for winter wheat, suggested that growing points would generally be above the soil surface when reaching stage 9 (central ridges of spikelet formation have expanded the length of the spike and culm elongation has moved the head 25 to 30 mm from the crown) or later, depending on cultivar and environment. Results from this study with TAM W101 showed stage 12 (spikelet primordia differentiation can be detected throughout the head and the apical spikelet shows well-defined ridges) or later to be the stage in which the developing spike reached ground level. In year 1, early joint was defined on 6 March, 1984, for each N level evaluated. Although plants within N_2 plots displayed growing points a few mm higher than those within N_1 and N_0 plots, differences in elevation were minimal and they shared a common developmental stage just beyond 12. In year 2, however, plants within N_1 and N_2 plots reached early joint 11 days (6 March, 1985) prior to those in N_0 plots (17 March, 1985) and no detectable differences between plants sampled from N_1 and N_2 plots were observed. Although these results indicate no significant early jointing date differences between plants grown on plots which received N, they do suggest, depending on the environment, that N can accelerate culm elongation and place the growing point at or above the soil surface sooner than for plants grown on soils that contain little N.

These results stress that routine plant observations should be practiced to maximize potential forage production without increasing the danger of reducing subsequent grain yield. Terminating grazing on the basis of calender dates has been useful. However, since these dates are determined based on the average of many environments they can be misleading, and depending on the particular environment, could rob the grower of increased forage or result in decreased grain yields.

Forage and grain yield responses which describe yield trends as affected by N fertility levels and clipping treatments terminated at successively later stages of plant development on the basis of accumulated GDD after early joint are presented in Figures 1 through 4. Development of a single model for forage and grain yield responses from combined data was not possible since different trends in year 1 and 2 were encountered. Therefore, discussion will pertain to individual yield responses that describe trends produced in appropriate environments. In general, however, delaying the final forage harvest until later stages in plant development after early joint resulted in increased forage and decreased grain yields for both years across all N levels.

In 1983-84, forage production for the delayed clipping treatments was significantly affected by N. Plants within N_2 plots produced an average of 20% more foliage than N_1, and N_1 76% more than N_0 plots (Table 6). However, since there was no interaction between N levels and clipping treatments, prediction equations for N_0, N_1, and N_2 fertility levels have a common positive and linear slope, which represent average forage yield increases of 8.2 kg ha^{-1} for each accumulated GDD delay in clipping termination after early joint for all fertility levels (Fig. 1).

The positive and linear effect of delayed termination of clipping increasing forage yield was continued in 1984-85 (Fig. 2), but the response differed significantly for each N level. As fertility levels were increased (N_0 vs N_1 vs N_2) forage yield per accumulated GDD increased 1.5, 4.9, and 6.7 kg ha^{-1}, respectively, compared to the 8.2 kg ha^{-1} increase for all N levels in the previous year. At the later stages in plant development, the pre-plant N applied to N_1 plots was apparently not sufficient for maximum production; while the additional topdress N on N_2 plots provided adequate nutrients that allowed plants to produce slightly more forage. These results support the importance of adequate N to assure a high rate of forage production if grazing is extended beyond jointing to help offset the expected grain yield reductions.

In year 1 and 2, grain yield reductions due to final forage harvests taken progressively after early joint displayed differing trends (Fig. 3 and 4, respectively). In year 1, clipping effects were best explained quadratically and in year 2, linearly. Based on the results of year 1, delaying the final harvest until later stages in plant development after early joint resulted in similar trends for all fertility levels as was the case for year 1 forage production. However, averaged over all delayed clipping treatments, grain yield differed over N levels with N_0 yielding significantly more than N_2. The N_1 treatment was intermediate and did not differ statistically from N_0 or N_2. This unexpected result of the check plots yielding more grain than the N fertilized plots may be due to the heavier forage produced and removed from the fertilized plots prior to jointing. According to Fig. 3, an average of 29, 52, 71, 84, and 91% grain yield decrease occurred by delaying the final forage harvest until 50, 100, 150, 200, and 250 GDD, respectively, after early joint. Average grain yield reductions of 29, 23, 19, 13, and 7% were observed during the first (0 to 50), second (50 to 100), third, fourth, and fifth 50 GDD increments, respectively. Therefore, dramatic yield reductions may occur even if grazing is extended for only a short time beyond jointing if heavy forage removal has occurred prior to jointing as in year 1.

In year 2, grain production (Fig. 4) was significantly reduced in a linear fashion and the response differed with N. Averaged over all clipping treatments, N_2 plots produced significantly higher yields than N_1 and N_1 higher yields than N_0 plots (Table 14). Even though N_2 and N_1 plots yielded more grain they were affected more drastically by delayed harvests. For each GDD by which the final clipping was delayed, N_0, N_1, and N_2 plots lost 1.7, 2.6, and 4.5 kg ha^{-1} in grain yield, respectively. Although three different regressions were fitted because of the interaction, only the slopes for N_0 and N_2 differed significantly.

Biologically, trend differences between 1983-84 and 1984-85 grain yield responses may be best explained by observing their forage production schemes both prior to and after jointing. Total forage production prior to jointing (DE_0) was almost 3 times greater in year 1 than in year 2. Furthermore, the rate of forage production after jointing was more than 8 kg ha^{-1} per GDD in year 1 compared to the 1.5 to 6.7 kg ha^{-1} per GDD in year 2. With this in mind, grain yield reductions due to clipping after jointing, whether drastic as in year 1 or moderate as in year 2, seem to be directly related to the quantity of forage removed both before and/or after jointing. In year 2, the higher rates of forage utilization after jointing with the higher N levels were also associated with greater rates of grain yield depression. Therefore, these results lend support to the idea that carbohydrate reserves stored within roots and crowns may have become limited after significant foliage was removed, thereby decreasing recovery potential.

Significant clipping treatment effects for harvests delayed until after early joint were found for all grain yield components (Table 12), but no one component accounted for all the grain yield reductions. In both years, fertile spikes area^{-1} was the grain yield component most affected by delayed clipping after early joint. In year 1, 88% and in year 2, 28% reductions in fertile spikes area^{-1} were observed. Kernel weights were reduced up to 36% in year 1 and 18% in year 2 with delayed clipping. Average number of kernels spike^{-1} were reduced slightly with delayed clipping both years. In year 2, where N increased grain yield of delayed clipping plots, N_2 plots produced 29% more fertile spikes area^{-1} than N_1 and N_1, 42% more than N_0 plots (Table 13). Also in year 2, N_2 plots provided heads with 4 more kernels than N_0 and 3 more than N_1 plots. In year 1, kernel weights were decreased with more nitrogen when grain yields were decreased with the highest N fertility level. On the other hand, in year 2 when grain yields increased with more N, fertile spikes area^{-1} increased significantly, but kernel weights were not affected by N.

CHAPTER III

Summary and Conclusions

In agreement with many previous studies, the results from this two year test indicate that the effects of N and clipping on forage and grain production are often inconsistent since they are sensitive to environmental conditions that may differ from year to year. However, 2 to 3 fold forage yield increases may be obtained prior to jointing if adequate preplant N is applied to soils low in N. To maximize forage production prior to jointing, topdressed N must be applied early enough for plants to utilize the N. Furthermore, twice as much forage can possibly be produced when clipping is extended to early joint instead of grazing only in December. Results indicated grain yields of the simulated typical grazing management system treatments decreased as the forage utilization increased. Values ranged from 0.70 to 0.57 kg grain yield reduction for every kg forage utilized. Effects of N ranged from slightly depressing to significantly increasing grain yields.

Environmental conditions prevailed during the course of these studies which produced inconsistent yearly jointing trends. Effects on jointing dates ranged from no effect at any fertility level to an 11 day delay for plants which grew in low N soil environments. These results stress that routine plant observations for growing point elevation should be practiced to maximize potential forage production without increasing the danger of reducing subsequent grain yield. Terminating grazing on the basis of calender dates can be misleading and depending on the particular environment, could rob the grower of increased forage or result in decreased grain yields.

The development of a single prediction model for forage and grain yield response to clippings delayed by successive GDD after early joint was not possible since years differed. Instead individual responses were derived for each environment. Results indicated that delaying the final forage harvest until later stages in plant development after early joint would increase forage and decrease grain yields.

Forage production from the delayed clipping treatments was significantly affected by N. Effects of clipping ranged from an 8.2 kg ha^{-1} increase for each accumulated GDD when clipped after early joint for all fertility levels in year 1 to a lesser effect which increased with N fertility levels in year 2. In this case, 1.5, 4.9, and 6.7 kg ha^{-1} forage increases were obtained for each accumulated GDD after early joint for the N_0, N_1, and N_2 fertility levels, respectively. At the later stages in plant development the preplant only N application in certain instances was apparently not sufficient for maximum production; while the additional topdress N applications provided adequate nutrients that allowed plants to produce more forage. These results support the importance of adequate N to assure a high rate of forage production if grazing is extended beyond jointing to help offset the expected grain yield reductions.

Grain yield reductions due to forage harvests taken progressively after early joint displayed differing trends ranging from quadratic to linear effects. Results indicate that dramatic yield reductions may occur even if clipping is extended only a short time beyond jointing if heavy forage removal has occurred prior to jointing. Furthermore, grain yield reductions due to clipping, whether drastic or moderate, seem to be directly related to the quantity of forage removed both before and/or after jointing. These results lend support to the idea that carbohydrate reserves stored within roots and crowns may have become limited after significant foliage was removed; thereby decreasing recovery potential. No specific grain yield component accounted for all yield variability, but fertile spikes area^{-1} was the most closely associated.

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Table 1. Monthly, annual, and long term mean precipitation at the Perkins Agronomy Research Station.

Month	1983	1984	1985	Long term+ average
	cm			
Jan.	1.78	1.12	5.84	3.89
Feb.	9.88	2.72	14.02	3.71
Mar.	8.61	15.04	16.15	5.59
Apr.	5.44	9.25	16.61	8.03
May	15.52	9.80	7.14	12.93
June	13.77	10.36	17.73	11.63
July	0.05	0.13	12.12	8.76
Aug.	2.44	3.91	6.45	8.10
Sept.	4.88	3.68	14.05	9.68
Oct.	27.03	10.72	11.53	8.15
Nov.	4.47	6.02	10.80	4.83
Dec.	0.74	15.70	1.47	3.61
Total	94.59	88.44	133.91	88.90

+Long term average (30 years) from the city of Perkins located about two miles south of the test site.

Table 2. 1983-84 maximum and minimum daily temperatures, growing degree days, and days after early joint of TAM W101 wheat at Perkins, Oklahoma.

Month and Date	Daily Temperature Tmax	Tmin	Daily Growing Degree Days	Sum of Growing Degree Days After Early Joint	Sum of Days after Early Joint
	C				
3/6+					
3/7	17.2	-4.4	6.40	6.40	1
3/8	4.4	-6.1	-0.85	6.40	2
3/9	11.7	-3.3	4.20	10.60	3
3/10	12.8	-1.7	5.55	16.15	4
3/11	10.0	2.2	6.10	22.25	5
3/12	10.0	- 1.1	4.45	26.70	6
3/13	20.0	3.9	11.95	38.65	7
3/14	23.3	16.7	20.00	58.65	8
3/15	27.8	13.9	20.85	79.50	9
3/16	8.9	1.1	5.00	84.50	10
3/17	15.6	3.3	9.45	93.95	11
3/18	17.8	-1.1	8.35	102.30	12
3/19	1.7	-4.4	-1.35	102.30	13
3/20	15.0	-2.2	6.40	108.70	14
3/21	16.7	2.2	9.45	118.15	15
3/22	15.6	3.3	9.45	127.60	16
3/23	7.8	2.2	5.00	132.60	17
3/24	9.4	3.3	6.35	138.95	18

Table 2. Continued

Month and Date	Daily Temperature		Daily Growing Degree Days	Sum of Growing Degree Days After Early Joint	Sum of Days after Early Joint
	T_{max}	T_{min}			
	C				
3/25	15.6	7.2	11.40	150.35	19
3/26	15.6	6.1	10.85	161.20	20
3/27	13.9	0.6	7.25	168.45	21
3/28	8.3	0.6	4.45	172.90	22
3/29	10.0	-0.6	4.70	177.60	23
3/30	12.8	1.7	7.25	184.85	24
3/31	6.7	1.7	4.2	189.05	25
4/1	14.4	3.9	9.15	198.2	26
4/2	20.6	3.3	11.95	210.15	27
4/3	13.3	2.8	8.05	218.2	28
4/4	11.1	-1.7	4.7	222.90	29
4/5	17.2	3.3	10.25	233.15	30
4/6	23.9	11.1	17.5	250.65	31
4/7	15.0	7.8	11.4	262.05	32
4/8	12.8	6.1	9.45	271.50	33
4/9	17.2	7.2	12.2	283.7	34
4/10	17.2	8.3	12.75	296.45	35
4/11	23.3	6.1	14.7	311.15	36

+ Defined point of early joint

Table 3. 1984-85 Maximum and Minimum Daily Temperatures, Growing Degree Days, and Days after Early Joint of TAM W101 at Perkins, Oklahoma

Month and Date	Daily Temperature T_{max}	T_{min}	Daily Growing Degree Days	Sum of Growing Degree Days After Early Joint N_0	N_1 & N_2	Sum of Days after Early Joint N_0	N_1 & N_2
	C						
3/6+							
3/7	17.2	11.1	14.15	—	14.15	—	1
3/7	19.4	7.2	13.30	—	27.45	—	2
3/9	17.8	15.0	16.40	—	43.85	—	3
3/10	23.3	19.4	21.35	—	65.20	—	4
3/11	22.2	5.6	13.90	—	79.10	—	5
3/12	10.0	4.4	7.20	—	86.30	—	6
3/13	11.1	0.6	5.85	—	92.15	—	7
3/14	16.1	0.0	8.05	—	100.20	—	8
3/15	16.7	5.0	10.85	—	111.05	—	9
3/16	14.4	3.3	8.85	—	119.90	—	10
3/17++	17.8	3.3	10.55	—	130.45	—	11
3/18	21.7	7.2	14.45	14.45	144.90	1	12
3/19	21.1	7.2	14.15	28.60	159.05	2	13
3/20	11.1	7.2	9.15	37.75	168.20	3	14
3/21	10.0	5.6	7.80	45.55	176.00	4	15
3/22	13.3	4.4	8.85	54.40	184.85	5	16
3/23	17.8	3.9	10.85	65.25	195.70	6	17

Table 3. Continued

Month and Date	Daily Temperature T_{max}	T_{min}	Daily Growing Degree Days	Sum of Growing Degree Days After Early N_0	N_1 & N_2	Sum of Days after Early Joint N_0	N_1 & N_2
	C						
3/24	21.1	5.0	13.05	78.30	208.75	7	18
3/25	23.3	8.3	15.80	94.10	224.55	8	19
3/26	19.4	13.9	16.65	110.75	241.20	9	20
3/27	27.2	16.7	21.95	132.70	263.15	10	21
3/28	28.3	19.4	23.85	156.55	287.00	11	22
3/29	16.7	3.3	10.00	166.55	297.00	12	23
3/30	8.3	-0.6	3.85	170.40	300.85	13	24
3/31	14.4	2.2	8.30	178.70	—	14	—
4/1	15.0	3.3	9.15	187.85	—	15	—
4/2	25.6	9.4	17.50	205.35	—	16	—
4/3	29.4	15.6	22.50	227.85	—	17	—
4/4	27.2	7.2	17.20	245.05	—	18	—
4/5	16.7	4.4	10.55	255.60	—	19	—
4/6	20.6	7.8	14.20	269.80	—	20	—
4/7	15.6	8.9	12.25	282.05	—	21	—
4/8	15.0	7.2	11.10	293.15	—	22	—
4/9	21.7	10.0	15.85	309.00	—	23	—
4/10	20.0	11.7	15.85	324.85	—	24	—

+Defined point of early joint for N_1 and N_2
++Defined point of early joint for N_0

Table 4. Number of growing degree days accumulated after early joint when the delayed clipping treatments were cut for the various nitrogen levels in 1983-84 and 1984-85.

Delayed Clipping Treatments	1983-84	1984-85		
		N_0	N_1	N_2
	GDD			
DE_0	0	0	0	0
DE_1	39	78	79	79
DE_2	109	167	159	159
DE_3	218	245	241	241
DE_4	311	324	301	301

Table 5. Forage production of TAM W101 wheat clipped at three schedules during two growing seasons.

Clipping Treatment	1983-84 Fertility Level				1984-85 Fertility Level			
	N_0	N_1	N_2	Mean	N_0	N_1	N_2	Mean
	kg ha^{-1}							
D_0	1325	2521	2791	2212	282	1103	963	783
E_0	2064	3451	4161	3226	275	1320	1338	978
DE_0	1851	3948	4291	3363	548	1721	1454	1241
Mean	1746	3307	3748	2934	368	1381	1252	1001
CV (whole unit)				10				27
CV (sub unit)				14				21
L.S.D. for fertility levels (0.05)				304				272
L.S.D. for clipping treatments (0.05)				363				176

Table 6. Forage production of TAM W101 wheat clipped at successive stages of plant development after early joint during two growing seasons.

Clipping Treatment	1983-84 Fertility Level N_0	N_1	N_2	Mean	1984-85 Fertility Level N_0	N_1	N_2	Mean
	kg ha^{-1}							
DE_0	1851	3948	4291	3363	548	1721	1454	1241
DE_1	1943	4242	5384	3856	559	1646	1908	1371
DE_2	2601	4709	5853	4388	686	2080	2470	1745
DE_3	3569	5421	7071	5354	807	2748	2724	2093
DE_4	4151	6506	7128	5928	1051	3044	3644	2580
Mean	2823	4965	5945	4578	730	2248	2440	1806
CV (whole units)			14				29	
CV (sub units)			16				16	
L.S.D. for fertility levels (0.05)			479				401	
L.S.D. for clipping treatments (0.05)			617				235	
L.S.D. for interaction (0.05)			NS				408	

Table 7. Forage production of TAM W101 wheat for the December harvest during two growing seasons.

Clipping Treatment	December Harvest 1983-84	December Harvest 1984-85
	kg ha^{-1}	
D_0	2212	783
E_0	----	---
DE_0	2132	791
DE_1	2175	657
DE_2	2327	669
DE_3	2356	716
DE_4	2230	768
Mean	2238	731
CV	17	18

Table 8. Forage production of TAM W101 wheat from three fertility levels for the December harvest during two growing seasons.

Fertility Level	December Harvest	
	1983-84	1984-85
	kg ha^{-1}	
N_0	1316	300
N_1	2610	1016
N_2	2790	875
Mean	2239	731
CV	12	53
L.S.D. (0.05)	194	272

Table 9. Grain production of TAM W101 wheat clipped at three schedules during two growing seasons.

Clipping Treatment	1983-84 Fertility Level N_0	N_1	N_2	Mean	1984-85 Fertility Level N_0	N_1	N_2	Mean
	kg ha^{-1}							
Check	5816	6422	5057	5765	1743	2998	4079	2940
D_0	4490	4816	4019	4441	1738	2798	3076	2538
E_0	3656	3664	3444	3588	1236	2805	3103	2381
DE_0	3442	3133	2486	3020	1428	2085	2944	2152
Mean	4351	4509	3751	4204	1536	2671	3301	2503
CV (whole units)			31				24	
CV (sub units)			26				17	
L.S.D. for fertility levels (0.05)			NS				521	
L.S.D. for clipping treatments (0.05)			925				356	

Table 10. Simple correlation coefficients between grain yield and yield component means for all clipping by nitrogen treatment combinations (n = 24).

Year	Fertile Tillers/ Area	Kernels/ Spike	Weight/ Kernel
1984	0.943**	0.927**	0.745**
1985	0.963**	0.913**	0.353

**Significant at the 0.01 level of probability.

Table 11. Effect of forage removal from TAM W101 wheat clipped at three schedules on spike number, kernel number and kernel weight during two growing seasons.

Clipping Treatment	Year 1983-84	Year 1984-85
	Fertile Spikes $Area^{-1}$	
	$0.13\ m^2$	$0.25\ m^2$
Check	115	128
D_O	95	117
E_O	88	112
DE_O	75	109
CV	19	13
L.S.D. (0.05)	15	12.24
	Kernels $Spike^{-1}$	
Check	18	17
D_O	17	16
E_O	16	15
DE_O	15	15
CV	9	14
L.S.D. (0.05)	1.26	NS
	Weight $Kernel^{-1}$ (mg)	
Check	35	33
D_O	34	33
E_O	33	33
DE_O	33	33
CV	6	4
L.S.D. (0.05)	NS	NS

Table 12. Effect of forage removal from TAM W101 wheat clipped at successive stages of plant development after early joint on spike number, kernel number, and kernel weight during two growing seasons.

Clipping Treatment	Year 1983-84	Year 1984-85
	Fertile Spikes Area^{-1}	
	0.13 m^2	0.25 m^2
DE_0	75	109
DE_1	68	100
DE_2	47	93
DE_3	20	97
DE_4	9	78
CV	31	16
L.S.D. (0.05)	11.15	12.4
	Kernels Spike^{-1}	
DE_0	15	15
DE_1	13	14
DE_2	11	14
DE_3	11	14
DE_4	11	13
CV	24	14
L.S.D. (0.05)	2.38	1.6
	Weight Kernel^{-1} (mg)	
DE_0	33	33
DE_1	31	32
DE_2	29	31
DE_3	27	30
DE_4	21	27
CV	15	6
L.S.D. (0.05)	3.54	1.5

Table 13. Effect of forage removal from TAM W101 wheat grown in three fertility levels cut at three clipping schedules and at successive stages of plant development after early joint on grain yield components.

Fertility Level	Scheduled Clipping Harvests					
	1983-84			1984-85		
	Fertile Spikes Area^{-1}	Kernels Spike^{-1}	Kernel Weight	Fertile Spikes Area^{-1}	Kernels Spike^{-1}	Kernel Weight
	-0.13 m^2		- mg -	-0.25 m^2		- mg -
N_0	85	17	37	79	15	34
N_1	95	16	35	133	15	33
N_2	99	16	29	138	18	33
CV	19	8	6	11	19	8
L.S.D. (0.05)	NS	NS	1.74	10.7	NS	NS
	Delayed Clipping Harvests					
N_0	47	13	33	67	12	31
N_1	42	11	28	95	13	31
N_2	42	12	23	123	16	29
CV	39	26	14	21	14	10
L.S.D. (0.05)	NS	NS	3.05	15.7	1.5	NS

Table 14. Grain production of TAM W101 wheat clipped at successive stages of plant development after early joint during two growing seasons.

Clipping Treatment	1983-84 Fertility Level N_0	N_1	N_2	Mean	1984-85 Fertility Level N_0	N_1	N_2	Mean
	kg ha^{-1}							
DE_0	3442	3133	2486	3020	1428	2085	2944	2152
DE_1	2356	2265	1614	2078	858	1769	2961	1863
DE_2	1991	1267	580	1279	1104	1540	2176	1607
DE_3	938	182	407	509	1016	1585	2531	1711
DE_4	374	45	120	180	628	1163	1383	1058
Mean	1820	1378	1042	1413	1007	1628	2399	1678
CV (whole units)			56				33	
CV (sub units)			39				23	
L.S.D. for fertility levels (0.05)			609				423	
L.S.D. for clipping treatments (0.05)			455				316	
L.S.D. for interaction (0.05)			NS				547	

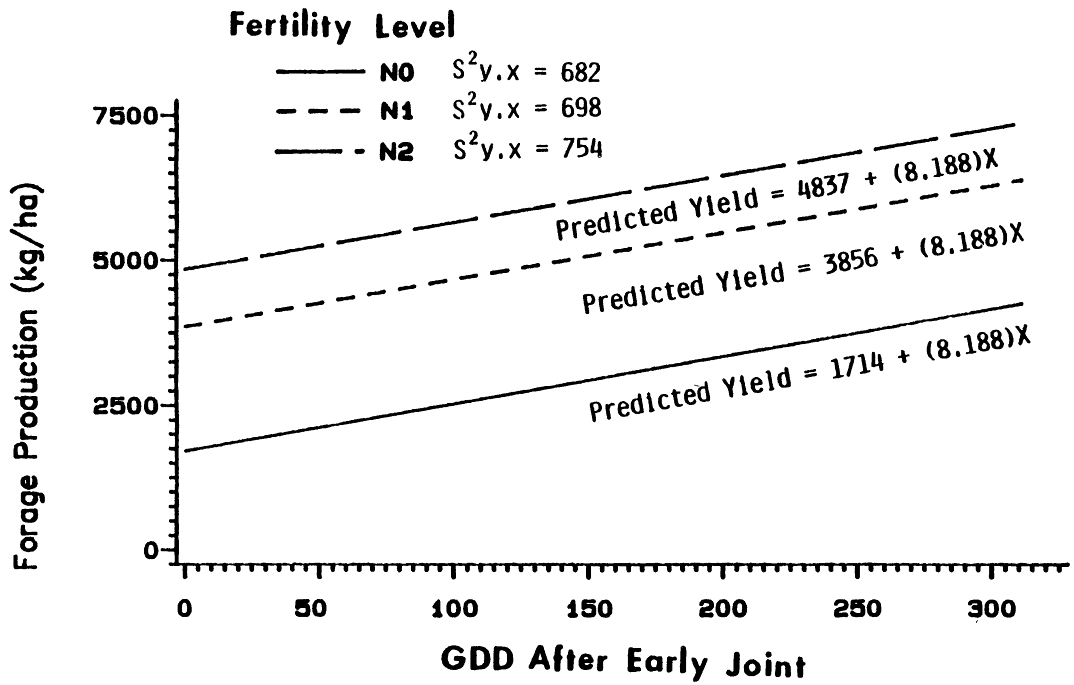

Fig. 1. 1983-84 Wheat Forage Production Response to Final Forage Harvest at Successive Growing Degree Days after Early Joint for Three Nitrogen Fertility Levels.

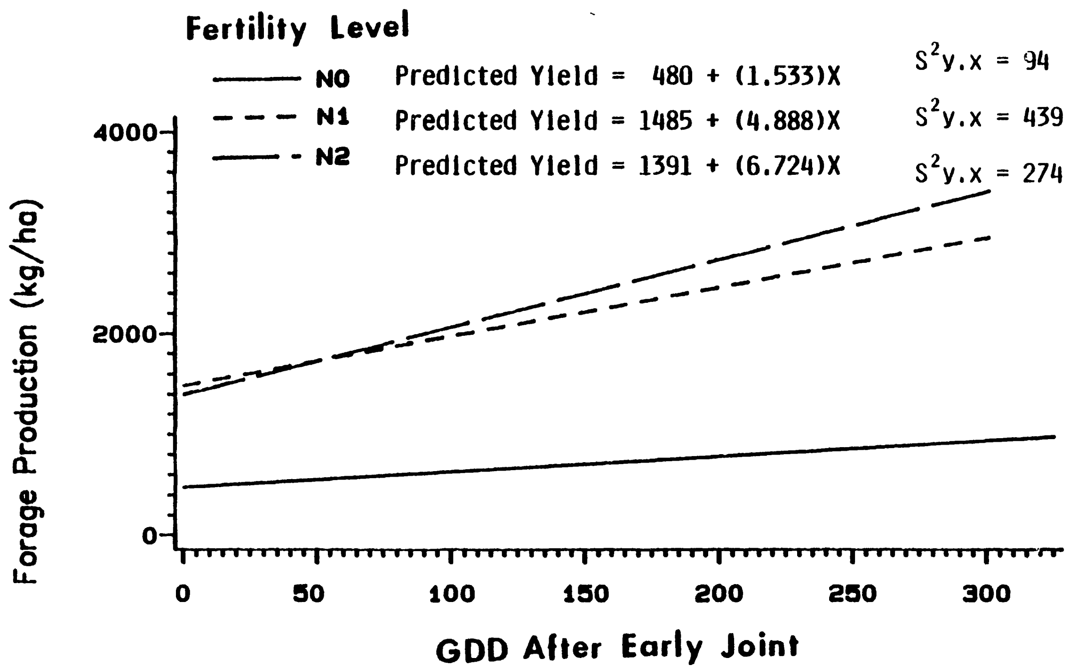

Fig. 2. 1984-85 Wheat Forage Production Response to Final Forage Harvest at Successive Growing Degree Days after Early Joint for Three Nitrogen Fertility Levels.

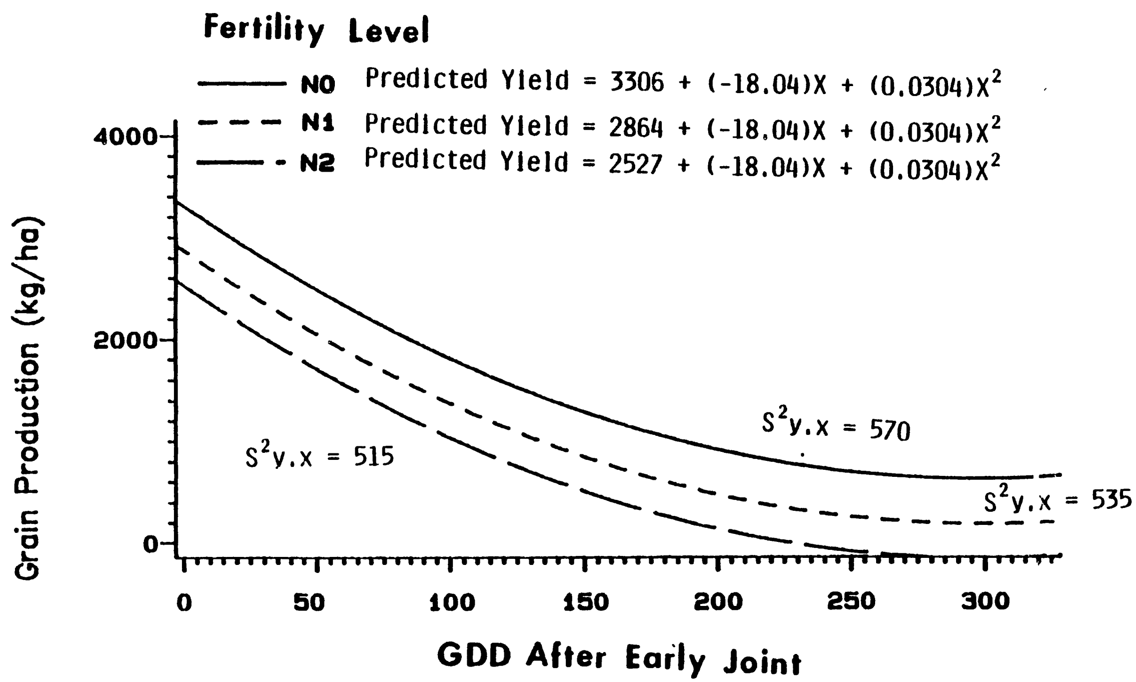

Fig. 3. 1983-84 Wheat Grain Production Response to Final Forage Harvest at Successive Growing Degree Days after Early Joint for Three Nitrogen Fertility Levels.

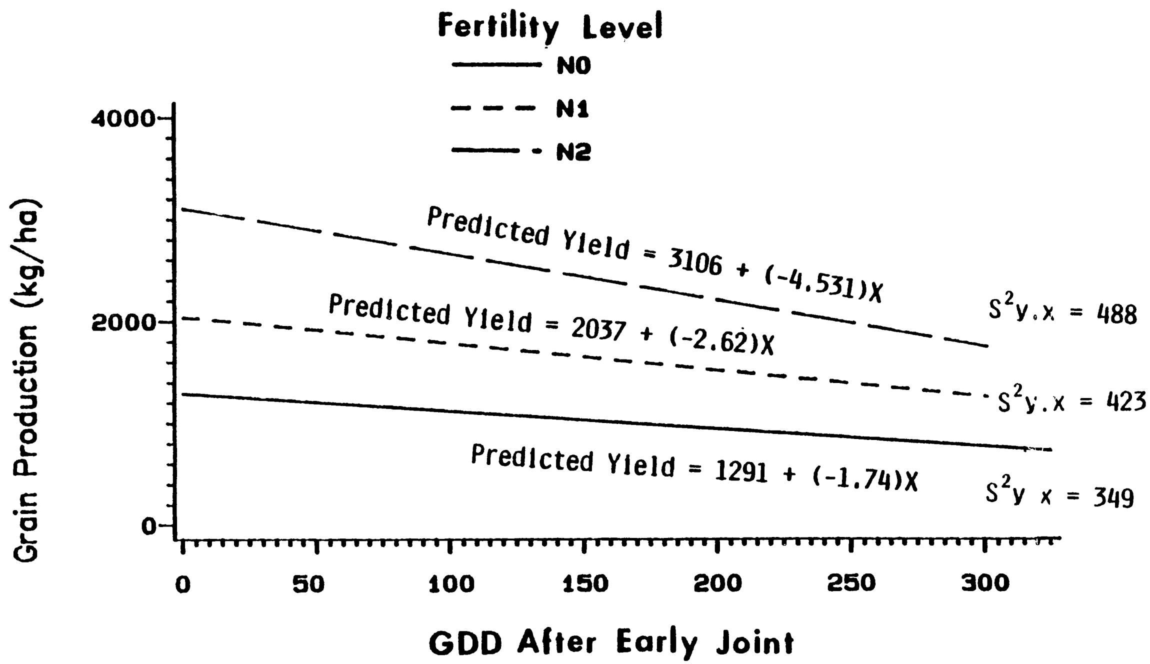

Fig. 4. 1984-85 Wheat Grain Production Response to Final Forage Harvest at Successive Growing Degree Days after Early Joint for Three Nitrogen Fertility Levels.

APPENDIXES

Table A1. Mean squares of total forage production for two growing seasons when clipping was terminated prior to early joint (Group 1) and after early joint (Group 2).

Source of Variation	Group 1			Group 2		
	D.F.	1983-84	1984-85	D.F.	1983-84	1984-85
		(10^{-4})	(10^{-4})		(10^{-4})	(10^{-4})
Block	3	12	11	3	295	35
Nitrogen Level (N)	2	1327**	365**	2	5099**	1754**
Error A	6	9	7	6	38	27
Clipping Treatment (C)	2	474**	63**	4	1337**	358**
NXC	4	35	6	8	32	47**
Error B	18	18	4	36	55	8

** Significant at the 0.01 level of probability.

Table A2. Mean squares of grain production for two growing seasons when clipping was terminated prior to early joint (Group 1) and after early joint (Group 2).

Source of Variation	Group 1			Group 2		
	D.F.	1983-84	1984-85	D.F.	1983-84	1984-85
		(10^{-3})	(10^{-3})		(10^{-3})	(10^{-3})
Block	3	39	8	3	8	6
Nitrogen Level (N)	2	38	190**	2	45	145**
Error A	6	25	5	6	9	4
Clipping Treatment (C)	3	254**	20**	4	240**	29**
NXC	6	5	5	8	5	4*
Error B	27	18	3	36	4	2

*, ** Significant at the 0.08 and 0.01 levels of probability, respectively.

Table A3. Mean squares of fertile spikes area^{-1} for two growing seasons when clipping was terminated prior to early joint (Group 1) and after early joint (Group 2).

Source of	Group 1			Group 2		
Variation	D.F.	1983-84	1984-85	D.F.	1983-84	1984-85
Block	3	685	195	3	230	452
Nitrogen Level (N)	2	764	17007**	2	189	15541**
Error A	6	317	153	6	292	411
Clipping Treatment (C)	3	3456**	844*	4	9822**	1601**
NXC	6	87	322	8	500*	188
Error B	27	323	213	36	181	224

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.

Table A4. Mean squares of the number of kernels spike^{-1} for two growing seasons when clipping was terminated prior to early joint (Group 1) and after early joint (Group 2).

Source of	Group 1			Group 2		
Variation	D.F.	1983-84	1984-85	D.F.	1983-84	1984-85
Block	3	1	19	3	11	12
Nitrogen Level (N)	2	7	36	2	23	97**
Error A	6	2	9	6	10	4
Clipping Treatment (C)	3	24**	9	4	49**	11*
NXC	6	1	4	8	11	3
Error B	27	2	5	36	8	4

*, * Significant at the 0.05 and 0.01 levels of probability, respectively.

Table A5. Mean squares of weight kernel^{-1} for two growing seasons when clipping was terminated prior to early joint (Group 1) and after early joint (Group 2).

Source of Variation	Group 1			Group 2		
	D.F.	1983-84	1984-85	D.F.	1983-84	1984-85
Block	3	1	3	3	21	10
Nitrogen Level (N)	2	266**	7	2	484**	19
Error A	6	4	7	6	15	8
Clipping Treatment (C)	3	6	0.3	4	271**	75**
NXC	6	6	3	8	20	3
Error B	27	4	2	36	18	3

** Significant at the 0.01 level of probability.

Table A6. Probability levels from four-degree polynomial regression analyses of forage and grain production on accumulated growing degree days (GDD) after early joint when clipping treatments were progressively terminated during two growing seasons.

Polynomial Regression Parameters	1983-84		1984-85	
	FORAGE	GRAIN	FORAGE	GRAIN
	PR > F			
GDD				
Linear	0.0001**	0.0001**	0.0001**	0.0001**
Quadratic	0.4718	0.0003**	0.0724	0.5438
Cubic	0.9712	0.2227	0.1344	0.0960
Quartic	0.6514	0.4468	0.0786	0.9269
GDD X N Level				
Linear	0.8709	0.1274	0.0001**	0.0115*
Quadratic	0.2299	0.4801	0.3993	0.1151
Cubic	0.8385	0.5917	0.1003	0.9759
Quartic	0.6184	0.4815	0.4402	0.0228*

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.

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VITA

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Candidate for the Degree of

Master of Science

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